STUDY ON PHYSICOCHEMICAL PARAMETERS OF SURFACE WATER OF VAIGAI RIVER NEAR MADURAI CITY, TAMIL NADU, INDIA.

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Abstract. The Vaigai river is playing fundamental role in local society, as a source of irrigation and drinking water, and as a sink for urban waste around Madurai, Tamilnadu, India. In order to characterize the spatial and temporal variability of surface water quality in the watershed, a Water Quality Index (WQI) was calculated from 22 physicochemical parameters, periodically measured at 7 sampling sites (January–November 2000). The results indicated a good water quality in the upper and middle parts of the watershed. Downstream of the City of Vaigai river water quality conditions were critical during the dry season, mainly due to the effects of the urban wastewater discharge. The pysico-chemical parameter are proposed as useful tools for monitoring river water quality trends in this and other, similar river watersheds in the India. Possibilities and limitations for the application of the developed methodology to watersheds in other parts of the world are discussed.

Keywords: Physico-chemical parameters of river water, Vaigai river, Water quality assessment, water pollution, River water quality.

Introduction

The health and well being of the human race is closely tied up with the quality of water used (Sharma et al, 2005 and Venkateswaran, 2011). Water quality has direct impact on public health (Kumar,2003 and Arunabh Misra et al,2010). People on globe are under tremendous threat due to undesired changes in the water quality parameters such as physical, chemical and biological characteristics of air, water and soil. These undesirable changes due to pollution caused by the addition of organic and inorganic materials from non point sources such as sewage, food waste, farm effluent, through drainage ditches, including artificial fertilizer residues, insecticides, herbicides, pesticides and farmyard waste, in addition from point sources such as electroplating, pesticide, fertilizer and beverage industries. Addition to these, disposal of dead bodies, discharge of industrial and sewage wastes and agricultural runoff, which are major cause of ecological damage and pose serious health hazards (Meitei et al., 2004a).

The pollutant from agricultural lands such as fertilizers, pesticides and fungicides and from anthropogenic activities such as mining, disposal of toxic metals, human and animal faeces, industrial, domestic, municipal wastes are continuously discharged into river, such as Vaigai, are the major casues for deterioration of water quality (Kar*et al*,2008 and Amman *et al*, 2002). In order to maintain the quality of drinking water, an essential component to humans and other living beings for survival of life on earth, a periodical analysis on physico chemical, biological and microbiological parameters is mandatorily required. (IAAB, 1998, Kulshrestha and Sharma, 2006, Shah et al, 2007 and Garg et al, 1990).

Indian government and the research agencies in implemented studies on the water quality, cleaning and protection steps on the major rivers such as Ganga, Yamuna, Brahmaputra, Godavari, Narmada, Krishna, Mahanadi, Kaveri, Tapati etc.. Addition to these major rivers, a large number of small rivers, throughout India, is the main water source for several millions of people in various states of India. All these small rivers are highly polluted by various industrial discharges and anthropogenic activities. The water quality study is essential for all these small rivers to assess the water quality, to prevent water pollution and to create awareness about the importance of water quality and human health among the people. Hence, in the present investigation, the river Vaigai has been selected and its water quality has been assessed by studying the physicochemical qualities such as colour, odour, temperature, transparency, electrical conductivity, pH, turbidity, dissolved oxygen, alkalinity, total dissolved solids, biological oxygen demand, calcium, chloride, fluoride, magnesium, manganese, nitrate, nitrite, sodium, sulphate and biological parameters such as phytoplankton and zooplankton communities.

Materials and method

Study site

The Vaigai river is the base for the existence of Madurai, a heritage city of 2500 years' history, in Tamilnadu, India. Vaigai river originates in the Periyar Plateau of the Western Ghats range and its chief tributaries are Siruliar, Theniar, Varaha Nadi, and Mangalar. The Vaigai is 258 kilometres (160 mi) long, with a drainage basin of 7,031 square kilometres (2,715 sq miles) large. It flows northeast through the Cumbam which lies between the Palani Hills to the north and the Varushanad Hills to the south. As it rounds the eastern corner of the Varushanad Hills, the river turns southeast, running through the region of Pandya Nadu. The river empties into the Palkstrait in Ramanathapuram District. But in the present study, part of Vaigai river from the place Anaipatti to Viraganoor were considered for the water sample collection. For this water sample collection, the sample sites such as Anaipatti, Sholavandam, Samayanallur, Gnanavadivupuram, Teppakulam and Virganoor were selected and they are denoted as AP, SH, SN, GP, TPK and VR for our convenience. In each water sample the physico-chemical parameters such as Colour, Odour, Temperature, Transparency, EC, pH, Turbidity, DO, Alkalinity, TDS, BOD, Calcium, Chloride, Fluoride, Magnesium, Manganese's, Nitrate, Nitrite, Sodium, Sulphate were estimated by using the standard APHA methodology.

Method of sample collection

Sample collection location and period

The water samples were collected in polyethylene bottles from all six sample sites in the Vaigai river near Madurai City during the months of Monsoon period 2013-2014. The water flow in the Vaigai River is seasonal. Adequate water flow in the Vaigai River occurs only in the seeing season. During other non-monsoon periods, the water in the Vaigai River is dried-up. For the research convenience, the entire monsoon periods were divided into three time periods such beginning of monsoon, (July, Aug and Sep), middle of monsoon (Oct, Nov and Dec) and end of the monsoon (Jan and Feb). The sample collection was done in all sample sites at 1st and 2nd day of all months of beginning, middle and end of the monsoon periods.

Labelling the samples bottle for identification

The sample details such as collection site, date and time were marked by permanent glass marker containing indelible ink directly on the sample collection bottle.

Preparation of samples bottle for water collection

Before filling the river water sample, the plastic sample bottle was brushed with phosphate free detergent and then rinsed three times with cold tap water, 10% percent hydrochloric acid and demonized water.

Ideal place in the river for sample collection

The stagnant places in the river were avoided to collect the sample. The water sample was collected only from the river bank in the main current, particularly, from the outside curve of the river.

Collection method

The cap from the bottle was removed just before sampling. Precautions were taken to avoid touching the inside of the bottle or the cap. The bottle was held facing upstream of the river. After filling, the bottle was closed tightly.

Preservation and processing of water sample in laboratory for estimation

Water samples (500 mL) collected from all the 07 sample sites at all monsoon months from July to February were kept in ice box and taken to the Zoology Department laboratory, Thigarajar College, Madurai for the estimation of Physico-chemical parameters.

Physico-chemical parameters:

Results

Table. 1. Physicochemical parameters at the beginning of monsoon in the sites located on Vaigai River near Madurai City

Parameters	Sample sites in segment-I(Upper reach)						
	VP	**AP**	**SH**	**SN**	**GP**	**TPK**	**VR**
Colour	Light Green	Light Green	Light Gray	Light Gray	Light Gray	Light Gray	Light Gray
Odour	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Temperature (°c)	27±1.35	27±1.62	27±1.89	27±2.16	28±2.52	28±1.12	26±0.78
Transparency(cm)	53±2.65	48±2.88	54±3.78	52±4.16	22±1.98	18±0.72	18±0.54
EC (μs/cm)	72±3.6	70±4.2	98±6.86	115±9.2	265±23.85	270±10.8	282±8.46
pH	7.5±0.375	7.8±0.468	8.1±0.567	8.1±0.64	5.8±0.522	6±0.24	6.1±0.183
Turbidity (NUT)	4.3±0.78	4.1±0.65	4.2±0.92	4±0.96	4.3±0.59	4.4±0.90	5±0.73
DO (mg/L)	7.5±0.375	7.2±0.432	6.9±0.48	7±0.56	3.2±0.288	2.1±0.084	4±1.2
Alkalinity	10.5±0.525	11.3±0.6	25.4±1.7	22.3±1.7	128±11.5	180±7.2	215±6.4

		78	78	84	2		5
TDS(mg/L)	105±5.25	100±6	110±7.7	112±8.96	240±21.6	280±11.2	305±9.15
BOD	1.7±0.085	1.8±0.108	2±0.14	2.1±0.168	3.4±0.306	3.2±±0.128	4.5±0.135
Calcium(mg/L)	18±0.9	16±0.96	14±0.98	27±2.16	47±4.23	50±2	65±1.95
Chloride(mg/L)	45±2.25	40±2.4	52±3.64	80±6.4	110±9.9	125±5	140±4.2
Fluoride(mg/L)	0.26±0.013	0.21±0.012	0.22±0.015	0.21±0.016	0.25±0.022	0.3±0.012	0.2±0.006
Magnesium(mg/L)	8.7±0.435	8±0.48	7±0.49	15±1.2	14±1.26	18±0.72	17±0.51
Manganese's(mg/L)	2.9±0.145	2.7±0.162	3.4±0.238	10.8±0.864	22.5±2.025	25.7±1.028	27.2±0.816
Nitrate(mg/L)	0.28±0.014	0.24±0.014	0.2±0.014	0.7±0.056	0.8±0.072	1.2±0.048	1.5±0.045
Nitrite(mg/L)	0.07±0.35	0.05±0.003	0.07±0.0049	0.09±0.007	0.07±0.006	0.09±0.003	0.08±0.002
Sodium(mg/L)	13.3±0.665	12±0.72	14±.98	15±1.2	20±1.8	19±0.76	22±0.66
Sulphate(mg/L)	6.9±0.345	6.5±0.39	22±1.54	20±1.6	135±12.15	185±7.4	225±6.75

Each value represents mean ±deviation of six values

Table. 2. Physicochemical parameters at the middle of monsoon in the sites located on Vaigai River near Madurai City

Parameters	**Sample sites in segment-I(Upper reach)**						
	VP	**AP**	**SH**	**SN**	**GP**	**TPK**	**VR**
Colour	Light Green	Light Green	Light Gray	Light Gray	Light Gray	Light Gray	Light Gray
Odour	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Temperature (°c)	27±0.81	28±1.12	28±1.4	29±1.74	29±2.03	29±2.32	29±2.61

Transparency(cm)	38±3.42	37±2.96	35±2.45	35±2.1	37±1.85	37±1.48	36±1.08
EC (µs/cm)	65±1.3	62±1.86	60±2.4	61±3.05	72±4.32	86±6.02	90±8.1
pH	7±0.63	7.1±0.568	7.2±0.432	7.4±0.37	7.5±0.3	7.8±0.234	7.7±0.154
Turbidity (NUT)	4.1±0.65	4.4±0.84	4.4±0.85	5.0±0.78	5.1±0.52	4.8±0.96	6±0.95
DO (mg/L)	7.2±0.576	7.3±0.511	7±0.42	7±0.35	6.8±0.272	6.5±0.195	6±0.12
Alkalinity	6.5±0.52	6.8±0.476	8±0.48	7.7±0.385	15±0.6	15±0.45	17±0.34
TDS(mg/L)	51±4.08	53±3.71	50±3	48±2.4	65±2.6	67±2.01	70±1.4
BOD	0.14±0.0112	0.12±0.008	0.14±0.008	0.17±0.008	0.35±0.014	0.41±0.012	0.45±0.009
Calcium(mg/L)	7±0.56	6±0.42	7±0.42	6±0.3	8±0.32	9±0.27	10±0.2
Chloride(mg/L)	31±2.48	32±2.24	30±1.8	31±1.55	40±1.6	43±1.29	45±0.9
Fluoride(mg/L)	0.24±0.019	0.26±0.018	0.23±0.013	0.21±0.010	0.24±0.009	0.22±0.006	0.23±0.004
Magnesium(mg/L)	7±0.56	8±0.56	7±0.42	7±0.35	10±0.4	11±0.33	13±0.26
Manganese's(mg/L)	1.5±0.12	1.6±0.112	1.7±0.102	1.6±0.08	8±0.32	9±0.27	10±0.2
Nitrate(mg/L)	0.17±0.013	0.13±0.009	0.14±0.008	0.15±0.007	0.5±0.02	0.6±0.018	0.7±0.014
Nitrite(mg/L)	0.014±0.0011	0.012±0.0008	0.013±0.0007	0.016±0.0008	0.072±0.002	0.074±0.002	0.75±0.015
Sodium(mg/L)	2.4±0.192	2.5±0.175	2.6±0.156	3.1±0.155	5.1±0.204	6.2±0.186	6.8±0.136
Sulphate(mg/L)	1.13±0.090	1.14±0.079	4.12±0.247	6.14±0.307	5.65±0.226	38.87±1.166	45.9±0.918

Each value represents mean ±deviation of six values

Table. 3. Physicochemical parameters at the end of the monsoon in the sites located on Vaigai River near Madurai City

Parameters	Sample sites in segment-I(Upper reach)						
	VP	**AP**	**SH**	**SN**	**GP**	**TPK**	**VR**
Colour	Light Green	Light Green	Light Gray	Light Gray	Gray	Gray	Gray
Odour	Nil	Nil	Nil	Nil	sewage	sewage	sewage
Temperature (°c)	27±0.81	28±1.12	27±0.54	28±1.4	28± 1.96	28±2.24	28±2.52
Transparency(cm)	59±1.77	61±2.44	60±1.2	58±2.9	165±11.5	168±13.44	171±15.39
EC (µs/cm)	115±3.45	108±4.32	90±1.8	80±4	74±5.18	62±4.96	58±5.22
pH	7.5±0.225	7.1±0.28	7.3±0.146	7.1±0.35	5.2±0.36	5.3±0.424	5.1±0.459
Turbidity (NUT)	4.6±0.72	4.5±0.91	4.8±0.82	4.5±0.8	5.1±0.72	5.5±0.98	5.7±0.84
DO (mg/L)	7.1±0.213	7.2±0.28	7.0±0.14	6.8±0.34	5.4±0.37	5.3±0.424	4.7±0.423
Alkalinity	6.1±0.183	6.3±0.252	6.2±0.124	6.0±0.3	9±0.63	10±0.8	10.6±0.95
TDS(mg/L)	41±1.23	42±1.68	45±0.9	49±2.45	78±5.46	82±6.56	89±8.01
BOD	0.11±0.003	0.12±0.004	0.14±0.002	0.13±0.006	0.6±0.042	0.7±0.056	0.9±0.081
Calcium(mg/L)	3.9±0.117	3.8±0.152	3.7±0.074	6.1±0.305	7.8±0.546	8.2±0.656	8.9±0.801
Chloride(mg/L)	21±0.63	20±0.8	22±0.44	21±1.05	47±3.29	52±4.16	65±5.85
Fluoride(mg/L)	0.15±0.004	0.16±0.006	0.17±0.003	0.16±0.008	0.35±0.024	0.48±0.0384	0.61±0.054
Magnesium(mg/L)	6±0.18	7±0.28	7±0.14	6±0.3	10±0.7	14±1.12	16±1.44

Manganese's (mg/L)	1.2±0.036	1.3±0.052	1.4±0.028	1.8±0.09	23±1.61	34±	40±3.6
Nitrate(mg/L)	0.12±0.003	0.12±0.004	0.14±0.002	0.26±0.013	0.58±0.040	0.71±	0.93±0.083
Nitrite(mg/L)	0.011±0.0003	0.013±0.0005	0.011±0.0002	0.012±0.0006	0.071±0.004	0.084±	0.092±0.008
Sodium(mg/L)	1.8±0.054	1.7±0.068	1.7±0.034	1.9±0.095	7.1±0.497	9.2±	11.4±1.026
Sulphate(mg/L)	4.11±0.123	3.13±0.125	15.14±0.302	16.02±0.801	27.17±1.9019	31.24±	49.24±

Each value represents mean ±deviation of six values

Results and discussion

Colour of water represents important water quality indicators. Pure fresh water may not contain any colour. Natural colour in surface water of the river reflects the presence of complex organic molecules derived from vegetable (humic) matter such as peat, leaves, branches and soon. The results obtained in the present investigation shows an agreement with the suggestion that it has been difficult to tease out a single factor causing brownification. There is an implicit consensus that the direct factor causing brownification is increased concentrations of terrestrially derived organic matter (OM) in the water (Pace and Cole, 2002; von Einem and Graneli, 2010).Water colour may be due to: (i) coloured organic substances due to natural vegetation and soil runoff (Research Committee on Color Problems 1967), (ii) presence of iron or manganese which can be due to weathering, corrosion of distribution system, industrial wastes (American Water Works Association 1971), natural organic substances (Black and Christman 1963), iron (Fe) (Pennanen and Frisk, 1984; Maloney et al.,2005) and peat cover more than 20%)(Maria Alannel, 2005., Canfield et al., 1984.,Pennanen and Frisk, 1984.,Heikkinen and Ihme, 1995.,Maloney et al., 2005). The sites VP and AP in the middle reach of Vaigai river showed light green colour at the beginning, middle and end of the monsoon. This may be due to the rich amount of phytoplankton and algal blooms. The sites SH,SN,GP,TPK, VR at the beginning , middle and end of the monsoon showed light grey water colour. This may be due to point and non point sources of sewage and industrial discharges. In all three monsoons the colourless water indicates the presence of good water quality on the basis of colour. The surface water of Vaigai river was odourless in all sites, this may be due to lack of eutrophication in the sample sites.

The temperature of water body influences its overall quality. In river, the temperatures are dynamic over space and time. Temperature directly and indirectly influences different types of life in aquatic environment (Welch, 1952). Water temperature has a strong influence on the physical characteristics of streams and rivers, such as surface tension, density and viscosity, solubility of gases and chemical reaction rates (Webb 1996, Webb and Nobilis 2007). In the present investigation, the temperature in all sites at the beginning, middle and end of the monsoon is not highly fluctuated and further, more or similar around 26º$_C$. Some of the minor fluctuations in the temperature of different sites within the segment may due to diurnal variations in the river Vaigai showed strong concurrences with the suggestion that lotic systems in regions of seasonal climates exhibit diel (daily) and annual (seasonal) temperature periodicity patterns (Ward, 1985). The downstream of the Vaigai river such as middele and lower reaches having raising temperatures in its surface water showed a clear agreement with the findings that the maximum temperatures increase downstream (Ward, 1985), while the maximum range is often found in the middle reaches (Vannote and Sweeney, 1980). Temperature exerts a strong influence on many physical and chemical characteristics of water including the solubility of oxygen and other gases, chemical reaction rates and toxicity, and microbial activity (Dallas and Day, 2004). Higher temperatures reduce the solubility of dissolved oxygen in water, decreasing its concentration and thus its availability to aquatic organisms. Chemical reaction rates and the toxicity of many substances (e.g.cyanide, zinc, phenol, xylene), and the vulnerability of organisms to these toxins, are intensified as temperature increases (Duffus, 1980).

Transparency is the basic indicator of river health. It depends on the intensity of sunlight, suspended soil particles, turbid water received from catchment area and density of plankton etc. (Mishra and Saksena, 1991; Singh, 1999; Kulshrestha and Sharma, 2006). Transparency of river water is also affected due to total solids, partly or fully decomposed organic matters, silts and turbulence caused by the currents, waves, human and cattle activities (Singh *et al*., 1999). In the present investigation, the mean minimum transparency ange 35.1 was noted at SN and the maximum range at TPK was observed. Hossain *et al.* (2012) stated that the transparency of the productive fresh water ranged from 35-45 cm. But in the present study, the observed result indicated for lower range of transparency was within the standard limit and suitable for aquatic environment. Many researchers observed that the seasonal impact on river water elevate transparency values during winter and summer seasons and decrease the values during monsoon season. The transparency values were less in monsoon season due to high current which erodes the bank of the river and due to turbid flood water, suspended matter and dissolved particles. The present results has some concordance in its transparency fluctuation with the high value of transparency in late post monsoon and winter months as has also by Singh et al. (1999), Nath and Srivastava (2001) and Shaikh and Yeragi (2004). Flow rate of water bodies generally depends upon the amount of water available and on its depth. Mean annual flow rate in Chambal river was found to be minimum (6.0 cm sec-1) at Station-B in the month of February and maximum (46.00 cm sec-1) at Station-C in the month of September. Light penetration varying from 30 cm to above 60 cm was acknowledged to be favourable for fish production (Boyd and Tucker, 1998; Ali *et al*., 2000). However, in this study, the estimated values of water transparency were within the permissible limits.

Just like metal, water can conduct (transport) electricity. This is because there are salts dissolved in the water. The 100% pure water with absolutely no salts will not conduct electricity and conductivity will be 0. In toxicological studies, the researcher can indirectly estimate pollutants in the form of salts and minerals by measuring the electrical conductivity of water. Electrical conductivity (EC) is a measure of water capacity to convey electric current. It signifies the amount of total dissolved salts (Shriniva and Venkateswaralu, 2000). EC values are a good measure of the relative difference in water quality between different aquifers (Rashid,1982). In the present investigation, all the sites in the Vaigai river showed EC ranges from 60 (NP)to 282(VR) at the beginning of the monsoon. At the middle of the monsoon, the minimum range 60 was at SH and maximum range 90 was at VR. The above results of EC observed in the present investigations were within WHO standard limit 1250 µS/cm (2011), WHO maximum permissible limit 1000 µS/cm and ICMR limit 300 µS/cm.

The pH of water is a measure of the concentration of hydrogen ions (Kaiff, 2002). pH indicates the intensity of the acidic or basic character of a solution and controlled by the dissolved chemical compounds and biochemical processes in the solution (Saksena and Kaushik,1994).pH can change rapidly, which in turn may have severe effects on the aquatic biota (DWAF, 1996). Katariα*et al.* (1995) pointed out that a suitable range of pH is necessary for fish survival in water bodies and acid waters reduce the appetite of fish and their growth. The pH of surface water in the Vaigai river in general showed a neutral, slightly alkaline and acidic tendency in some sites. The minimum pH noticed in the study period was 5.8 at GP and the maximum pH noticed was 8.1at SH and SN during beginning of the monsoon. In the middle of the monsoon, the minimum pH 7.0 was noticed at VP and maximum pH 7.8 was noticed at TPK. In the end of the monsoon, the minimum pH 5.1 was recorded at VR and maximum pH 7.5 was observed at VP. The results of the present study was within the WHO (2011)permissible limits 6.5 – 8.5 and ICMR (1975), WHO (1985) safe pH limit 7 to 8.5except for three sites GP,TPK and VR during the beginning and the end of the monsoon. In all these three sites, the pH is slightly acidic and hence goes behind the WHO permissible limit.

Turbidity is an optical determination of water clarity (EPA,2012). Turbid water will appear cloudy, murky, or otherwise colored, affecting the physical look of the water. High turbidity levels can diminish visibility and often feeding behaviors, in addition to physically harming aquatic life,the suspended solids may disrupt the natural movements and migrations of aquatic populations (Carlson ,2009).All the sample sites in the lower reaches of the Vaigai river at the beginning, middle and end of the monsoon were observed for their surface water turbidity levels. All the sites showed the turbidity values higher or equal to WHO recommended limit in the sites VR at beginning of the monsoon, SR, GP and VR at the middle of the monsoon and GP,TPK and VR at the end of the monsoon.The present results observed for all sites in all three monsoons are one fold lower when compared to the value recommended by Indian standard 10NTU. Exceeding of turbidity values in some sapmle sites of the Vaigai river may be due to land use, topography, vegetation, climate and hydrology impact of the water quality of a watershed (Morris et al, 1987). Runoff from snowmelt and storm events in areas burned by forest fires exhibit higher levels of suspended solids and turbidity relative to unimpacted watersheds(Hopkins, 2001). Increased surface runoff contributes to turbidity, which is an easily measured variable that is often associated with total suspended solids (TSS) (Packman, 1999) and microbial concentrations (Francy,1997).

Oxygen is a basic requirement of almost all aquatic life except anaerobic microbes. If sufficient oxygen is not available to the aquatic life, the ecosystem will be adversely affected. Dissolved oxygen may play a very crucial role for the survival of aquatic organism (YakubandUgwvmba, 2009). The high organic and inorganic pollutants received by water bodies through the discharge of industrial, sewage and solid wastes, require a high oxygen demand resulting in oxygen depletion (Osibanjo*et al* 2007).. Deficiency of DO gives bad odour to water due to anaerobic respiration of organic matter (Sallae*et al* 1974). Low level of DO is again indicative of polluted nature of water body. Such low level of oxygen was also noted by Iqbal*et al*. (2006). Aquatic life will be put under stress due to reduction in oxygen levels and fish would likely suffocate to death. (Miroslav& Vladimir, 1999.) The amount of oxygen molecules dissolved in water is a major indicator to determine the water quality. Naturally, the DO concentrations in 100-percent saturated fresh water ranges from 7.56 mg/L (or 7.56 parts oxygen in 1,000,000 parts water) at 30 degrees Celsius to 14.62 mg/L at zero degrees Celsius. In the present investigation, the sites VP,AP,SH,SN,GP,TPK and VR showed some remarkable fluctuated results in the surface water dissolved oxygen. For example, at the beginning of the monsoon, the sites VP, AP and SN showed dissolved oxygen above the 7. The remaining sites SH showed dissolved oxygen level 6.9 mg/L just below to 7. The sites GP, TPK and VR showed very low range of dissolved oxygen 3.2mg/L, 2.1 mg/L and 4.0mg/L respectively indicates existence of water pollution. Sites MAM and PK in the lower reach showed 5.1mg/L and 5.4mg/L indicates the moderate level of pollution in these areas.

The sites GP,TPK and VR at the middle of the monsoon showed a slight decrease in their dissolved oxygen i.e., 6.8, 6.5 and 6.0 respectively and this indicates a moderate level of pollution. The sites SN at the end of the monsoon showed the slight decrease in the dissolved oxygen around 6.9 to 6.4 mg/L that indicate invading of organic and inorganic anthropogenic inputs into the river. The sites GP,TPK and VR showed low level of oxygen such as 5.2mg/L,5.3mg/L and 5.1mg/L respectively at the end of the monsoon that indicates moderate level of pollution.

Alkalinity values serve as an index of productive potential of the water(Jain, 1996).Alkalinity is used as criteria for determining thenutrient status of waters (Sorensen, 1948; and Moyle, 1949).Alkalinity is a measure of buffering capacity ofwater and is important for aquatic life in a freshwater system because it equilibrates thepH changes that occur naturally as a result of photosynthetic activity of phytoplankton(Kaushik and Saksena, 1989). In the present study, the alkalinity of the sample sites GP,TPk and VR was noticed as 128, 180 and 215 mg/L at the beginning of monsoon which was moderately high when compared with WHO permissible limit 100mg/L and ICMR drinking water standard 120mg/L. Total alkalinity is caused by bicarbonates, carbonates, OH ions, borates, silicatesand phosphates (Kataria*et al.*, 1995). Bhatt *et al.* (1999) and Trivedy and Goel (1986) whoargued that alkalinity is usually higher during the pre-monsoon than the monsoon. Alkalinity of water is its capacity to neutralize a strongacid and is characterized by presence of all hydroxyl ions capable of combining with hydrogen ions (Koshy and Nayar, 2000). Rest of the sites at the beginning of the monsoon showed the alkalinity values within the permissible limit of WHO and ICMR. Kaul*et al.* (1980) found that with increase in atmospheric temperature and the consequent increase in the photosynthetic process in hot season, alkalinity values usually decrease in summer. Venkateswarlu (1969) also observed that alkalinity is affected by rain fall (Jayaraman *et al.* ,2003).

Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. Total Dissolved Solids measures the solids remaining in a water sample filtered through a 1.2 μm filter. According to the World Health Organization (WHO, 1996), the compounds and elements remaining after filtration are commonly calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulfate, silica and nitrate-n.TDS is normally associated with the electrical conductivity and these are the total dissolved materials in the water. TDS contains positive and negative ions such as dissolved chloride, phosphate,sulphate, carbonate, bicarbonate, magnesium, sodium, calcium and other organic and inorganic matters (Tjandraatmadja and Diaper, 2006). These compounds are the principal constituents of TDS. In the present study, the sites located on upper, middle and lower reaches of the Vaigai river showed maximum 305 mg/L at VR during the beginning of the monsoon and minimum value of 48mg/L at SN during middle of the monsoon. At the end of the monsoon, minimum value 40mg/L was observed at NK and maximum 89 was noticed at VR. From the present investigation, it was observed that both the lower and higher ranges noted in all three seasons were within the permissible limit 1200mg/L of WHO (2011) and drinking water standard 500mg/L recommended by ICMR. Water containing TDS concentrations below 1000 mg/Litre is usually acceptable to consumers. Natural weathering and decomposition of rocks, soils, and dead plant materials and the transport or dissolution of the weathered products in water contributes a natural "background" of suspended and dissolved materials to natural waters. Eroded soils are the most important type of suspended solids on a large-scale. Sand, silt, and clay are dislodged by rainfall and overland flow and carried into streams and lakes from rural and agricultural areas, forests, and urban areas (Likens et al., 1970; Bryan, 1971; Lin, 1972; Glancy, 1973; Sartor*et al*., 1974).

BOD is one another key indicator parameter in assessing the degree of pollution. Biochemical Oxygen Demand (BOD) is defined as the amount of oxygen required by microorganisms to stabilize decomposable organic matter at a particular time and temperature. The maximum BOD in the river may be due to higher rate of composition of organic matter at higher temperature, turbidity and less water current (Sanap et al.,2006). In the present investigation, the increased level of BOD, 4.5mg/L, 3.4mg/L and 3.2mg/L at the sites GP,TPK and VR of the Vaigai river at the beginning of monsoon indicates existence of moderate level of pollution. The same level of BOD 5.9mg/L, 5.0 mg/L, 2.7mg/L and 2.6mg/L at the sample sites VR, SN,TPK and GP during end of the monsoon indicates discharge of various pollutants into the Vaigai river due to human anthropogenic activities.Higher BOD indicate pollution and may be attributed to the percolation of waste water loaded with biodegradable compounds (Pitchammal*et al* 2009), which might be the result of untreated sewage, solid and industrial waste discharge respectively into eachsites (MimozaMilovanovic*et al* 2007).

Calcium is one of the most abundant substances in natural water. The quantity of Ca in natural water generally varies from 10-100 mgL-1 depending on the type of rocks (Trivedy and Goel, 1986). Magnesium and calcium, which occur naturally in water bodies, are among the most highly available alkali metals in the environment (Grochowska, Tandyrak 2009). The concentration of calcium ions (Ca^{2+}) in freshwater is found in a range of 0 to 100 mg/L, and usually has the highest concentration of any freshwater cation. Calcium content of the Vaigai river of all sites were ranged from 14mg/L (SH) to 65 (VR) at the beginning of the monsoon. It was ranged from 6 (KP,AP and SN) to10 (VR) at the middle of the monsoon and ranged from 3.7mg/L(SH) to 8.9 (VR) at the end of the monsoon. Both the upper and lower ranges observed for all sites at seasons were within the permissible limit 75 mg/L recommended by WHO (2011),ICMR and 50 mg/L recommended as the upper limit for drinking water. The calcium is not known to indicate or produce any hazardous effect on human health, (kulkarni R.R 2002). But at high level, they may form some defect on organisms. According to the obtained calcium content of the Vaigai river, the values observed in all sites at three seasons do not form any health hazard effect on both aquatic and terrestrial organisms that depend on the Vaigai river water for drinking purpose.

Chlorides are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$). It occurs naturally in all types of water. Sodium chloride is widely used in the production of industrial chemicals such as caustic soda, chlorine, sodium chlorite, and sodium hypochlorite. Sodium chloride, calcium chloride, and magnesium chloride are extensively used in snow and ice control. Potassium chloride is used in the production of fertilizers (Ottawa, 1978).Sources of sodium and chloride to ecosystems include road salt, oil field brine, water softeners, septic and sewage effluent,natural salt deposits, agriculture (fertilizer and livestock), rock weathering, and wet and dry deposition (Nimiroski and Waldron,. 2002., Boutt,et al .2001.,Peters and Turk, 1981 and Sherwood,, 1989).In humans, 88% of chloride is extracellular and contributes to the osmotic activity of body fluids. The electrolyte balance in the body is maintained by adjusting total dietary intake and by excretion via the kidneys and gastrointestinal tract. The most important source of Cl in water is the discharge of domestic sewage. Man and other animals excrete very high quantities of Cl together with nitrogenous compounds. The results obtained for the present study showed that all the sample sites of the Vaigai river contain minimum chloride value 43mg/L was at AP and the maximum chloride value 140mg/L was at VR during beginning of the monsoon. It was recorded

30mg/L as minimum was at SH and 45 mg/L as maximum at VR during middle of the monsoon. The sample collection done at end of the monsoon that showed the minimum of 20mg/L and maximum of 65mg/L were at the sites AP and VR. The chloride concentrations for all the sites in the present investigation did not exceed the recommended permissible limit 250mg/L (WHO,2011) and ICMR. The chloride concentrations for the river sample sites located at human habitations were mostly through the sewage that contained human excretion. Calculated sewage (septic and sewage treatment plant)input to the watershed using an estimate of 3.3 kg chloride per person per year by excretion, 9.1 kg chloride per person per year from other household wastes, 0.73 kg per person per year from chlorination at the sewage treatment plant (Peters and Turk, 1981).

Fluorine is a common element that does not occur in the elemental state in nature because of its high reactivity. It accounts for about 0.3 g/kg of the Earth's crust and exists in the form of fluorides in a number of minerals, of which fluorspar, cryolite and fluorapatite are the most common.Inorganic fluorine compounds are used in industry for a wide range of purposes. They are used in aluminium production and as a flux in the steel and glass fibre industries. They can also be released to the environment during the production of phosphate fertilizers (which contain an average of 3.8% fluorine), bricks, tiles and ceramics. Fluorosilicic acid, sodium hexafluorosilicate and sodium fluoride are used in municipal water fluoridation schemes (IARC, 1982; IPCS, 2000).Elevated fluoride intakes can also have more serious effects on skeletal tissues. Skeletal fluorosis (with adverse changes in bone structure) may be observed when drinking-water contains 3–6 mg of fluoride per litre. Crippling skeletal fluorosis usually develops only where drinking-water contains over 10 mg of fluoride per litre (IPCS, 1984). The USEPA (1985b) considers a concentration of 4 mg/Litre to be protective against crippling skeletal fluorosis. In the present investigation, according to the observed results, the mean fluoride contents in the sites of Vaigai river showed the ranges from 0.2 ± 0.006mg/L (VR) to 0.3 ± 0.012mg/L at the beginning monsoon and from 0.21 ± 0.010mg/L (SN) to 0.26 ± 0.018mg/L at the middle of the monsoon from 0.15 ± 0.004mg/L (VP) to 0.61 ± 0.054mg/L (VR) at the end of the monsoon. The above results obtained from the present investigation clearly indicate that the fluoride values for all sites were within the recommended limit 1.5mg/L (WHO, 2011) and Indian standard of desirable limit 0.6 t01.5mg/L. The Indian Council of Medical Research (The Indian Council of Medical Research, 1975) has given the highest desirable limit of fluoride as 1.0 mg/L and the maximum permissible limit as 1.5 mg/L. The Bureau of Indian Standards has recommended the limit as 1.5 mg/L.

Magnesium is a silvery white metal that is insoluble in water; however magnesium salts are able to dissolve in water. It is found in rocks and mineral deposits present in the earth's crust. Magnesium deficiency increases risk to humans of developing various pathological conditions such as vasoconstrictions, hypertension, cardiac arrhythmia, atherosclerotic vascular disease, acute myocardial infarction, eclampsia in pregnant women, possibly diabetes mellitus of type II and osteoporosis (Rude, 1998; Innerarity, 2000; Saris *et al*, 2000).The permissible limit of Magnesium (Mg^{++}) concentration in irrigation water is 121.55 mg/L

(Ayers and Westcot,1985). According to the results in the present investigation, all the sites showed the minimum 7 ± 0.49mg/L (SH) and maximum 18 ± 0.72mg/L (TPK) at the beginning of the monsoon, minimum 7 ± 0.38mg/L (SN) and maximum 13 ± 0.26mg/L (VR) at the middle of the monsoon, minimum 6 ± 0.3mg/L (SN) and maximum 16 ± 1.44mg/L (VR) at the end of the monsoon. The magnesium concentrations observed in all sites were within limit of drinking water standard recommended 30 mg/L (ICMR, 2011 and WHO permissible limit 50mg/L. That indicates the water of the river was safe for drinking and irrigation purposes with respect to Magnesium (Mg++) concentration.

Manganese is one of the most abundant metals in Earth's crust, usually occurring with iron. It is a component of over 100 minerals but is not found naturally in its pure (elemental) form (ATSDR, 2000). Manganese is an element essential to the proper functioning of both humans and animals, as it is required for the functioning of many cellular enzymes (e.g. manganese superoxide dismutase, pyruvate carboxylase) and can serve to activate many others (e.g. kinases, decarboxylases, transferases, hydrolases) (IPCS, 2002). Manganese is used principally in the manufacture of iron and steel alloys and manganese compounds and as an ingredient in various products (IPCS, 1999;ATSDR, 2000). Potassium permanganate is used as an oxidant for cleaning, bleaching and disinfection purposes (ATSDR, 2000; HSDB,2001). Manganese greensands are used in some locations for potable water treatment (ATSDR, 2000).In fresh water at concentrations exceeding 0.1 mg/L, the manganese ion imparts an undesirable taste to beverages and stains plumbing fixtures and laundry (Griffin, 1960). Dissolved Mn concentrations of about 1 mg/L can cause toxic effects in aquatic organisms, and many countries have adopted 0.2 mg/L for protection of 95% of species with 50% confidence (Howe*et al*. 2004).Mn compounds are well known neurotoxic substances that may cause manganism in humans, a severe neurological disorder characterized by disturbances of movement, as well as Parkinson's disease (Howe et al. 2004; Olanow 2004). The present study, the sites VP, AP, SH, SN, GP, TPK and VR of the Vaigai river showed 1.0 ± 0.162mg/L (AP) and 1.2 ± 0.816mg/L (VR), 1.4 ± 0.12mg/L (VP) and 1.0 ± 0.2mg/L (VR), respectively as minimum and maximum mean manganese at the beginning, middle and end of the monsoon. According to above observed results, the manganese concentrations of all the sites were within the recommended limit 0.1mg/L (WHO,2011) and just above to the Indian desirable limit 0.1mg/L.

Nitrates (NO3-) are chemical compounds made from the elements nitrogen (N2) and oxygen(O2). When plants and animals die, proteins are broken down by bacteria to form ammonia (NH3). Ammonia is broken down by other bacteria to form ntrite (NO2-). Nitite is then consumed by a third type of bacteria to form nitrates (NO3-). Nitrate is used mainly in inorganic fertilizers. It is also used as an oxidizing agent and in the production of explosives, and purified potassium nitrate is used for glass making. Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater treatment and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. The nitrate is taken up by plants during their growth and used in the synthesis of organic nitrogenous compounds. Surplus nitrate readily moves with the groundwater (USEPA, 1987; van Duijvenboden & Matthijsen, 1989). According to the present study data, the lowest and highest average of nitrate for all the sites of Vaigai river showed 0.2 ± 0.014mg/L and 1.5 ± 0.045mg/L, 0.5±0.02mg/L and 0.17±0.013mg/L, 0.12±0.003mg/L and 0.93±0.083mg/L respectively during beginning, middle and end of the monsoon.From the above results, it is concluded that all the nitrate values were within the maximum permitted limits recommended 45 mg/L of WHO (2011) and ICMR (2011).So, the nitrates in all sites in the Vaigai river were safe for drinking and irrigation purpose.

Nitrites are composed of nitrogen and oxygen with the nitrite ion found in salts having the chemical formula NO2 - . Nitrites are part of the nitrogen cycle that is the transformations of nitrogen and nitrogen containing compounds in nature. While nitrites alone do not signify a pollution problem, their presence in combination with ammonia and nitrate may indicate environmental contamination. Nitrite is mainly produced as a result of oxygen depletion, anaerobic biological conditions dominate and reduction sets in. Nitrite occurs naturally in lakes and rivers as a result of nitrification of ammonia and denitrification of nitrate. Generally effluents containing ammonia are main sources for nitrite content. Probably, the commonest source of ammonia is sewage effluent. Significant amounts of ammonia released in the form of effluents from coal, gas, coke and fertilizers producing industries and from agriculture silage, manure and fertilizer converted into nitrates by nitrification and then to nitrites by denitrification process. Nitrite is absorbed in the intestine into the blood stream. Concentrations of 45 mg/L produce methaemoglobinemia (Elytingon,1983). Nitrite (NO2 -) has the ability to react with secondary amines present in human body and form carcinogenic nitrosamine(Sampat,2000). According to the present study results, the sample sites VP, AP, SH, SN, GP, TPK and VR of the Vaigai river showed the minimum and maximum value of nitrite 0.05 ± 0.003 mg/Lat AP and 0.09 ± 0.007mg/L at SN during beginning of the monsoon, minimum 0.012 ± 0.0008mg/L at AP and maximum 0.75 ± 0.015mg/L at VR during middle of the monsoon and minimum 0.12 ± 0.003 at VP and maximum 0.93 ± 0.083mg/L at VR during end of the monsoon respectively. From the above results, it is concluded that all the nitrite values were within the WHO recommended standard 3mg/L. Hence, the Vaigai river water is safe for both drininking and agriculture purposes.

Sodium is one of the alkali metals belonging to group 1 of the periodic table, along with Li, K, Rb and Cs. The element has an atomic number of 11, an atomic mass of 23, one oxidation state (+1) and one natural isotope (^{23}Na). It is the most abundant of the alkali metals, the fifth most abundant metal in the Earth’s crust with an average value of 22,700 mg kg^{-1} (Fyfe 1999).Sodium is essential to human life. It forms an important part of blood plasma, and is used in functioning of the nervous system, controlling muscle contraction and aiding digestive processes. Too much Na in the diet can, however, damage kidneys and increase the chances of high blood pressure. It is a necessary dietary component to maintain electrolyte and fluid balance, in excess it has been shown to have deleterious health effects (WHO, 2005).Humans are genetically programmed for salt intake of 2500 mg/day, and excess intake can present a major challenge to the physiologic systems working to excrete excess through the kidneys. Excess sodium intake can lead to fluid retention, increased blood pressure, stroke, left ventricular hypertrophy, stomach cancer, kidney disease, renal stones and osteoporosis, and asthma (He & MacGregor, 2010). The present study the minimum and maximum concentrations of all sites in the Vaigai river were ranged from 12 ± 0.72mg/L to 140.98mg/L, 2.4±0.192mg/L to 6.8±0.136mg/L , 1.7±0.068mg/L to 11.4±1.026mg/L respectively at the beginning, middle and end of the monsoon. All the above results were within the recommended maximum permissible limits 100mg/L (WHO,2011) and FAO guidelines value < 3 3-6 9>mg/L. So, The Vaigai river water is safe for drinking as well as irrigation purpose.

Sulphtes occur naturally in the form of numerous minerals, including barite ($BaSO4$), epsomite ($MgSO4·7H2O$) and gypsum ($CaSO4·2H2O$) (Greenwood and Earnshaw, 1984). They dissolved in water during rain and runoff is the important sources of minerals that contribute to the mineral content of many drinking-waters. Sulfate is a primary constituent of the effluent waste (Rose and Cravotta, 1998). The different froms of Sulphate and sulphuric acids are used in various house hold things in day to day life. The anthropogenic sources of sulphate can account for 20 to over 90 percent of the sulphur found in some surface waters (Nriagu, 1978). Major anthropogenic sources of sulphate include industrial waste waters, mine wastes, smelting, the burning of fossil fuels, agricultural runoff, dyes, glass, paper, soaps, textiles, fungicides, insecticides, astringents and emetics. Addition to these, the sulphate enters surface waters like rivers and lakes from groundwater, the oxidation of sulfide minerals during chemical weathering, atmospheric deposition from acid rain, human and animal waste, farming, and industrial processing and manufacturing (Soulingny et al, 2001).In drinking water (humans and livestock), sulphates in excess of 5OOmg/L can exert purgative and/or laxative effects (Singleton, 2000). In the present study, the sulphate in all the sites of Vaigai river were ranged from, 6.5 ± 0.39 to225 ± 6.75 mg/Lat the beginning of the monsoon 1.13 ± 0.09 mg/Lto 45.9 ± 0.918mg/L at the middle of the monsoon, 3.13 ± 0.125mg/L to 49.24 ± 4.121mg/L at the end of the monsoon.The above obtained results indicated that all the sulphate values were within the recommended drinking water standard of 150mg/L (ICMR,2011) and Indian standard limit 150mg/L. It indicates that the obtained sulphate levels in the Vaigai river were safe for drinking as well as irrigation purposes.

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