CHROMIUM AND LEAD LEVEL IN THE SEDIMENT SAMPLES OF SELECTED SITES OF VAIGAI RIVER MONSOON - 2011

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ABSTRACT

The Vaigai River is one of the famous River in south part of Tamil Nadu. It irrigates six districts such as Theni, Madurai, Dindugal, Ramanathapuram, Periyakulam and Sivagangai. The people living in all six districts mostly depends the Vaigai River water for their livelihood in the agriculture practices. Addition to this the Vaigai River irrigates the kanmmai(Large pond), pond, oorani(Small pond) and kulam(Type of small pond) situated in all four districts. Recently the residence and different types of industries located in the Vaigai River bank due to urbanization and industrialization pollute other domestic in the agriculture purpose. Everyday several thousand liters of sewage industrial waste water discharged into Vaigai River. This practice increase the chemical load of Vaigai River in the form of heavy metals and pesticides. Hence, in the present investigation the highly toxic heavy metals such as cadmium and chromium were analysed in the sediment samples of selected sites located from Vaigai dam to all strait along the length of Vaigai River.

Keywords:
Heavy metal, Cadmium, Chromium, Vaigai River, Sediment.

Introduction

Of all the planet earth’s renewable natural resources, water occupy a unique place because of its essential for sustaining all forms of life, food production, global economic development, and for the general well being. Water is also one of the most manageable of the natural resources as it is capable of diversion, transport, storage, and recycling. All these properties impart to water its great utility for human beings (Rakesh Kumar et al., 2005). Water quality is considered the main factor controlling health and the state of disease in both man and animals. Surface water quality in a region is largely determined both by natural processes (weathering and soil erosion) and by anthropogenic inputs (municipal and industrial wastewater
discharge). The anthropogenic discharges constitute a constant polluting source, whereas surface runoff is a seasonal phenomenon, largely affected by climate within the basin (Singh et al., 2004). Hence, today, people are concerned about the quality of the water they drink.

Degradation of water quality is caused by even though the augmentation of variety of toxic chemical, the heavy metals occupy an unique priority due to their potential toxicity for the environment and human beings (Gueu et al., 2007; Lee et al., 2007; Adams et al., 2008; Vinodhini and Narayanan, 2008). Heavy metals are considered as critical contaminants of aquatic ecosystems due to their high potential to enter and accumulate in food chains (Olojo et al., 2005; Erdoğan, and Erbilir, 2007) and their ecological impact can be substantial because of their toxicity, persistence, and nondegradability in the environment (Louma, 1983; De Souza et al., 1986; Lacerda et al., 1992; Allen and Hansen, 1996, and Yang et al., 2009).

The accumulation of heavy metal pollutants in the water bodies only indicates the short-term pollution history. But the accumulation of these pollutant materials on sediments indicates the long-term history of pollution conditions; Riverine sediments play an important role as pollutants and they reflect the history of the river pollution (Jain, 2004). Sediments act as both carriers and sinks for contaminants in aquatic environments. Sediments are important sinks for various pollutants like pesticides and heavy metals and also play a significant role in the remobilization of contaminants in aquatic systems under favorable conditions (Ikem et al., 2003). Particularly, the river sediment is an important sink of heavy metals, but also is a secondary contamination source affecting the health of river ecosystems (Fan et al., 2002; Wang et al., 2010). Sediments play an important role in the transport of nutrients, metals, and other contaminants through river systems to the world’s oceans and seas. Sediments also act as metal reservoirs, with the primary exchange modes being adsorption or precipitation, and can
alsoproduce a reasonably accurate history of pollution in the river (Gibbs, 1977; Jain and Sharma, 2001; Filgueiras et al., 2002). Sediments have a high storage capacity for pollutants. In any part of the hydrological cycle far less than 1% of these are actually dissolved in the water and more than 99% are stored in the sediments (Salomons and Stigliani, 1995). The toxic effluents and domestic sewages from various point and non point sources discharged into Vaigai river containing toxic metals, inorganic and organic compounds sink into the Vaigai river bed during dry season. But during monsoon season due to high water flow all these toxic materials leached and dissolved in the water and pollute the aquatic system of Vaigai river. Addition to these the agricultural runoff containing pesticide and fertilizer also pollute the Vaigai river. The Vaigai river is the life for million of Vaigai river bed people but due to increasing pollution load the health of these river bed people is questionable now. The periodical monitoring of pollution status of the Vaigai river by government and independent research is the way to alarm the danger in front of river bed people. Hence, the present study has been framed to heavy metals chromium and lead accumulation in the sediments of Vaigai River from Vaigai Dam to park strait.

Materials and method

Background information about the Vaigai river

The Vaigai river is the base for the existence of Madurai, a heritage city of 2500 years’ history, in 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 sqmiles) 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 Palk strait in Ramanathapuram District. In the present study, the Vaigai
river from Vaigaidam to Palkstrait has been selected for investigation of persistence of
heavymetals such as cadmium and chromium in the bottom sediments…

**Samples collection sites in the Vaigai river**

For this study, water, sediment and fish samples were collected from 2 to 6 sampling sites
from each place such as Vaigai Dam, Kullapuram, Anaipatti, Sholavanthan, Thuvarimaan to
Guru Theatre bridge, Madurai, Thiruppuvanam, Manamadurai, Paramakkudi and Nathipallam
based on the pollution discharge area along the length of the Vaigai river. The abovementioned
study sites’ names and their short forms and location in the globe are given in Table 1.1.

<table>
<thead>
<tr>
<th>Serial Number</th>
<th>Name of the site</th>
<th>Sub divisions</th>
<th>Location of the sample collection site</th>
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<tr>
<td>3</td>
<td>Anaipatti</td>
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<td>10° 00' 48.86&quot;N 77° 57' 41.55&quot;E</td>
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<td>5</td>
<td>Thuvarimaan to Guru theatre bridge</td>
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</table>
Work design

The Vaigai river is 258 kilometer long from its place of origin to its mouth on Palkstrait. The Vaigai river from Vaigai dam to Palkstrait has been considered for present study. Totally, 10 locations including 40 sites were selected for the present study, along the length of the Vaigai river. Sediment samples were collected from each study site. The accumulation of heavy metals such as cadmium and chromium from each sample site has been studied.

Method of sample collection

Sample collection location and period

The sediment samples were collected in metallic core-liner from all 40 sample sites along the length of the Vaigai river during the month of December (monsoon period) 2011. The first day sample collection trip was made on 11th December in VD-1, VD-2 and VD-3 near Vaigai dam, KP-1, KP-2 and KP-3 near Kullapuram, AP-1, AP-2 and AP-3 near Anaippatti, SO-1, SO-2, SO-3, SO-4 and SO-5 near Sholavanthan, and TM.GB-1, TM.GB-2, TM.GB-3 and TM.GB-4 near Thuvarimaann to Guru Theatre bridge. In the second day, 12th December 2011, the sample collections were done at sample sites MA-1, MA-2, MA-3, MA-4, MA-5 and MA-6 in Madurai, TH-1, TH-2 and TH-3 near Thiruppuvanam, MM-1, MM-2, MM-3, MM-4 and MM-5 near Manamadurai, PK-1, PK-2, PK-3, PK-4 and PK-5 near Paramakudi, and NP-1, NP-2 and NP-3 near Nathipalam.

Labeling 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.

Sediment collection site selection

In general, the finer and more polluted sediments will deposit along the edge of a river channel, on the inside edge of a curve in a river and on the down drift side of river. All these points were considered for the selection of sediment sample collection site. In the present study,
the sediments were collected only in the places near to human settlement along the length of the Vaigai river. The location of sampling site was defined by Google earth maplink 2011 and visual estimates.

**Sediment collection methods**

Core sampling method was selected for the present study. The stainless corer has 2 inch inside diameter and 4 ft length with CAB plastic liner is used. During the time of sampling, the core sampler was allowed to fall from a certain distance above bottom. After landing the core sampler on the sediment bottom, the sediments were automatically loaded inside the corer and after 10 minutes the core sampler was lifted out from the water. The samples lodged inside the corer was separated and transferred to metallic made core liner which is capped at both ends. The core liner was labeled to identify the top and bottom of the core. Actually the sample testing laboratory is at 2-150 kilometers distance from the sample sites and so immediate analysis is impossible and delayed analysis leads to the degrading of quality of results. To avoid all such problems the samples were placed in an ice chest with wet ice for storage. The temperature was maintained at approximately 4°C to prevent biological activity and unwanted chemical reactions.

**Processing of sediment samples for heavy metal analysis**

The sediments taken out from the ice chest was dried, ground, and homogenized. They were then sieved through a 2 mm stainless steel mesh. 0.5 g of the resulting homogenous sample was weighed into a 120 ml of acid cleaned Teflon microwave vessel. 5 ml of ultra pure nitric acid and 2 ml ultra pure hydrofluoric acid were added and digested for 30 min at 200°C. After allowing at least 2 h for cooling, the vessels were opened and 0.8 g boric acid was added to dissolve the fluoride precipitates. The final volume was made up to 50 ml by deionized water and taken to detect the heavy metals by Atomic Absorption Spectrometer.

**RESULT AND DISCUSSION**

The Vaigai river irrigates the 7,000 sq-km area covering four districts - Theni, Madurai, Sivagangai and Ramanathapuram in Tamil Nadu. It increases the ground water level in the riverbank during flowing period. This river is seasonal one. The water for the Vaigai river comes from various sources like its chief tributaries such as Suruliar, Theniar, Varaha Nadihi, and Manjalar. It flows through a length of 150 miles (240 km), generally southeast. The western and northwestern parts of the basin receive heavy rainfall during the monsoons, with an average rainfall of 850 mm over the basin. This rainfall is the main reason for flood in the Vaigai river. The Vaigai river from Vaigai dam to Palk Strait crosses many cities, towns and villages. During dry seasons, the household domestic waste and sewage water released from these cities, towns and villages as a non point and point source and the effluents from industries are let into the Vaigai river. This waste water is mostly chemicals and metal rich immature. They are easily dried up by sunlight or absorbed by sand bottom of the river. The chemicals and metals in the waste water persist as a residue in the sand. But during rainy seasons, these chemical and metals immediately dissolve in the water and contaminate the ground water and the river water.

Hence for the present investigation, the sediment and animal samples have been collected from different selected sites along the Vaigai river from Vaigai Dam to Palk straight to evaluate heavy metals pollution in the Vaigai river. The main sources of pollution of the Vaigai river are urban, agricultural and industrial waste waters. Industrial waste waters and sewage of metropolitan centres, small electroplating workshops, repair shops, hospitals, medical and scientific laboratories, as well as surface runoff of cities are the main sources of such urban wastewaters (Babich and Stotsky, 1982). The residents who are living in the Vaigai river bed dump millions of tonnes of waste water into the Vaigai river every day as domestic wastes and sewagewater by their anthropogenic activities. Due to this reason, the Vaigai river water is turned into black colour, dead and unfit for human consumption in many places. The river plays
a major role in assimilation of carrying off municipal and industrial wastewater and runoff from agricultural land. The municipal and industrial wastewater discharge constitute a constant polluting source, whereas the surface run-off is a seasonal phenomenon. Seasonal variations in rainfall, surface run-off, interflow, ground water flow and pumped in and outflows have strong effects on river discharge and subsequently on the concentration of pollutants in river water (Vega et al., 1998). Sediments are known to accumulate trace metals in aquatic ecosystems. It acts as storage sinks for various pollutants. If the storage function overtakes its role, they cause problems such as pollution. This is particularly true of depositional sediments in close proximity to anthropogenic metal discharges.

The chemical composition of the sediments can be used as a powerful tool to determine the provenance (Vital and Stattegger, 2000). Sediments can be sensitive indicators for monitoring contaminants in aquatic environments. These sediments were polluted with various kinds of hazardous and toxic substances (Kamaruzzaman et al., 2011). Sediments can also act as a scavenger agent for heavy metal and an adsorptive sink in aquatic environment. It is therefore considered to be an appropriate indicator of heavy metal pollution (Idris et al., 2007). Determination of metal concentrations in suspended and bed sediments is more sensitive than the dissolved concentrations as indicators of contamination in hydrologic system (Salmons and Forstner, 1984; Luoma, 1990). Sediments not only act as the carrier of contaminants, but also as the potential secondary sources of contaminants in aquatic system (Calmano et al., 1990; Salomons and Forstner, 1984). Such sediments may become so elevated in trace metals that they pose a risk to the associated benthic biota. For organisms closely associated with surface sediments, the uptake of metals may result from exposure to the overlying water, the sediment pore-water, sediment/food ingestion, or a combination of the three (Ankley, 1996; Lee et al., 2000). Hence, in the Vaigai river, the sediment, were taken from 40 sites located in 10 different locations and they were analyzed for some selected heavy metals to estimate contamination of Vaigai River.

In this study, concentrations of cadmium in sediments, of the Vaigai river system is determined from all forty sediment samples. The mean value for every sample site along the length of the Vaigai river from Vaigai dam to Palk strait are reported in Table 1-10 and the graphical forms of the result are shown in Figure 1-2. In India, various levels of cadmium concentration have been reported to be present in aquatic ecosystem which is more than 5ng/ml in the Yamuna river water at Agra, Delhi, Etawah and Mathura (Ajmal et al., 1985) and 0.50-114.8mg/kg in the Yamuna river sediments at Agra and Delhi but the water around the industrial areas have been found to contain higher levels of cadmium (Singh, 2001 and Kaushik et al., 2003). Similarly, the Vaigai river also has been contaminated with the heavy metal cadmium. Moreover, the maximum and the minimum mean levels of Cd in sediment samples obtained from the Vaigai river system ranged from 9.66±1.27mg/kg to 4.22±0.52mg/kg for all the forty sediment sampling points as placed in Table 1-10; Fig 1-2. The highest level of cadmium in sediment was obtained at sampling point MA-5 (near Madurai city) and the lowest at sampling point KP-2 (Vaigai river near Kullaparam) as depicted in the Table 1-10. The mean Cd concentrations obtained for all these forty sediment samples are many fold higher than the GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Pollution) recommended threshold limit 0.11mg/kg. The cadmium concentrations in the sediment sample sites VD-1, VD-2, VD-3, KP-1, KP-2, KP-3, AP-1, AP-2, AP-3, TH-1, TH-2, TH-3, NP-1, NP-2 and NP-3 are very near to the minimum range value because all these are sites located in the industrial free and residential free areas. Even though, the cadmium level is manifold higher than the WHO recommended threshold, this may be due to the runoff that come from the...
fertilizer utilizing agricultural land. The runoff and waste water come from the nearby agricultural land situated on both sides of the river bed into the Vaigai river during the time of heavy rain augment the highest cadmium in the sediments. Trace metal enrichment in soil by mineral fertilizers is the most documented for cadmium (Cd) and was first identified in Australia (Williams and David, 1973). The retrospective analysis of archived soil samples from Rothamsted (UK) unequivocally showed that long-term phosphorus (P) fertilizer application was a major source of Cd in soil (Jones et al., 1987a). The most likely origin of the excess Cd is from heavy applications of cheap, contaminated phosphate fertilizers (Booth, 2005; Stephens and Calder, 2005). This agricultural runoff increases the cadmium concentration in the Vaigai river surface water which was collected from the sample sites located in the industrial and residents-free remote areas.

Chromium compounds are mostly produced in two forms from the chemical industry. They are chromium (III) and chromium (VI) which are used in chrome plating, leather tanning, wood preserving and the manufacture of dyes, pigments, alloy formation and steel works (Shanker et al., 2005; Ryan et al., 2002). From all these industries, large quantities of chromium compounds are discharged into the waterways in the form of liquid, solid, and gaseous wastes. Chromium is an essential trace metal for living organisms (Anderson, 1997; Cefalu and Hu, 2004). Trivalent chromium (Cr (III)) compounds are necessary to drive sugar and lipid metabolism in human at trace amount while Cr (III) is not readily absorbed into the human body (Katz and Salem, 1993). However, it shows a high toxicity, that renders it hazardous even at very low concentration (20μg/l) (EPA, 1998; Cheung and Gu, 2003). Cr(VI) is relatively mobile, readily soluble in water, generally more bioavailable than Cr(III) and can easily permeate the biological membranes (Mugo and Orias, 1993; Kaz et al., 2008) and can enter the cell where it is chemically transformed into the more stable Cr (III) form. Inside the human cell, Cr(III) can damage the DNA. Hexavalent chromium (Cr (VI)) is also extremely toxic and carcinogenic owing to its ability to oxidize other species (EQSWP, Nriagu and Nieboer, 1998; Kota’s, 2000). These highly toxic chromium compounds are dumped into the Vaigai river in huge amounts every day along with household sewage and industrial discharge. This was evidenced by the obtained high level chromium content in the sediment, water and animal samples collected from all the forty sites along the length of the Vaigai river from Vaigai dam to Palk Strait. The minimum and the maximum range of chromium concentration in the sediment samples of all the forty sites of the Vaigai river show 19.12±2.12mg/kg and 46.25±5.57mg/kg which is 0.53±0.35μg/l. The above mentioned maximum ranges of chromium in the sediments of the selected sites of the Vaigai river may be due to the releasing of effluents from chromium plating industry, gold jewelry making places (goldsmith workshops), steel work, wood processing and dye industries. Chromium is extensively used in electroplating, paint and pigment manufacturing, textile, fertilizer and leather tanning industries that discharge the trivalent and hexavalent chromium with wastewater to the soil and surface water (Ganguli and Tripathi, 2002).

The minimum sediment chromium range 19.12±2.12mg/kg observed in the Vaigai river is merely three fold lower than the TEC (Threshold Effect Concentration) 43.4 mg/kg and many fold lower than the PEC (Probable Effect Concentration) 111mg/kg suggested by Mac Donald et al., (2000). The maximum range 46.25±5.57mg/kg was more or less equal to the TEC and lower than the PEC. Consensus based sediment quality guidelines for freshwater ecosystem developed by Mac Donald et al., (2000) recommended TEL (Threshold Effect Concentration) is 35.7 mg/kg, LEL (Lowest Effect Level) is 16mg/kg, MET (Minimal Effect Threshold) is 28 mg/kg, ERL (Effect Range Low) is 70 mg/kg and TEC (Threshold Effect Concentration) is 31.6mg/kg in the sediments of drinking water. The minimum and the maximum range observed in the sediment samples of all sites of the Vaigai river show some association with the chromium levels
6.8 to 35.0mgkg⁻¹ observed in the Yamuna river sediments by Kaushik et al., (2009) and 40.34μg/g in the sediments of the Chakighera river bed (Abdul Rauf1 et al., 2009).

**Summary**

The Vaigai River is one of the most important watersheds in Tamil Nadu State, India. It runs across many villages, small towns and large cities of five districts. Over 50% of the people along the Vaigai river basins get drinking water from the ground water below the Vaigai river basins. Further, the Vaigaidam, located in the upper reach of the Vaigai river, provides water supply for cultivation of paddy twice in a year and some for other agriculture purposes by direct link. At the same time, through the indirect link like Kanmai(large pond), Oorani (small pond) and Kulam (type of small pond) the Vaigai river provides water supply for 60% of agricultural lands located in all six Theni, Madurai, Dindigul, Sivagangai, Madurai and Ramanathapuram districts. Therefore, the Vaigai river and its tributaries are crucial for all six district residents for social, economic, community health and recreations. In this situation, if any negative changes occur in the water quality of the Vaigai river, it reflects their negative impact on aquatic fauna and flora of the Vaigai river and the tanks, and ponds depend upon by the Vaigai river. Through food chain, it reaches the human body and creates various health hazardous effects. Hence the present study has been carried out to check important toxic metals cadmium and chromium in the Vaigai River sediments to areas the toxicity nature of Vaigai River.
Table 1. Heavy metals concentration (mg/kg) in the sediment samples of Vaigam Dam, Kullapuram, Anaipatti and Sholavanthan sites of Vaigai River near Vaigai Dam, Madurai City.

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<th>Metals</th>
<th>Sample Sites</th>
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<tr>
<td></td>
<td>VD-1</td>
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<tr>
<td>Cadmium</td>
<td>6.33±0.59</td>
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<tr>
<td>Chromium</td>
<td>27.66±3.51</td>
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Table 2. Heavy metals concentration (mg/kg) in the sediment samples of Thuvaram, Madurai City and Thiruppuvanam sites of Vaigai River near Vaigai Dam, Madurai City.

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<tr>
<td>Cadmium</td>
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<tr>
<td>Chromium</td>
<td>41.15±6.03</td>
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Table 3. Heavy metals concentration (mg/kg) in the sediment samples of Manamaduerai, Paramakudi and Ramanthapuram sites of Vaigai River near Vaigai Dam, Madurai city.

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<tr>
<td>Chromium</td>
<td>37.85±4.58</td>
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Fig.1. Fluctuation of mean cadmium concentrations in the sediment of all sample sites during November-2011.
References


