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HEAVY METALS LOAD AND ITS IMPACT ON SURFACE WATER QUALITY OF VAIGAI RIVER NEAR MADURI CITY

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ABSTRACT

Vaigai river is the main water source for the five districts namely Theni, Madurai, Dindugal, Sivagangai and Ramanathapuram of southern Tamilnadu, India. The river is highly polluted with innumerable kinds of xenobiotics including heavy metals. In the recent years, the Vaigai river is immensely contaminated with toxic metals due to anthropogenic input by rapid urbanization and industrialization. Hence, the present study is intended to evaluate water quality in terms of heavy metals load in fifteen sample sites located in upstream and downstream of Vaigai river in and around Madurai. From this study, it is inferred that overall water quality in close proximity to city is found to be unfit for drinking and irrigation purpose.

KEYWORDS: Heavy Metal Index, Vaigai River, Madurai City, Contamination degree.

INTRODUCTION

Water is the key component in determining the quality of our lives. Although water covers more than 70% of the Earth, only 1% of the Earth's water is available as a source for drinking. This 1% water is enough for today's population if any wastage of water is not caused by contamination. But our society continuously contaminates this precious resource and creates water deficiency artificially by reducing its quality to certain extent and thus renders it unfit for life. The main reasons for water contamination are anthropogenic activities. Rapid urbanization and industrial development during the last decade have provoked some serious concerns for the environment. Rapid urbanization, especially in developing countries like India, has affected the quality of the water resources.[1] Population

growth and continuing land development have substantially degraded the quality of receiving water bodies and waterways due to the increased input of man-driven pollutants.[2] The rapid population growths, land development along river basin, urbanization and industrialization have subjected the rivers to increased stress, giving rise to water pollution and environmental deterioration.[3] Most of the rivers in the urban areas of the developing world are the end point of effluents discharged from the industries.[4] In India, urban runoff and sewage disposal in river catchment areas is the major challenge of river water quality maintenance. Addition to these, rapid industrial development in the last few decades has added huge loads of pollutants to our rivers.[5] Out of these pollutants, heavy metals are of major concern because of their persistent and bio-accumulative nature. The heavy metals contamination in rivers is one of the major quality issues in many fast growing cities, because maintenance of water quality and sanitation infrastructure have not increased along with population and urbanization growth especially for the developing countries.[6-9]

Heavy metal pollution is a major environmental problem in the world. The term 'heavy metal' is somewhat imprecise, but includes most metals with an atomic number greater than 20, but excludes alkali metals, alkaline earths, lanthanides and actinides. The heavy metals are those metals that have a density greater than five, that include about thirty eight elements.[10] Apparently, studies on pollution of heavy metals in the urban environment became prominent after the mid sixties, concurrent with enhanced urbanization and industrialization processes worldwide. Trace metal contaminations are important due to their potential toxicity for the environment and human beings.[11-14] Heavy metals are considered as critical contaminants of aquatic ecosystems due to their high potential to enter and accumulate in food chains[15-16] and their ecological impact can be substantial because of their toxicity, persistence and non degradability in the environment.[17-20] Heavy metal pollution of aquatic ecosystems is becoming a growing global problem as population increases, and urbanization and industrialization expand. There are a lot of findings and they have been recorded in connection with the industrial release of heavy metals into the environment. Hence, the present study has been carried out to find the level of heavy metals load and their impact on plankton diversity and assemblage.

Information about the Vaigai River

Rivers and riverbanks are the cradles of human civilization. The Vaigai river is the base for the existence of Madurai, a heritage city of 2500 years old history, in southern Tamilnadu,

India. It originates in the Periyar Plateau of the Western Ghats range. The Vaigai River rarely floods 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.

Work design

The Vaigai River is 258 kilometer long from its place of origin to its mouth on palkstrait. fifteen sites in the Vaigai River near Madurai city were selected for the present study. The surface water samples were collected from each study site to evaluate the range of heavy metals such as cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc. In the same sites, plankton collections were also done to study its diversity.

Method of sample collection

Sample collection location and period

The Vaigai River near Madurai selected for the present study was divided into three major segments. The first segment of Vaigai starts from Thuvarimaan village, west to Madurai city and ends near Fatima College bridge of Aarapalayam, middle of Madurai city. The second segment of Vaigai starts half kilometer from the bridge and ends near Viraganoor village and the third segment starts half kilometer away from Viraganoor and ends at Thiruppuvanum, east to Madurai.

Each segment is approximately 10 kilometer in its length. The total study area is 30 kilometers. From each segment, 5 sample sites were selected. In this way, totally 15 samples sites were selected from the Vaigai River near to Madurai. The water samples were collected in polyethylene bottles from all 15 sample sites during the month of December (monsoon period) 2014. The sample collection trip was made on 2nd December for all fifteen sample sites. In all 15 sample sites, the water sample was collected only from the main current of river, particularly, from the edge of the river. The stagnant water collections were avoided in river. Before filling the river water, the plastic sample bottle was brushed with phosphate free detergent and then rinsed three times with cold tap water, 10% percent hydrochloric acid and deionized water. 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 by cap. The sample details such as collection site, date and time were marked by permanent glass marker containing indelible ink directly on the out surface of collection bottle.

Water samples (500 ml) collected from all the 30 sample sites were kept in ice box and taken to laboratory for investigation. In the laboratory, a part of water sample (250ml) was filtered using Whatman No. 41 (0.45 µm pore size) filter paper for estimation of dissolved metal content. Filtrated water samples (500 ml each) were collected and preserved with 2 ml nitric acid to prevent the precipitation of metals.

Calculation of Water Quality Indices

The following four indices such as Contamination Degree (Cd), Heavy Metal Pollution Index (HPI), Heavy Metal Evaluation Index (HEI) and Metal Index (MI) were calculated from the surface water samples in order to measure the water quality of the Vaigai River.

Contamination degree (Cd)

Contamination degree (Cd) of Chromium, Cadmium, Copper, Iron, Lead, Mercury, Nickel, and Zinc were calculated in Vaigai river near Madurai by using the following formula.

$$c_{\mathrm{d}} = \sum_{i=1}^{n} \mathrm{C_{ft}}$$

C*fi* is obtained by using the following formula

$$C_{ft} = \frac{C_{At}}{C_{Nt}} - 1$$

Cfi: Contamination factor for its parameter

CAi: Measured value for its parameter

CNi: Standard allowed value for its parameter (Mohan *et al.*, 1996).

In the present study, the contamination degree of heavy metals were measured and compared with other indices such as HPI and MI of Vaigai River. Based on the Contamination degree value, the water samples of Vaigai river were categorized into three groups which include low contamination (Cd <1), moderate contamination (1< Cd <3) and high contamination (Cd >3).

Heavy Metal Pollution Index

The calculation of heavy metal pollution index is one of the best methods to symbolize the overall water quality bases on heavy metals.[21] The heavy metal pollution index was calculated by using the following formula.

$$Q_t - \sum \frac{\{M_t(-)I_t\}}{(S_t - l_t)} \times 100$$

∑

Mi: Measured value for its parameter

Ii: Ideal value for its parameter

Si: Standard value allowed for its parameter

$$HPl = \frac{\sum_{t-1}^{N} W_t Q_t}{\sum_{t-1}^{N} W_t}$$

Qi Sub index calculated value for its parameter

Wi: Weight assigned to its parameter

The calculated the index, weight and ideal values for the elements Cr,Cd,Cu,Fe, Pb, Ni and Zn are given in Table 1.

Water quality of Madurai Vaigai river samples were categorized into three groups based on heavy metal pollution index calculated for the present study. They are1) Low heavy metal pollution (HPI <100), 2) Heavy metal pollution on the threshold risk (HPI = 100) and 3) High heavy metal pollution (HPI>100). If the samples have heavy metal pollution index values greater than 100, water is not potable.[21] Calculated values of this index for the sample are presented in Tables.

RESULTS

The river Vaigai touches and irrigates the pond, lake, kanmai and agricultural lands of all four district such as Theni, Madurai, Dindugal, Sivagangai and Ramanathapuram only during southwest and northeast monsoon period. In the other periods, the Vaigai River receives the industrial effluents, domestic sewages and the waste due to anthropogenic activities of river bed residents. The peculiar condition of Vaigai River is, it receives both anthropogenic waste water and pure rain water alternatively in a year. The waste water is not continuously running

in the Vaigai river because of low in the amount and immediate absorption by sand. But rain water gets into Vaigai river due to flood condition by heavy rain during monsoon. Hence, in the present investigation, the heavy metals such as chromium, cadmium, copper, iron, lead, mercury, nickel and zinc of Vaigai river were observed only in the monsoon period to predict the water quality. Heavy metal concentrations in aquatic ecosystems are usually monitored by measuring their concentration in water.[22]

According to the obtained results, the mean chromium concentrations for all five sites in the segment-I was ranged between 0.04 to 0.76; cadmium between 0.04 to 0.13; copper between 1.001 to 7.08; iron between 0.08 to 1.0; lead between 0.34 to 1.5; nickel between 0.005 to 0.42 and Zinc between 0.87 to 2.86. In the segments II, the heavy metals such as Cr, Cd, Cu, Fe, pb, Ni and Zi Values were recorded as 0.003 to 0.92., 0.001 to 0.68., 0.032 to 1.01., 0,072 to 0.58., 0.002 to 0.96., 0.004 to 0.018 and 0.012 to 1.66 respectively. In the third segment, these values were recorded as 0.2 to 0.86 for Cr 0.001 to 0.6 for Cd, 0.018 to 0.40 for Cu 0.018 to 1, for Fe, 0.018 to 1.5 for Pb, 0.001 to 0.42 for Ni and 0.28 to 2.86 for Zi. The mean heavy metals ranges for all sites in the second segments were higher when compared to all the sites of first and third segments. The second segment of Vaigai River selected for this study is running through the middle of the Madurai City from west to east direction. The small and large scale industrial effluents, sewage and house hold wastes from the residential area of both north and south sides of the Vaigai River are dumping inside the Vaigai river may be the main reasons for this high level contamination. Human activities have led to accumulation of toxic metals in the natural environment.[23] The most anthropogenic sources of metals are industrial, petroleum contamination and sewage disposal.[24] HPI value for second segment- II exceeds (HPI>100) the 100 indicates, water in this segment is not potable. The mean values observed for all the sites in this segment is higher than the standard limits (Table 1) recommended by FEPA (2007) and WHO permissible limit. The Cd (contamination degree) is high in all sites located in all three segments except the first site in first segment 1.33>1(moderate contamination) and fourth site in third segment -4<.1 (low contamination). This may be attributed to the huge amounts of raw sewage, agricultural and industrial wastewater discharged into the Lake.[25] Movement of heavy metal is higher where sewage waste is disposed on sandy, acidic and low organic matter soils, receiving high rainfall or irrigation water.[26] The HPI values for the sites in the segment- II are not exceeds 100 indicate, the level of pollution is low and the water is potable. The same results were obtained in the IInd, IIIrd and IVth sites of segment –III indicate the good quality of water and its potable

condition. This may be due to Madurai city has 36637 domestic connections, 5223 commercial connections and 290 industrial connections. The total number of connections is 42150. This figure is too low when compared with the present total number of houses, commercial places and industrial sites which are yet to get the sewage connection in the city. Totally, 63% of the population in Madurai city has not got proper sewage connection system till the date. They release their house hold sewage water into the nearby water system or nearby waste land. Particularly, the people who are living on both sides of the river bank release their household sewage into Vaigai river. Addition to these, the Vaigai river bed has 110 rubber,480 plastic,220 auto body building,460 stainless steel,1177 appalam,860 industries, oil, rice and dhall mills, 495 repairing and service units,54 power looms,75 readymade Garments,50 Granite Units,03 Soft drink and beverage units,01 tyre and tube automobile works(TVS), 01 fan belt, oil seals, conveyer belt(Fenner),01 Milk and milk products(Co-Operative). The waste water released from most of these industries dumped into the Vaigai river cause serious heavy metals augmentation inside the river.

Table -1. Heavy metal pollution index table for site I in the First segment of Vaigai River near Madurai city.

Heavy metal mg/l	Mean Value	Standared value(Si) FEPA-2007	Baseline Value(Ii)	Unite weightage (Wi)	Subindex (qi)	WiQi	WHO Permissible Limit
Cr	0.3	0.05*	1	20	73.6	1472	0.1
Cd	0.13	0.003	0.02	333.33	9.3	3099.96	.01
Cu	0.001	1.0	0.04	1	4	4	2
Fe	0.08	0.3	0.03	3.33	18.5	6.1605	0.05
Pb	0.4	0.01	0.17	.01	7	0.7	1
Ni	0.17	0.023	0.48	43.478	97.4	4234.75	5
Zn	1.76	3.0	0.03	0.333	58.2	19.3806	0.2

∑Wi 401.481

∑WiQi 8827.5511

Table-2.The HPI value for all fifteen sites in all three segments of Vaigai River in Madurai city

Name of the sites	First Segment	Second Segment	Third Segment
I	21.98*	110.41	103.31
II	54.43*	104.24	78.09*
III	79.14*	74.52*	61.20*
IV	50.23*	199.96	94.112*
V	82.35*	443.09	108.87

Table-3. The Cd value for all fifteen sites in all three segments of Vaigai River of Madurai city.

Name of the sites	First Segment	Second Segment	Third Segment
I	1.33	11.88	26.4
II	8.34	16.32	8.48
III	83.91	10.97	74.19
IV	20.9	47.82	-4.64
V	32.85	35.84	4.5

Fig. 1. Flood in the Vaigai River in Madurai City during heavy rain during Monsoon seasons.

Fig. 2. Low water level in the Vaigai river in Madurai City during heavy rain post monsoon season.

CONCLUSION

The heavy metal analysis in the Vaigai River near Madurai shows high level contamination at segment-II than segment-I and III. This may be due to all the sites in the segment-II situated in-between the city area, the polluted water come from various anthropogenic activities directly dumped into the river.

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