The seasonal variation of water quality parameters in Vaigai River at Madurai, Tamilnadu, India

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ABSTRACT

River water is the major source of water supply for domestic purposes in Urban as well as Rural parts of India. Now-a-days river water is likely to fall in its source level due to the lack of rainfall, deforestation, urbanization etc. Monitoring of water quality levels is thus important to assess the levels of pollution and also the potential risk to the environment. The Water samples were collected at 8 different sampling stations in Madurai. The samples were analyzed for the various physicochemical parameters using the standard methods and procedures were used for quantitative estimation of water quality parameters. Most of the WQPS of the ground water samples are found to be above the tolerance limits prescribed by BIS and WHO. The results of WQI values show that all the water samples are found to be well above the permissible limit (0-100) and unfit for drinking purposes. Most of the people in and around the study area depend on river water for drinking, bathing and washing purposes. The water quality has also been changed due to many anthropogenic activities. It is concluded that the water quality is affected by the seepage of sewage, waste water and urban runoff due to the lack of sewage facility.

Key words: *Water Quality Parameter, WQI, SAR.*

INTRODUCTION

Water pollution is not a new problem except in dimensions which we face today. Man has been using water around him for dumping wastes. In the early stages of human history, domestic discharges probably posed no problem as nature has the capacity to degrade waste and restore normal conditions. Nature still does, but with the advent of urbanization and industrialization we have been overloading the systems beyond their tolerance limit. Consequently our water bodies such as rivers, streams and lakes are increasingly getting polluted, threatening the safety, welfare and the very existence of mankind.

In recent years the newer environmental issues regarding hazardous waste, global climate change, stratospheric ozone depletion, groundwater contamination, disaster mitigation and removal of pollutant have become the focus of environmental attention. Though all the segments of environment are being polluted in various ways, the study of water pollution is preferred as it is not an ordinary liquid but is the elixir of life. Moreover, water is the most common liquid but it is also one of the most unusual because of its unique property.

MATERIALS AND METHODS

The water samples were collected at 8 different sampling stations during May 2011 to April 2012 in three seasons viz., summer, monsoon and winter. The samples were analyzed for the following physicochemical parameters viz., temperature, turbidity, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), chemical oxygen demand (COD), total hardness (TH), total alkalinity (TA),calcium, magnesium, sodium, fluoride, chloride, sulphate and nitrate. The standard methods and procedures were used for quantitative estimation of water quality parameters and followed as in, "Standard methods of analysis of water and waste water" (APHA)[1-2].

RESULTS & DISCUSSION

The sampling stations are given in table 1. The standard permissible value prescribed by Bureau of Indian Standard and World Health Organization are presented in table 2.

Temperature

Temperature is one of the important factors in an aquatic environment for its effects on the chemical and biological reactions in the organisms. Temperature of water may not be as important in pure water because of the wide range of temperature tolerance in aquatic life, but in polluted water, temperature can have profound effects on dissolved oxygen and biological oxygen demand [3]. There is a very close similarity between the temperature of atmosphere and water due to the depth of reservoir. Water temperature of the studied site varied from 28.2^{o}C to 30.2^{o}C, 26.6^{o}C to 28.3^{o}C and 22.8^{o}C to 24.3^{o}C during summer, monsoon and winter respectively and it is found to be maximum value during summer. Higher temperature during summer was due to greater heating [4]. Table - 1 Name and the station code of water samples collected in Vaigai River

S. No	Station Code	Name of the Station
1	S1	Thuvariman
2	S2	Kochadai
3	S3	Nagu nagar
4	S4	Sellur
5	S5	AV Bridge
6	S6	Theppakulam
7	S7	Puliyankulam
8	S8	Silaiman

Table - 2 Standard parameters for water characterization

S. No	Parameter	Standard Values	
		BIS	WHO
1.	pH	6.5-8.5	6.5-8.5
2.	Specific Conductance (µmhos/cm)	750-2250	500
3.	Turbidity (NTU)	5	2.5
4.	Total dissolved solids (mg/l)	500	500
5.	Dissolved oxygen(mg/l)	8	8
6.	Chemical oxygen demand (mg/l)	10	10
7.	Biological oxygen demand (mg/l)	5	5
8.	Total alkalinity (mg/l)	200	250
9.	Total hardness (mg/l)	300	500
10.	Calcium (mg/l)	75	75
11.	Magnesium (mg/l)	30	30
12.	Sodium(mg/l)	100	100
13.	Potassium(mg/l)	12	10
14.	Sulphate (mg/l)	200	250
15.	Nitrate (mg/l)	45	45
16.	Chloride(mg/l)	250	250
17.	Fluoride(mg/l)	1.5	1.5

Turbidity

Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter and other microscopic organisms. Turbidity is a measure of the dispersion of light in a column of water [5]. In the present study turbidity ranged from 9.4 NTU to 42.5 NTU, 2.3 NTU to 5.9 NTU and 4.9 NTU to 9.7 NTU during summer, monsoon and winter respectively. The drinking water limit for turbidity as prescribed by WHO is 2.5 NTU and Indian standards up to 5 NTU. This shows that the water is clearly in excess of drinking water turbidity standards during summer and winter in all sampling stations. Surface runoffs and domestic wastes are mainly contributed to the increased turbidity of the reservoir.

pH

pH is an important factor that determines the suitability of water for various purposes, including toxicity to animals and plants. The pH is a measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. It has no direct adverse affect on health, however, a low value, below 4.0 will produce sour taste and higher value above 8.5 shows alkaline taste. As per WHO and BIS standards pH for aquatic life is in the range of 6.5 to 9.0 and for drinking purpose standard is 6.5 to 8.5.The pH ranged from 7.7 to 8.6, 7.1 to 7.7 and 7.0 to 7.3 during summer, monsoon and winter respectively and it is found to be present under desirable limit. It was found to be slightly acidic to slightly alkaline during summer season. The variation can be due to the exposure of river water to atmosphere, biological activities and temperature change.

Table - 3 Seasonal variations among WQPS for water samples

	S1			S2			S3			S4		
WQP	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN
TEMP°C	28.4	26.6	22.9	29.3	27.1	22.8	29.4	27.5	24.3	29.1	27.4	22.8
pH	7.7	7.4	7.0	7.9	7.1	7.0	8.1	7.6	7.1	8.4	7.5	7.0
EC	208	77	129	298	138	182	878	472	647	892	506	672
DO	5.3	5.8	6.6	5.6	6.5	7.2	6.5	7.1	8.4	6.6	7.2	8.5
TDS	347	133	192	481	223	332	1395	650	1022	1489	732	1112
TA	84	31	52	109	45	57	312	112	107	309	226	223
TH	112	51	84	128	64	98	603	135	376	612	246	392
Ca^{2+}	56	20	33	87	41	55	339	82	212	307	139	197
Mg^{2+}	34	14	23	39	25	29	212	29	141	224	94	132
Na^{+}	77	19	52	79	25	63	236	74	135	298	85	175
K^{+}	13	3	8	17	4	12	65	13	36	59	16	32
NO_3^{-}	6.9	1.3	2.8	6.8	1.9	3.6	34.2	4.4	8.3	36.8	4.3	8.6
SO_4^{2-}	39	6	26	65	11	27	169	16	51	165	23	52
Cl^{-}	59	15	32	92	44	69	289	94	190	292	87	145

F^-	0.26	0.11	0.17	0.28	0.12	0.21	0.55	0.19	0.36	0.58	0.22	0.36
COD	4.4	2.6	1.6	4.8	3.5	2.4	13.8	9.1	4.9	21.2	11.9	7.3
BOD	1.6	1.2	0.7	2.1	1.2	0.7	4.2	2.8	1.4	4.4	2.5	2.1

SUM - Summer, MON – Monsoon, WIN – Winter All units - mg/l, EC- µmhos/cm

Table - 4 Seasonal variations among WQPS for water samples

WQP	S5			S6			S7			S8		
	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN
TEMP°C	29.4	28.3	23.5	30.2	27.8	23.1	28.5	26.9	23.5	29.2	27.5	23.3
pH	8.6	7.7	7.2	8.4	7.6	7.1	8.0	7.5	7.3	8.1	7.2	7.1
EC	912	521	694	923	518	682	621	278	332	490	186	321
DO	6.6	7.2	8.3	6.8	7.1	8.5	6.4	6.5	7.3	5.8	6.6	7.4
TDS	1528	743	1110	1612	728	1076	988	458	668	818	343	565
TA	356	255	191	312	178	120	226	89	94	194	57	69
TH	656	242	359	621	212	408	445	127	232	233	72	103
Ca^{2+}	345	128	211	362	125	209	241	74	139	125	40	64
Mg^{2+}	198	92	113	178	86	115	162	34	54	71	26	32
Na^+	312	92	151	278	102	132	142	91	108	135	69	92
K^+	62	14	28	46	13	23	34	11	19	28	12	15
NO_3^-	36.5	3.8	9.7	38.6	5.2	9.2	18.9	3.7	6.1	14.5	2.5	5.3
SO_4^{2-}	187	28	63	198	27	71	127	14	38	79	11	33
Cl^-	233	93	121	278	97	169	145	47	112	118	45	71
F^-	0.59	0.23	0.38	0.63	0.22	0.39	0.36	0.13	0.25	0.31	0.15	0.23
COD	23.2	12.8	8.2	24.8	14.7	7.6	7.9	6.4	3.9	5.1	3.6	2.6
BOD	4.5	3.6	2.1	4.8	3.8	2.4	2.5	1.9	1.1	2	1.5	1.1

SUM - Summer, MON – Monsoon, WIN – Winter All units - mg/l, EC- µmhos/cm

Electrical Conductivity

Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, on their total concentration, mobility, and valency and on the temperature of measurement [8]. Increasing levels of conductivity and cations are the products of decomposition and mineralization of organic materials[4]. In the present observation the electrical conductivity varied from 208 µmhos/cm to 923 µmhos/cm, 77 µmhos/cm to 518 µmhos/cm and 129 µmhos/cm to 694 µmhos/cm during summer, monsoon and winter respectively and it is found to be above the desirable limit at midstream during summer and winter. In all the stations minima observed in monsoon season due to dilution with rain water and maxima in summer owing to evaporation and reduced discharge of sewage water to the river.

Total Dissolved Solids

Total Dissolved Solids **(**TDS) is a measure of the solid materials dissolved in the river water. The concentration of TDS that are too high or too low may limit growth and lead to the death of the many aquatic life forms [9]. Water containing more than 500 mg/l of TDS is not considered desirable for drinking water supplies, but in unavoidable cases 1500 mg/l is also allowed [6].

In the present study TDS ranged from 347 mg/l to 1612 mg/l, 133 mg/l to 743 mg/l and 172 mg/l to 1092 mg/l during summer, monsoon and winter respectively and it is found to be above the prescribed value given value by BIS and WHO in middle and downstream sampling stations during all the three seasons. Total dissolved solids analysis has great implications in the control of biological and physical waste water treatment processes. The largest amount of TDS adds to the highest turbidity and electrical conductivity.

Total hardness

Hardness is the property of water which prevents the lather formation with soap and increases the boiling points of water. Hardness of water mainly depends upon the amount of calcium or magnesium salts or both [8]. The Hardness in water is derived largely from contact with the soil and rock formations and it is objectionable from the view point of water use for laundry and

domestic purposes, since it consumes a large quantity of soap. Total hardness of water is an important consideration in determining the suitability of water for domestic and industrial uses. Although hard water has no known effect on health, but is unsuitable for domestic uses [10]. Water containing more than 300 mg/l of TH is not considered desirable for drinking purpose. In the present study, TH ranged from 112mg/l to 656 mg/l, 51 mg/l to 246 mg/l and 84 mg/l to 408 mg/l during summer, monsoon and winter respectively and it is found to be above the prescribed value given value by BIS and WHO in middle and downstream sampling stations during summer and winter. Total hardness of all the sites showed summer maxima due to reduced in flow and evaporation, and monsoon minima due to increasing inflow and dilution

Total Alkalinity

Alkalinity of natural water is due primarily to the salts of weak acids, although weak or strong bases may also contribute. Bicarbonate represents the major form of alkalinity, with that carbonate and hydroxide alkalinity also. Total Alkalinity (TA) values provide guidance in applying proper doses of chemicals in water and wastewater treatment processes particularly in coagulation, softening and operational control of anaerobic digestion. Water containing more than 200 mg/l of TA is not considered desirable for drinking purpose [7]. In the present study observed values ranged from 84 mg/l to 356 mg/l, 31 mg/l to 255 mg/l and 52 mg/l to 223 mg/l during summer, monsoon and winter respectively. It is found to be above the prescribed value given value by BIS and WHO in middle and downstream sampling stations during summer and winter. Higher values can be attributed to the industrial effluents discharged into river and this may cause corrosion in water pipe lines. In the present investigation total alkalinity reveals summer maximum and monsoon minimum values.

Calcium

Calcium is directly related to hardness. In order of abundance, calcium is the fifth element which is commonly present in all water bodies where it usually comes from the leaching of rocks. Calcium is very essential for nervous system and for formation of bones and teeth [11]. It is an important micronutrient in an aquatic environment and calcium hardness of the river water is of considerable significance in connection with the discharge of the sewage and industrial effluent containing pollution [12]. Water containing more than 75 mg/l of calcium is not considered desirable for drinking purpose [7]. The concentration of calcium in Vaigai River water samples in summer, monsoon and winter ranged from 56 to 362 mg/l, 20 to 139 mg/l and 33 to 212 mg/l respectively. It is clearly noted that the sampling stations S3 to S6 showed higher values than prescribed value by BIS and WHO, which may due to the discharge of domestic sewage at this stations.

Magnesium

Magnesium is also directly related to hardness. Magnesium as co-factor for various enzymatic transformations within the cell especially in the trans-phosphorylation in algal, fungal and bacterial cell [6]. Water containing more than 30 mg/l of magnesium is not considered desirable for drinking purpose. The concentration of magnesium in Vaigai river water samples in summer, monsoon and winter was found to be in the range of 34 to 224 mg/l, 14 to 94 mg/l and 23 to 141 mg/l respectively. It is clearly noted that the sampling stations S3 to S6 showed higher values than prescribed value by BIS and WHO.

Sodium

The percentage of sodium is often taken important parameter indicating in deciding the suitability of water for irrigation. Excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability. Water containing more than 100 mg/l of sodium is not considered desirable for drinking purpose. In the present study sodium ranged from 77 mg/l to 312 mg/l, 19 mg/l to 102 mg/l and 52 mg/l to 175 mg/l during summer, monsoon and winter respectively and it is found to be above the prescribed value given value by BIS and WHO in middle and downstream sampling stations during summer and winter. Sodium concentration of all the sampling stations showed summer maxima due to reduced in flow and evaporation, and monsoon minima was due to increasing inflow and dilution. This could be due to washing clothes, utensils and bathing using soaps and detergents directly with river water.

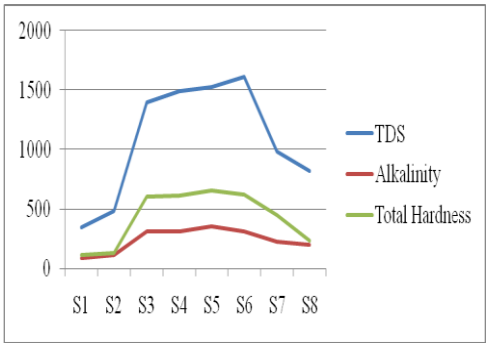

Figure.1 Concentration of TDS, Alkalinity and TH (mg/l) during summer

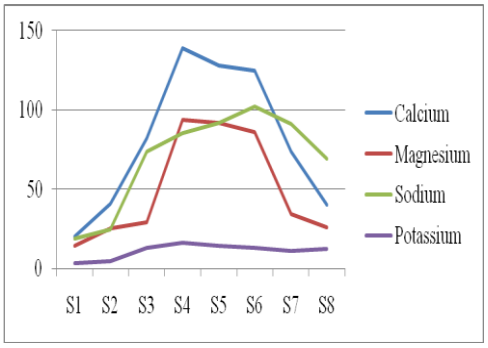

Figure.5 Concentration of Calcium, Magnesium, Sodium and Potassium (mg/l) during monsoon

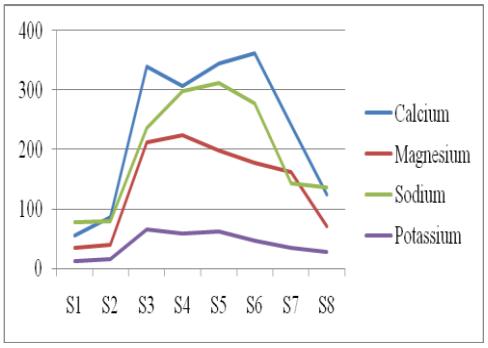

Figure.2 Concentration of Calcium, Magnesium, Sodium and Potassium (mg/l) during summer

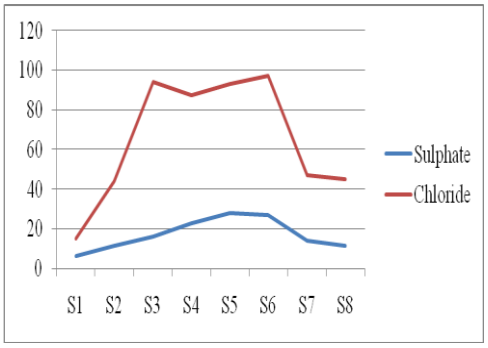

Figure. 6 Concentrations of Sulphate and Chloride (mg/l) during monsoon

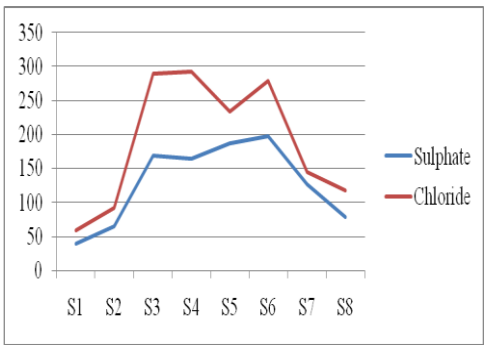

Figure.3 Concentration of Sulphate and Chloride (mg/l) during summer

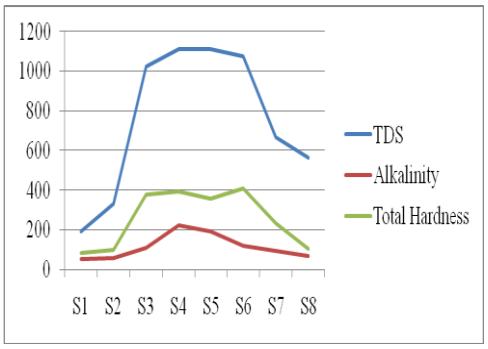

Figure 7.Concentration of TDS, Alkalinity and TH (mg/l) during winter

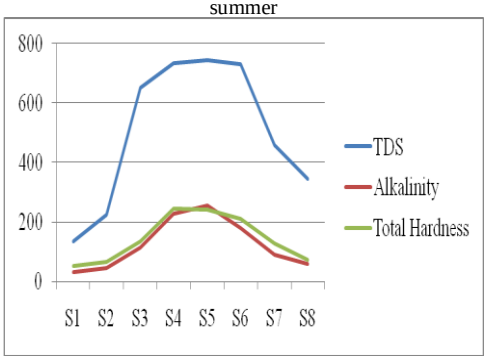

Figure.4 Concentration of TDS, Alkalinity and TH (mg/l) during monsoon

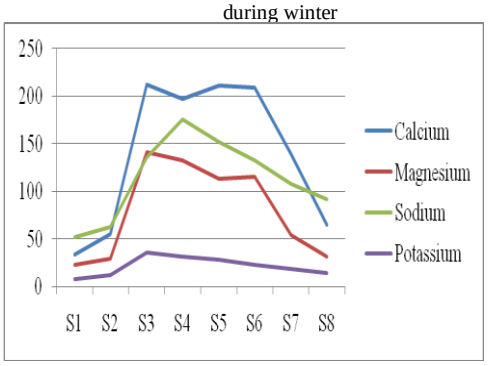

Figure.8 Concentration of Calcium, Magnesium, Sodium and Potassium (mg/l) during winter

Potassium

The major source of potassium in natural fresh water is weathering of rocks but the quantities increase in the polluted water due to disposal of waste water. Water containing more than 12 mg/l of potassium is not considered desirable for drinking purpose. In the present study potassium ranged from 13 mg/l to 65 mg/l, 3 mg/l to 16 mg/l and 8 mg/l to 36 mg/l during summer, monsoon and winter respectively. It is found to be above the prescribed value given value by BIS and WHO in all sampling stations during summer and middle and downstream sampling stations during winter.

Nitrate

Increasing concentration of nitrogen compounds in river and reservoirs lead to eutrophication and could be due to sewage water with agricultural wastes. Nitrate concentration also depends on the activity of nitrifying bacteria which in turn get influenced by presence of dissolved oxygen. Water containing more than 45 mg/l of nitrate is not considered desirable for drinking purpose. The concentration of nitrate in Vaigai River water samples in summer, monsoon and winter ranged from 6.8 to 38.6 mg/l, 1.3 to 5.2 mg/l and 2.8 to 9.7 mg/l respectively. The highest values in summer may be due to the higher phytoplanktonic production, decaying macrophytes and concentration of nutrients owing to the evaporation of river water with subsequent increase in nitrate value [8]. Decrease in nitrate content during monsoon and winter was probably due to its utilization as nutrient by the algal community.

Sulphate

Sulphur is utilized by all living organisms in the form of both mineral and organic sulphates. Surface run-off bringing into the river more suspended solids along with organic matter and soluble salts from the catchment area. The concentration of sulphate is positively related with rainfall. Sulphate content of natural waters is an important consideration in determining their suitability for public and industrial supplies. Discharge of industrial wastes and domestic sewage tends to increase its concentration [13]. Water containing more than 200 mg/l of sulphate is not considered desirable for drinking purpose. In the present study sulphate ranged from 39 mg/l to 198 mg/l, 6 mg/l to 28 mg/l and 26 mg/l to 71 mg/l during summer, monsoon and winter respectively and showing that the sulphate concentration in all sampling stations found to be below the prescribed value. It is found to be below the prescribed value given by BIS except at S6 during summer. Higher concentration of Sulphate in water can cause malfunctioning of alimentary canal and shows cathartic effect on human being.

Chloride

Chlorides occur naturally in all types of water. This is the most common inorganic anion present in water. High concentration of chloride is considered to be the indicators of pollution due to organic wastes of animal or industrial origin. Chlorides are troublesome in irrigation water and also harmful to aquatic life [5]. Main sources of chloride in river waters are sediments, sewage and trade and industrial effluents. Sewage brings with urine, man and animals excrete which are rich in chloride content. The BIS suggested the standard of chloride is 250 mg/l. The concentration of chloride in Vaigai River water samples in summer, monsoon and winter ranged from 58-295 mg/l, 16-112 mg/l and 33-196 mg/l respectively. The values for sampling station S3 to S6 were higher than the prescribed limit during summer period. Higher chloride concentration in samples may be due to big discharge of sewage near the sampling sites.

Fluoride

Fluoride concentration is an important aspect of hydro geochemistry, because of its impact on human health. The recommended concentration of fluoride in drinking water is 1.50 mg/l. Low fluoride content (< 0.60 mg/l) causes dental caries, whereas high (>1.20 mg/l) fluoride levels result in fluorosis. Hence, it is essential to have a safe limit of fluoride concentration of between 0.60 and 1.20 mg/l in drinking water. The Bureau of Indian Standards (BIS) prescribed a limit between 1.0 and 1.5 mg/l. Probable source of high fluoride in Indian water seems to be that during weathering and circulation of water in rock and soil. In the present study fluoride values ranged from 0.26 mg/l to 0.63 mg/l, 0.11 mg/l to 0.23 mg/l and 0.17 mg/l to 0.39 mg/l during summer, monsoon and winter respectively. The content of fluoride is found that within the prescribed limit during the study period.

Dissolved Oxygen

Dissolved oxygen content is one of the most important factors in stream health. Its deficiency directly affects the ecosystem of a river due to bioaccumulation and biomagnifications. The oxygen content in water samples depends on a number of physical, chemical, biological and microbiological processes. DO values also show lateral, spatial and seasonal changes depending on industrial, human and thermal activities. DO levels below 1 mg/l will not support fish; levels of 5 to 6 mg/l are usually required for most of the fish population. The BIS suggested the standard permissible limit in drinking

water for DO is 8 mg/l. The concentration of DO in Vaigai River water samples in summer, monsoon and winter ranged from 5.3 to 6.8 mg/l, 5.8 to 75.2 mg/l and 6.6 to 8.5mg/l respectively. The content of DO is found that within the prescribed limit during the study period.

Biological Oxygen Demand

Biological oxygen demand (BOD) is a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in the water and increases the biochemical oxygen demand [4]. Rivers with low BOD have low nutrient levels; therefore, much of the oxygen remains in the water. Unpolluted, natural waters will have a BOD of 5 mg/l or less. BOD directly affects the amount of dissolved oxygen in rivers and streams. Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff [15]. The BIS suggested the standard permissible limit in drinking water for BOD is 5 mg/l. The content of BOD is found that within the prescribed limit during the study period.

The concentration of BOD in Vaigai river water samples in summer, monsoon and winter ranged from 1.6 to 4.8 mg/l, 1.2 to 3.8 mg/l and 0.7 to 2.4 mg/l respectively.

Chemical Oxygen Demand

Chemical oxygen demand (COD) is a measure of the oxidation of reduced chemicals in water. It is commonly used to indirectly measure the amount of organic compounds in water. The measure of COD determines the quantities of organic matter found in water. This makes COD useful as an indicator of organic pollution in surface water. In the conjunction with the BOD test, the COD test is helpful in indicating toxic conditions and the presence of biologically resistant organic substances [8].Chemical oxygen demand also gives valuable information about the pollution potential of industrial effluents and domestic sewage. The concentration of COD in Vaigai River water samples in summer, monsoon and winter ranged from 4.4 to 24.8 mg/l, 2.6 to 14.7 mg/l and 1.6 to 8.2 mg/l respectively. Water containing more than 10 mg/l of COD is not considered desirable for drinking purpose. The values for sample from points S3 to S6 were higher than the prescribed limit during summer and monsoon. The highest values of COD indicates that most of the pollution in study area is caused by industrial effluents discharged by industrial units, other activities like bleaching and dyeing clothe along the river banks and inside the river also.

Water Quality Index

Accurate and timely information on the quality of water is necessary to shape a sound public policy and to implement the water quality improvement programmes efficiently. One of the most effective ways to communicate information on water quality trend is water quality index (WQI) and it is commonly used for the detection and evaluation of water pollution and may be defined as "a rating, reflecting the composite influence of different quality parameters on the overall quality of water." Here attempt has been made to calculate the water quality index of Vaigai River on the basis of Harkins and Tiwari[14] based on the physico-chemical data.

Table -5 Water Quality Index and their status

WATER QUALITY	STATUS
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
100 and Above	Unsuitable

In the present investigation, eleven water quality parameters have been selected. These eleven parameters are pH, Electrical Conductivity, Total Dissolved Solids, Total hardness, Total Alkalinity, Calcium, Magnesium, Chloride, Sodium, Potassium and Sulphate. The WQI values are recorded maximum values during summer season ranged from 79 to 337. It is clearly found that the water quality of the sampling stations S3 to S8 showed WQI values greater than 100 and are unsuitable for the drinking and domestic purposes.

Table - 6 WQI Values for sampling stations S1 to S8

Station Code/ Season	S1			S2			S3			S4		
	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN
WQI	79	27	37	103	25	55	332	78	125	331	101	158
Station Code/ Season	S5			S6			S7			S8		
	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN
WQI	337	99	146	272	91	125	199	68	100	158	59	71

SUM - Summer, MON – Monsoon, WIN – Winter

The WQI values during monsoon season are ranged from 25 to 101 for and the water quality of sampling stations S1 and S2 are good and that of S7 and S8 is poor remaining stations showed very poor quality and is unsuitable for the drinking and other domestic purposes. The WQI values during winter season are ranged from 37 to 158 and the water quality of sampling stations S3, S4, S5 and S6 showed WQI values greater than 100 and are unsuitable for the drinking and other domestic purposes. In general, from the WQI values the water quality of Vaigai River is found to be very poor in the summer and winter seasons during the study period.

Sodium Adsorption Ratio (SAR)

The water is classified in relation to irrigation based on the ranges of SAR values. In this study the SAR value in the Vaigai River water ranged from minimum 9.95 at S2 and to maximum 18.94 at S5 during summer, minimum 4.35 in S2 and to maximum 12.38 in S7 during monsoon, and minimum 9.72 in S2 and to maximum 13.64 at S4 during winter season. Sodium adsorption ratio values (SAR) are presented in tables 7 and 8**,** have shown that all samples are in first and some are in second category that is low and medium sodium water and little danger.

Sodium Percentage (Na %)

Sodium percentage values reflected that the water is under the category of 'good' (20-40 Na %), 'permissible' (40-60 Na %) and 'doubtful' (60 – 80 Na %) class. The sodium percentage values of the Vaigai River water ranged from minimum 29.95 in S7 and to maximum 49.4 in S1 during summer, minimum 27.52 in S4 and to maximum 58.45 in S8 during monsoon and minimum 31.34 in S6 and to maximum 53.16 in S8 during winter season for the year 2010-11. Almost all water samples in upstream are categorized as 'excellent' to 'good' classes with respect to Na% values, however the downstream samples are categorized as 'doubtful' to 'unsuitable' for irrigation usage.

As per ISI 2000 guidelines, the maximum tolerance limit of Na% for inland surface water used for irrigation is 60%. Accordingly all water samples of Vaigai River are suitable for irrigation, where as Na% is higher than 60 in case of polluted station. This higher value of Na% was due to contribution of sewage discharge from the city. The sodium percentage value in the Vaigai River water ranged from minimum 30.4 in S7 and to maximum 50 in S1 during summer, minimum 30.24 in S4 and to maximum 55.1 in S8 during monsoon, and minimum 32.36 in S6 and to maximum 52.71 in S8 during winter season.

Table -7 Sodium Adsorption Ratio values (SAR)

SAR	**Category**	**Precaution and Management Suggestions**
0 – 10	1 (low Na water)	Little danger
10 - 18	2 (medium Na water)	Problems on fine texture soils and sodium sensitive plants, especially under low-leaching conditions. Soils should have good permeability
18 – 24	3 (high Na water)	Problems on most soils. Good salt tolerant plants are required along with special management such as the use of gypsum
24	4 (very high Na water)	Unsatisfactory except with high salinity (>2.0 dS/m), high calcium levels and the use of gypsum

High concentrations of sodium in soils affect its physical condition and soil structure resulting in formation of crusts, water-logging, reduced soil aeration, reduced soil permeability; excessive concentrations of sodium in soils may also be toxic to certain types of crops. SAR gives a very reliable assessment of water quality of irrigation waters with respect to sodium hazard, since it is more closely related to exchangeable sodium percentages in the soil than the simpler sodium percentage [11]. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure and becomes compact and impervious.

Table - 8 SAR and Na %, Values for sampling stationsS1 to S8 during

Station Code/ Season	S1			S2			S3			S4		
	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN
SAR	11.48	4.61	9.83	9.95	4.35	9.72	14.22	9.93	10.16	18.29	7.88	13.64
Na %	50	39.29	51.72	43.24	30.53	47.17	35.33	43.94	32.63	40.2	30.24	38.62
Station Code/ Season	S5			S6			S7			S8		
	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN	SUM	MON	WIN
SAR	18.94	8.77	11.86	16.92	9.93	10.37	10	12.38	10.99	13.64	12.01	13.28
Na %	40.79	32.52	35.59	37.5	35.28	32.36	30.4	48.57	39.69	45.4	55.1	52.71

SUM - Summer, MON – Monsoon, WIN - Winter

CONCLUSION

Based on the experimental results and statistical methods employed for the analysis of data, the following conclusion have been made during the course of present investigation in various smpling station located in Vaigai River ,Madurai, South India.A significant hydrochemical trend is observed in the study areas, which are above the prescribed limit given by BIS and WHO, whereas , little seasonal variations are noticed during all the three seasons among WQPS.WQI computation techniques indicate that the Vaigai river water quality in Madurai is not suitable for portable purposes. Na% values of the downstream samples are categorized as 'doubtful' to 'unsuitable' for irrigation usage. Sodium adsorption ratio values (SAR) have shown that all samples are in first and some are in second category that is low and medium sodium water and little danger. Finally, the water quality of Vaigai River water at Madurai is very disturbed by untreated waste waters and sewage disposal directly to it.

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