Urbanization Impact on Various Physicochemical Parameters and Developing an Eco-Heart Index

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Abstract

In the present study, the quality of Vaigai River at two distinct places Madurai and Manamadurai were studied. The river water samples from three places in the upstream side and downstream side of each of the sites were collected and used for water quality analysis. The samples were subjected to various physicochemical parameters like pH, dissolved oxygen, electrical conductivity, chlorides, and heavy metals as per the standard procedure. The obtained values were used to prepare the community friendly Eco-heart index. The river water samples at the upstream of Madurai were found to be having concentrations of pH – 8.32±0.28, turbidity - 32±8 nephelometric turbidity unit and total dissolved solids- 1765±55 mg/L (moderately contaminated) compared to downstream side (pH – 8.77±0.25, turbidity – 107±12 nephelometric turbidity unit and total dissolved solids- 2180±95 mg/L (highly contaminated). Similarly, in the Manamadurai site also the concentrations were higher in downstream side (pH–8.94±0.15, turbidity -235±18 nephelometric turbidity unit, total dissolved solids- 2755±32 mg/L) than upstream side (pH -8.72±0.23, turbidity - 74±22 nephelometric turbidity unit and total dissolved solids- 2110±25 mg/L). Similarly, the Eco-Heart index value also shows that there is no proper heart shape at any point, symbolizes that Vaigai River water is unfit to drink in Madurai and Manamadurai. Hence, the results conclude that the river water has to be extensively treated before used for drinking or cooking purpose. The dumping of solid waste and discharge of wastewater in the course of the river body has to be avoided.

Keywords: Eco-heart; Dissolved salts; Heavy metals; Vaigai River; Water quality.

1. INTRODUCTION

The water is the prime natural source for the survival of the humans, flora, fauna, other creatures, and considered as the chief constituent of ecosystem. The drinking water sources are mainly in the form of rivers, lakes, glaciers, groundwater and rain water, etc. Additionally, the water sources arealso essential commodity for agriculture, livestock production, hydropower, and fisheries. The quality and quantity of the freshwater availability is declining on daily basis due to various anthropogenic activities like increasing population, high living standards, industrialization and urbanization, etc (Tyagi *et al.,* 2013; Naubi *et al.,* 2016; Ramprasad and Philip, 2016). The quality of the water at the specific location can be determined by conducting water quality analysis for the various physic-chemical parameters using standard methods. The values obtained should be within the prescribed standard limits, if exceeded it causes harmful impacts for human health (Katyal, 2011; Ren *et al.,* 2014; Balaji and Thirumaran, 2019). Many countries in the world including India, follow that water quality index (WQI) as the tool to denote the suitability of the river water for a variety of uses such as agriculture, aquaculture, drinking purpose, industrial uses etc., (Yisa and Jimoh, 2010; Naubi *et al.*, 2016). There are many literature supports showing that qualities of many perennial and non-perennial rivers in the world are declining in quality due to various anthropogenic activities.

The Langat river basin in Malaysia was assessed for the different water quality parameters during two different seasons and for the entire river stretch. They found that the water quality in upstream is clean compared to downstream. The quality of Langat River was found to be unfit for drinking as it approaches the downstream side, due to anthropogenic activities experienced. The authors also developed a novel index method named "Eco-heart" and compared the correlation with conventional WQI (Sakai *et al.*, 2018). Sener *et al.*, (2017) evaluated the water quality using water quality index for the Aksu River in Turkey. They investigated various physic-chemical parameters of the river in 21 different locations through the flow path of the river. They found that at the upstream side the water quality was good and in the north and south of the basin (downstream side) the quality was poor and very poor. The Dongjiang River in the southern china is considered as a significant water source for irrigation and portable purposes for the population in Hongkong and Pearl River Delta (PRD) (Sun *et al.*, 2016). The authors used WQI as the tool to assess the spatial and temporal variability of the water quality in the river. They conclude that the tributary of the river that carry water to the reservoir had an excellent water quality, the upstream of the river has a good water quality and medium and poor water quality in the downstream. The above condition suggests that the urban wastewater generated from the community and the industrial developments led to the deterioration of water quality (Sun *et al.*, 2016). There are many other reports showing the WQI and water quality of various surface and groundwater contamination around the world (Ali *et al.*, 2018; Ewaid *et al.*, 2018; Kawo and Karuppannan, 2018; Wu *et al.*, 2018; Chetty and Pillay, 2019). Similar kind of condition prevails in India too, Vasanthavigar *et al.*, (2010) found that the groundwater

quality and WQI of the Thirumanimuttar sub-basin was understood by collecting 148 bore and tube well samples. It was found that the levels of major cations, anions, SAR, % Na and total hardness were much higher in both the seasons and were concluded that the water is unfit for irrigation purpose. Another study evaluated the quality of one of the important perennial rivers of India, the River Yamuna (Sharma and Kansal, 2011). The study identifies various critical pollutants that affect the quality of the river during its course through various cities. The water quality indices for the river at four locations were computed during the monsoon, pre-monsoon and post-monsoon seasons. At the upstream (Palla region) the water quality ranged from good to marginal category and in the other locations the water quality was poor. They authors also conclude that BOD, DO, total hardness, coliform, free ammonia and salts were found to be critical for deciding the water quality (Sharma and Kansal, 2011).

The water quality assessments of River Ganga in Rishikesh, India was carried out by Haritash et al., (2016).They say that the river water quality was suitable for industrial, domestic and irrigation application and also show that there are no specific industrial inputs to stream. Padmaja, (2019) assessed the water quality of Nallavagu River in Sangareddy city in Telangana state. The author indicated that the river water was varying from acidic to alkaline conditions and most of the physiochemical parameters of the river was higher than the prescribed limits as per BIS : 10500 – 2012. It can be concluded from the above literature survey that as the river progress into the developed urban sectors, the contamination levels are much higher than the upstream side.

In India, the river water quality monitoring and assessments are carried out once in a year for each and every river by central pollution control board (CPCB) and the reports were published in their website. The report delivers about the quality of the river through the water quality index (WQI), which considered being one of the effective ways to describe the quality of the river. The WQI relates a group of parameters to a common scale and combining them into a single number (Sun et al., 2016; Sutadian et al., 2016; Sener et al., 2017; Wu et al., 2018). As many of the environmentalist and policy makers recognize the WQI as one of the most effective tool to provide feedback on the quality of the water (Naubi et al., 2016). The water quality at a certain time and location was evaluated by analyzing various physicochemical parameters and WQI was developed by providing weighing factors to each parameter (Bhutiani et al., 2016; Shah and Joshi, 2017).The water quality indices are not a common feature all over the world; each country has their own way of evaluating their river water quality and subsequently the indices values. Meher et al., (2015) used a total of 14 parameters such as pH, total dissolved solids (TDS), alkalinity, dissolved oxygen (DO), conductivity, turbidity, and other parameters for developing a water quality index for different sections of the Ganges River. Al-Shujairi (2013) proposed a WQI formula that used seven water quality parameters (TDS, total hardness, pH, DO, biochemical oxygen demand (BOD), nitrate (NO_3), and phosphate) to evaluate water quality in the Tigris and Euphrates rivers in Iraq. There are many studies showing the procedure for the WQI values calculation and the averaging and assessing

methodology for different river water quality (Sutadian et al., 2016;Bora and Goswami, 2017;Shah and Joshi, 2017; Sener et al., 2017; Verma et al., 2017). Terrado et al., (2010) performed a sensitivity analysis for the WQI in order to select the best procedure for calculating and assigning the values for the parameters. The average weighing factor provided for the parameters are varying significantly from country to country as well as from various monitoring agencies to agencies. In general, the public point of view on the WQI is recognized as a complicated or not easily understandable, requires high level of skills plus knowledge and requires sophisticated instruments (Naubi et al., 2016; Sidek et al., 2016). Therefore, there is an urgent need to develop a tool that complements the present WQI values and are easily understandable by the common public and assess the water quality at the local scale level with lesser and cost effective techniques. The one such technique is the development of "Eco-Heart" index.

The Eco-heart index is the novel water quality indicator that draws a universal peace and love symbol "heart shape" based on the 6 vital water quality parameters (pH, dissolved oxygen, chlorides, dissolved solids, sulphates and hardness). The above mentioned water quality parameters are essential and can be easily measured in the field itself using water test kits (no sophisticated instruments are required). The full heart shape indicates that the quality of the river water is good and fit for drinking purpose, and if the shape of heart is broken or irregular then it is considered as polluted (Sakai et al., 2018). In the present study, the quality of one of the most important river in the southern Tamil Nadu, the Vaigai was evaluated. The various physicochemical parameters as prescribed by BIS 10500: 2012 was measured for the water samples collected in the upstream and downstream of two cities (Madurai and Manamadurai). The quality of the river was checked with the standard value provided in Indian standard code (BIS 10500: 2012), and the possible reason for contamination and solutions for it are provided. Further, in the present study a novel community based user friendly index "Eco heart index" was developed, to clearly understand about the quality of river at two different places. The present study was carried out during the post-monsoon period (December-January, 2017-18) at two distinct places in the Vaigai River viz. a viz., Madurai and Manamadurai in India.

2.   MATERIALS AND METHODS
2.1   Study area

The current study was carried out in Tamil Nadu, Southern India across the Vaigai River, it is considered as one of the most vital river that provides water for irrigation and drinking purpose for three districts of Tamil Nadu. The catchment area of Vaigai River is widespread and lies between the GPS coordinates of 09°39'15.0" N to 09°20'52.7" N in latitude and 77°29'42.3'' E to 78°59'53.4" E in longitude. It originates in Varusanadu Hills, the Periyar Plateau of the Western Ghats range, and flows northeast through the Kambam Valley, and drains near the Palk Strait near Uchipuli, close to Pamban bridge in Ramanathapuram District. The Vaigai River is 258 Km long and has a drainage basin of 7031 sq. km in Tamil Nadu (Sankar, 2002). In the present study, the water samples were collected in two distinct locations say, Madurai and Manamaduari located on the course of the river (Fig. 1).
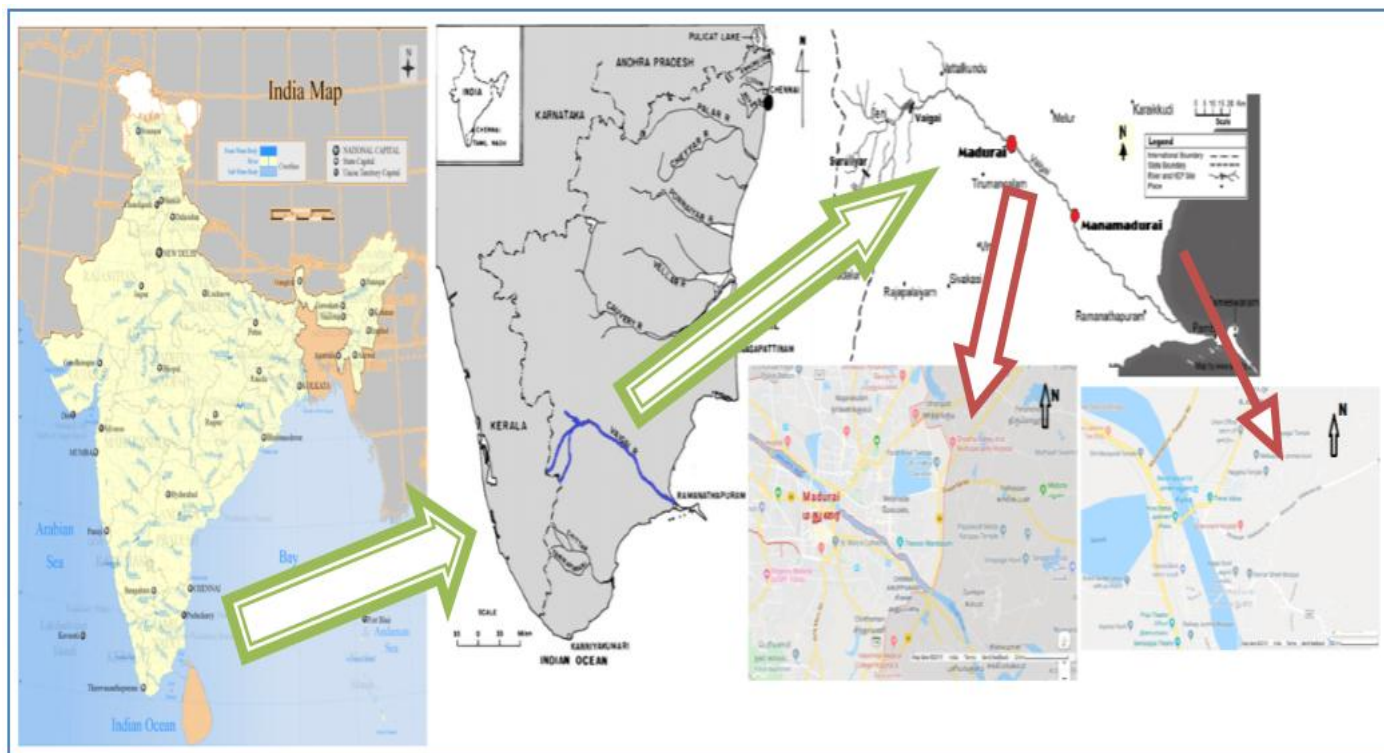
Fig. 1: Geographic location of the study area in Vaigai River (a) Madurai (b) Manamadurai in India

The Madurai city is located in the upstream side of the Vaigai River and considered as the temple city. The water samples (3 numbers) from the upstream side of river were taken closer to the intake structures. The GPS coordinates are as follows; latitude was 09°55'35.5" N and longitude was 78°07'23.1" E. The water from the River Vaigai was taken for domestic application, industrial uses and partly for irrigation. It was observed during the sampling that the river predominantly carrying wastewater and solid waste. Another set of three samples were collected from the downstream side, closer to the wastewater discharge points. The GPS coordinates of the downstream side are as follows; latitude was 09°55'16.3" N and longitude was 78°07'56.6" E (Fig.1). The Manamadurai is located in the downstream side of the River Vaigai, which is very closer to the delta region. Similar to Madurai site, the three water samples of each were collected from upstream as well as downstream side. The GPS coordinates of the Manamadurai site was at the upstream side, latitude was 09°42'01.3" N and longitude was 78°26'55.4" E and at the downstream side, latitude was 09°41'17.8" N and longitude was 78°27'21.4" E (Figs.1a and b).

2.2   *Physicochemical analysis of water samples*

A fresh polystyrene bottle of 2 L capacity was used to collect the water samples from the rivers. The bottles were rinsed thoroughly with distilled water before the collection, and were stored in an ice box before transported to the laboratory. In the laboratory, 500 mL of sample was separated out and preserved with Boric acid and Hydrochloric acid for the measurements of trace elements in a 500 mL Borosil glass bottles. The samples were stored in refrigeration at 4 °C before the analysis. The collected water samples were subjected to various physicochemical parameters like pH, dissolved oxygen, electrical conductivity, turbidity, total solids, suspended solids, dissolved solids, total alkalinity, total hardness, chlorides, and sulphates are measured as per standard operating procedure prescribed by American Public Health Association (APHA, 2012). The trace elements including, manganese, iron, calcium, manganese, zinc, sodium, and cadmium were measured using X-ray fluorescence diffraction and elemental analyzer (XRF, Bruker S8 Tiger, USA). The water samples were lyophilized using liquid nitrogen to remove the moisture and were freeze dried, and then the powdered samples were measured using XRF for the trace elements concentration.

2.3   *Eco-heart index: Development and Assessment*

The vital six parameters (pH, dissolved oxygen, dissolved solids, hardness, chlorides and sulphates) from the analysis were taken for preparing the "eco-heart" index. The "Eco-heart" index was developed by following the three steps: marking, connecting and assessing (Sakai et al., 2018), (Fig.2). In step 1, the parameters were marked by dividing the circle into six different axes, and at each axis for each parameter the scales / levels were labeled as per BIS: 10500 - 2012.
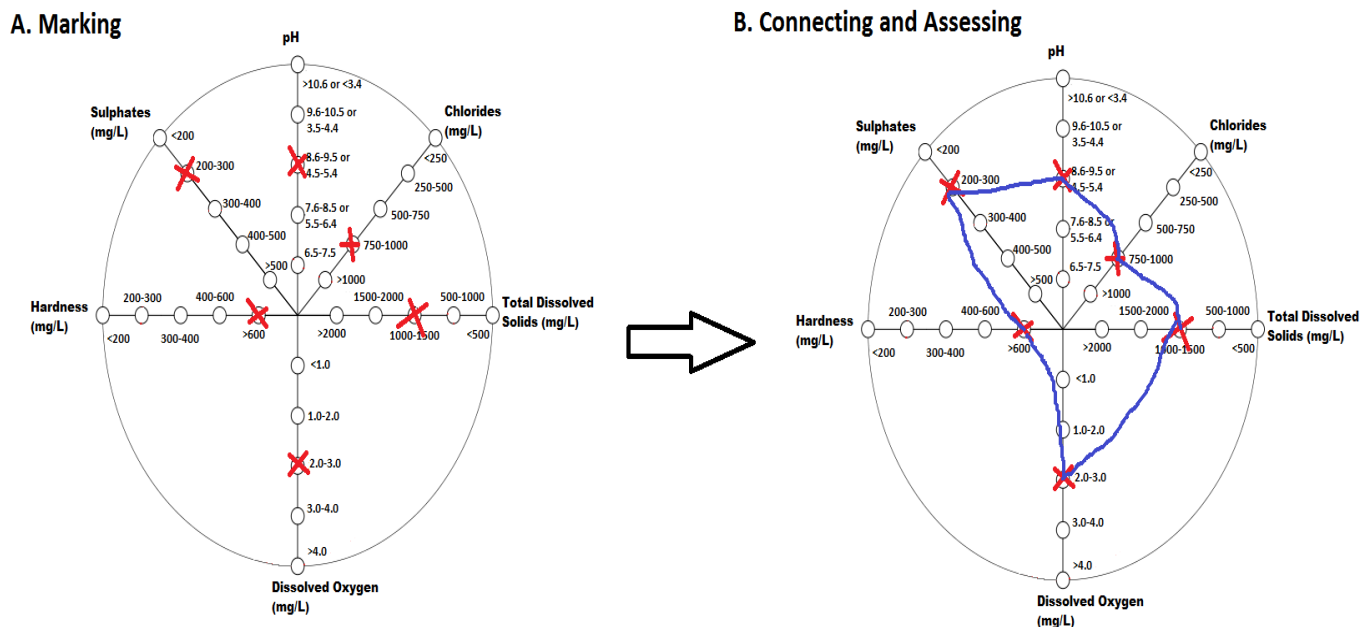
Fig. 2: Overall concept of Eco-Heart index (a) Marking (b) Connecting and Assessing

As per Bureau of Indian Standards (BIS: 10500 – 2012), the 6 parameters that were selected for the preparation of "eco-heart index" were classified into different levels depending on the pollution level and were decided based on the standard values. The water quality levels and the classification of the pollution scenario were tabulated in Table 1. In step 2, the parameters were connected based on the analysis values. Finally in step 3, the obtained shape was assessed based on the pollution level, and the solution for the problem is provided. The assessment of the river quality was based on the shape that was obtained,

if the shape of the plotted graph is representing a perfect heart shape, and then the water is considered to be clean. If the plotted graph is in irregular shape, then it represents the different stages of pollution level. The plotted graph is showing a corrugated heart shape, and then the pollution level is very high and unfit for drinking and other purposes. The intermediate shapes of the heart represent the other levels of pollution (moderate to heavy) and more details were discussed in the following sections.

Table 1: Classification of water quality levels as per Bureau of Indian Standards (BIS: 10500 - 2012)

Parameter / Levels	pH	Dissolved Oxygen (mg/L)	Total Dissolved Solids (mg/L)	Total Hardness (mg/L)	Sulphates (mg/L)	Chlorides (mg/L)
Level – I ; Clean	6.5 – 7.5	>4	< 500	< 200	< 200	< 250
Level – II; Moderate	7.6 – 8.5 or 5.5 – 6.4	3.0 – 4.0	501 – 1000	201 – 300	201 - 300	251 – 500
Level – III; Slightly Polluted	8.6 – 9.5 or 4.5 – 5.4	2.0 – 3.0	1001 – 1500	301 – 400	301 - 400	501 – 750
Level – IV; Polluted	9.6 – 10.5 or 3.5 – 4.4	1.0 – 2.0	1501 – 2000	401 - 600	401 - 500	751 - 1000
Level – V; Heavily Polluted	>10.6 or < 3.4	<1.0	>2000	>600	>500	>1000

3. RESULTS AND DISCUSSION

3.1 Water quality of Vaigai River

3.1.1 At Madurai

The Madurai is one of the fast growing cities in South India of Tamil Nadu. The expansions of industrial and residential zones are predominantly concentrated near to the banks of the River Vaigai. The Vaigai is a non-perennial river and the water were taken for drinking, industrial and other applications from various intake structures in the course of river. During the sampling period, it was observed by the team that the Vaigai River upstream of Madurai is comparatively cleaner than the downstream side. There are many solid waste humps, domestic wastewater discharges and some industrial effluents found in the river course. The physico chemical characteristic of Vaigai River water in the upstream and downstream side of Madurai are tabulated in Table 2.

Table 2: The quality of water in upstream and downstream side of Vaigai river at Madurai

Sl. No	Parameter	Unit	Upstream side	Downstream side	Drinking water standards (BIS:10500-2012)
1	pH		8.32 ± 0.28	8.77 ± 0.25	6.5 – 8.5
2	Dissolved Oxygen	mg/L	2.5 ± 1.2	1.2 ± 0.8	>4.0
3	Turbidity	NTU	32 ± 8	107 ± 12	<5.0
4	Electrical Conductivity	mS/cm	1.122 ± 0.41	1.884 ± 0.55	<0.5
5	Total Hardness	mg/L	512 ± 20.5	705 ± 52	200 – 600
6	Total Alkalinity	mg/L	715 ± 32.5	720 ± 18	200 – 600
7	Chlorides	mg/L	1727 ± 106	1988.5 ± 82	250 – 1000
8	Sulphates	mg/L	404 ± 7.5	515 ± 22	200 – 400
9	Total Suspended Solids	mg/L	138 ± 8	305 ± 21.5	NA
10	Total Dissolved Solids	mg/L	1765 ± 55	2180 ± 95	500 – 2000
11	Total Solids	mg/L	1903 ± 47	2485 ± 73.5	NA
12	Calcium	mg/L	15.8 ± 2.1	19.7 ± 3.5	75 – 200
13	Sodium	mg/L	33.5 ± 2.7	38.1 ± 3.8	NA
14	Magnesium	mg/L	7.29 ± 2.7	9.38 ± 4.77	30 – 100
15	Potassium	mg/L	3.14 ± 1.08	5.99 ± 1.2	NA

NA: Not Applicable

The values of pH, turbidity and electrical conductivity in upstream and downstream are much higher than the BIS drinking standards. The dissolved oxygen level of the river is under a pathetic condition with the values < 1.0 mg/L in the downstream side of Madurai. The value clearly indicates that there is high chance of wastewater discharges in the river bodies; the result also correlates our visual inspection. The results were in good agreement with Ramprasad et al., 2017; the authors proved that as the wastewater mixes the DO concentration decreases. The other parameters such as solids, alkalinity and hardness concentrations were much higher than the standard prescribed values. It denotes that there is high possibility of risk to human life as they drink the contaminated water. Sengupta, 2013explained that drinking hard water causes cardiovascular diseases, growth and reproductive retardation due to high amount of calcium and magnesium deposits either from anthropogenic or natural ways. The similar kind of results was obtained by Cheng et al., 2018 and Dunca, 2018, as the water enters the human settlements the concentration in the river exceeds the standard values.

3.1.2 At Manamadurai

The Manamadurai is situated at the downstream side of the Vaigai basin (Fig. 1), the concentrations of the various physicochemical parameters are provided in the Table 3. It was observed that the concentrations of all the parameters are much higher than the Madurai samples. As mentioned earlier that Manamadurai is nearer to the drain and possibility of anthropogenic discharges from the cities/towns are more leading to more concentration of water quality parameters.

Table 3: The quality of water in upstream and downstream side of Vaigai river at Manamadurai

Sl. No	Parameter	Unit	Upstream side	Downstream side	Drinking water standards (BIS:10500-2012)
1	pH		8.72 ± 0.23	8.94 ± 0.15	6.5 – 8.5
2	Dissolved Oxygen	mg/L	0.9 ± 0.4	0.2 ± 0.2	>4.0
3	Turbidity	NTU	74 ± 22	235 ± 18	<5.0
4	Electrical Conductivity	mS/cm	1.414 ± 0.72	1.955 ± 0.39	<0.5
5	Total Hardness	mg/L	650 ± 25	695 ± 20	200 – 600
6	Total Alkalinity	mg/L	822 ± 15.2	864 ± 29.4	200 – 600
7	Chlorides	mg/L	2172.77 ± 27	2577.5 ± 35	250 – 1000
8	Sulphates	mg/L	475 ± 18.5	522.5 ± 15.5	200 – 400
9	Total Suspended Solids	mg/L	313 ± 38	555 ± 15	NA
10	Total Dissolved Solids	mg/L	2110 ± 25	2755 ± 32	500 – 2000
11	Total Solids	mg/L	2423 ± 13	3310 ± 17	NA
12	Calcium	mg/L	21.8 ± 3.1	29.7 ± 5.2	75 – 200
13	Sodium	mg/L	55.8 ± 5.1	68.9 ± 12.2	NA
14	Magnesium	mg/L	11.8 ± 3.5	19.7 ± 5.2	30 – 100
15	Potassium	mg/L	6.08 ± 0.88	6.43 ± 2.1	NA

NA – Not Applicable

3.2   Heavy metals concentration

The heavy metal such as Aluminum, Iron, Copper, Zinc, Silver, Boron, etc., if found to be present in the surface water bodies more than the permissible level causes harm to flora, fauna and humans (Begum *et al*., 2008; Ali *et al*., 2016; Patel *et al*., 2018).The natural sources and anthropogenic activities are responsible for the abundant levels of heavy metals in the surface and ground water bodies (Khan *et al*., 2008; Ali *et al*., 2016). The water samples taken from Madurai and Manamadurai (upstream and downstream) sites showed that the concentrations of Iron, Boron, Copper, Silver and Zinc are much higher than the prescribed value (Fig.3a and b). It was also observed that the heavy metal concentrations in the downstream side of particular site were much higher than the upstream side of that particular site. Similar trend was observed by numerous authors earlier for Karnaphuli River, Bangladesh (Ali *et al*., 2016), Sinu River, Colombia (Marrugo-Negrete *et al*., 2017) and Swarnamukhi River (Patel et al., 2018). As per the Toxicity Reference Values (TRV) prescribed by USEPA, 1999 that all the heavy metals concentrations greatly exceed the safety limit for drinking / cooking. Hence, the river Vaigai in both Maduari and Manamadurai are vulnerable to cause health effects on humans and other living organisms and concluded that unfit for drinking / cooking.
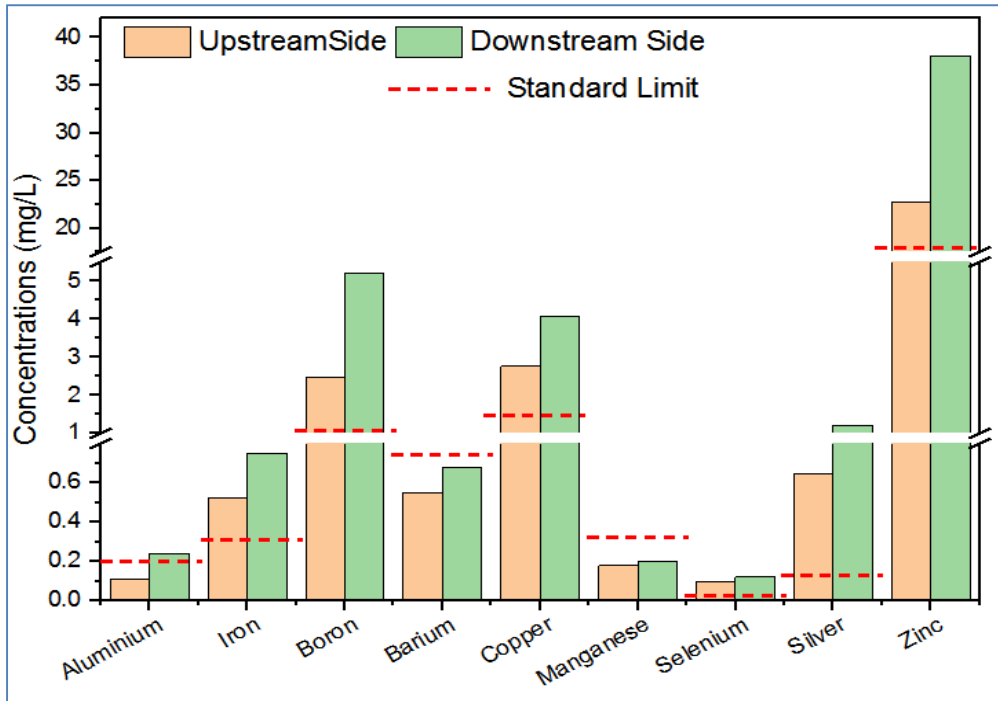
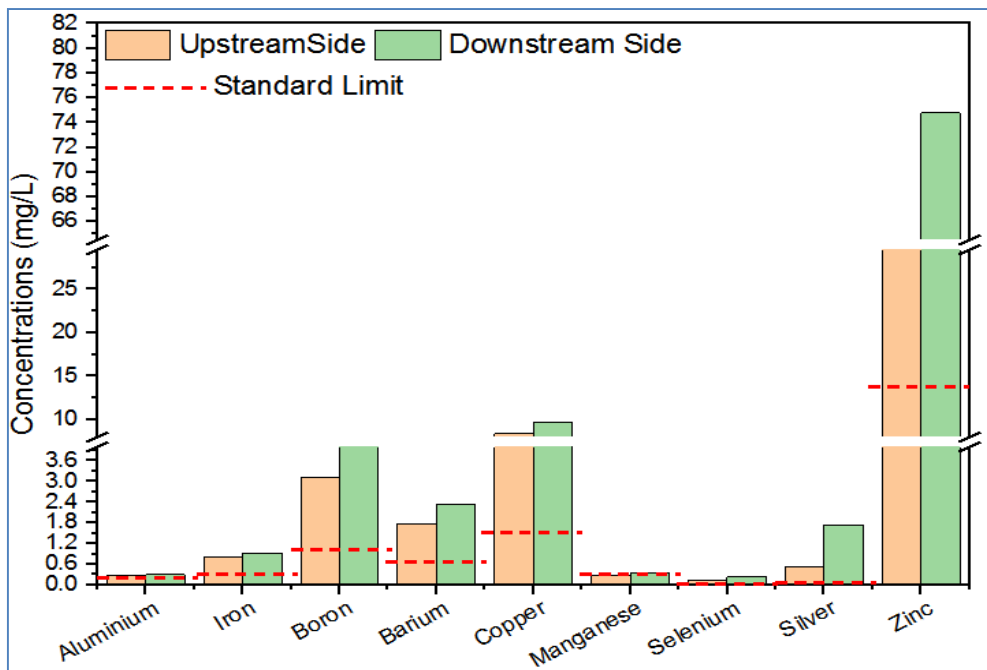**Fig. 3a:** Heavy Metal Concentrations in Upstream and Downstream side of Madurai on Vaigai River

Fig. 3b: Heavy Metal Concentrations in Upstream and Downstream side of Manamadurai on Vaigai River

3.3   Eco-heart Index

The eco-heart index for the two sites (Madurai and Manamadurai) in upstream and downstream side was displayed in the Fig.4 (a) – (d). For the Madurai upstream side the Eco-heart index showed an "irregular shell" shape (Fig 4(a)), it represents the water sample is predominantly contaminated with chlorides and reduced dissolved oxygen (DO) concentration. The decrease in DO level is mainly attributed due to the disposal of wastewater into the river. Similar results were observed by Ramprasad et al., 2017 that in the greywater as the organic fraction is increased the DO level dropped significantly. The other sites like downstream of Madurai and Manamadurai (upstream and downstream) Eco-heart index showed a "Rabbit ear" shaped pattern (Fig. 4 (b) - (d)). The above outline represents that the river water is completely contaminated with a wastewater from industries

and domestic dwellings. Hence, it can be concluded that the river water is unfit to drink at Madurai and Manamadurai sites. The policy makers are required to enforce a stringent law towards the polluters to the rivers and levy heavy fine.

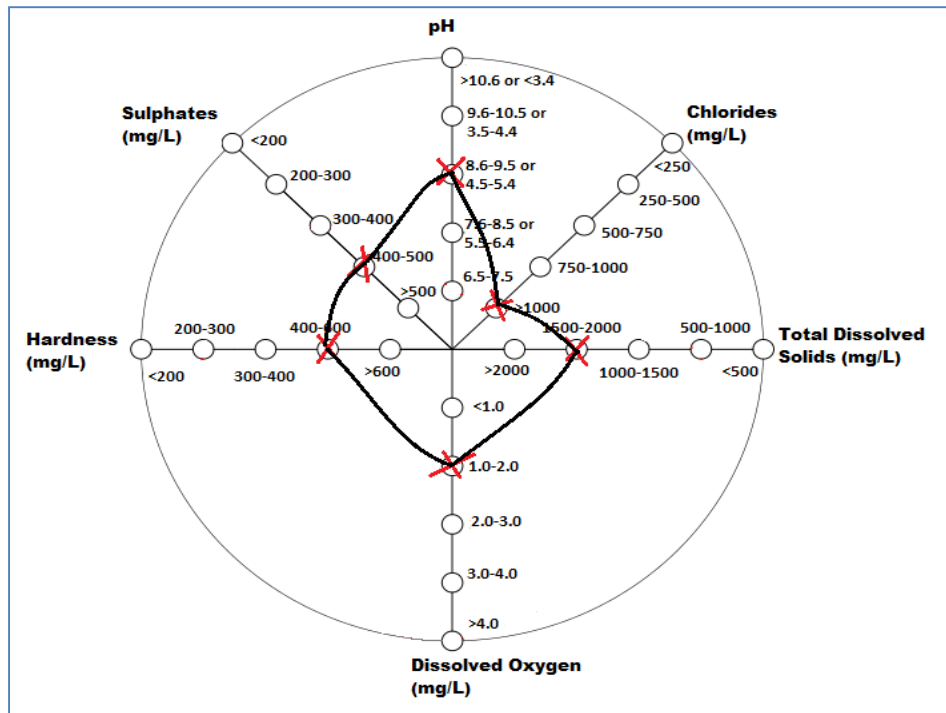Adopt the strategy of "polluters pay principle" and "absolute liability" policies.

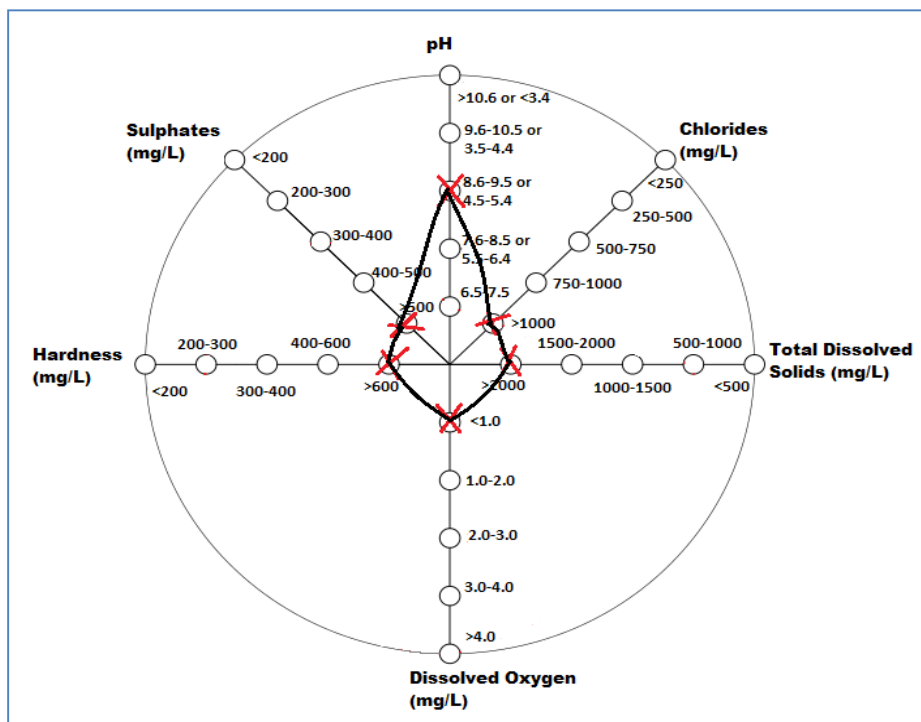**Fig.4a:** Eco-heart map for the upstream side of Madurai basin

Fig.4b: Eco-heart map for the downstream side of Madurai basin
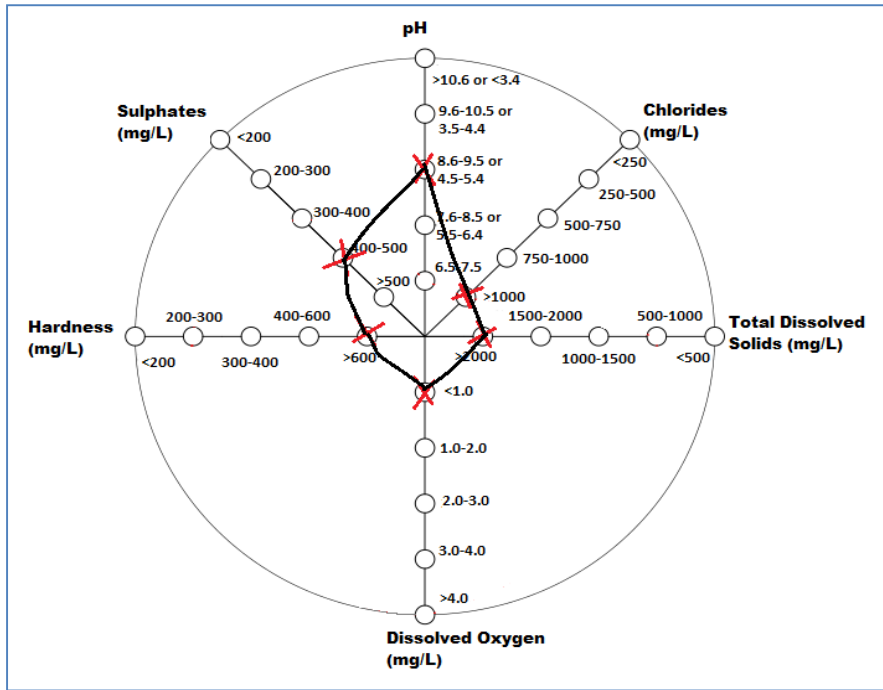
Fig.4c: Eco-heart map for the upstream side of Manamadurai basin
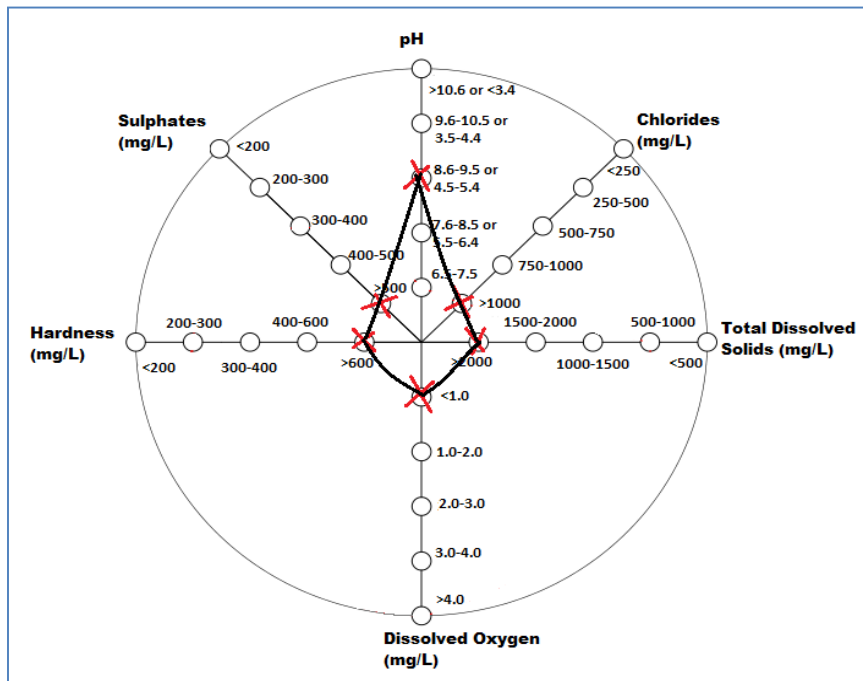

Fig.4d: Eco-heart map for the downstream side of Manamadurai basin

4.   CONCLUSION

The present study evaluated the surface water quality of the River Vaigai in the most polluted watershed area at Madurai and Manamadurai. The study concluded on the basis of the Eco-Heart index and shape of it indicates that the slightly polluted to highly polluted quality of river water in the pre-monsoon season at all the sampling sites. The concentrations of various physic-chemical pollutants including heavy metals are much higher than the standard values. The total dissolved solids (TDS) concentration in the upstream of Madurai was 1765±55 mg/L and in the downstream it was 1960±95 mg/L, while in the upstream of Manamadurai the TDS values were in the range of 2110±25 mg/L and in the downstream it was 2755±32 mg/L. Similarly, the dissolved oxygen content was also dropping down gradually from 2.5±1.2 mg/L in the upstream of Madurai and 0.2±0.2 mg/L in the downstream of

Manamadurai. The other parameters like turbidity, hardness, alkalinity and chlorides were comparatively much higher in Manamadurai site than Madurai site. The concentrations of water samples in the downstream side of Madurai sites are turbidity 107±12 NTU (Nephelometric turbidity unit), alkalinity 720±18 mg/L and chlorides 1988.5±82 mg/L. In the downstream side of Manamadurai, the water sample concentrations were, turbidity was 235±18 NTU, alkalinity was 864±29 mg/L and a chloride was 2578±35 mg/L. The reasons for higher level of contamination in River Vaigaias well as steady decline in the pollution levels as it approaches the delta are due to the discharge of effluent from domestic and small scale industrial dwellings. The eco-heart index map also clearly visualizes that in the downstream of the Madurai and Manamadurai the index obtained was a "Rabbit Ear", represents poor quality water. While, in the upstream of the sites, the eco-heart index showed a "Shell shape" structure, which shows it is moderately polluted. It has to be noted that, the "heart shape" was never occurred in the Vaigai River at the two sites monitored. The study also concludesthat the water quality of River Vaigai at Madurai and Manamadurai was found not suitable for drinking purpose directly. A proper treatment like activated carbon filter or pressure sand filter should be adopted before direct utilization of river water.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy to have been completely observed by the authors.

ABBREVIATIONS

°C	Degree Celsius
%	Percentage
BIS	Bureau of Indian Standard
BOD	Biochemical oxygen demand
CPCB	Central pollution control board
DO	Dissolved oxygen
E	East
Fig	Figure
GPS	Global positioning system
L	Liters
mg/L	Milligram per liter
mL	Milliliter
mS/ cm	Miili Siemens / centimeter
N	North
Na	Sodium
NA	Not Applicable
NO_3	Nitrate
NTU	Nephelometric turbidity unit
pH	Hydronium ion concentration
SAR	Sodium absorption ratio
Sq. km	Square Kilometer
TDS	Total dissolved solids
TRV	Toxicity reference value
TSS	Total suspended solids
WQI	Water quality index
XRF	X-ray fluoresce diffraction analysis

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