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Research Article

Concentration of Cadmium Metal in Water, Sediment and Fish *(Catla catla)* Parts from Cauvery River, Mettur, Tamil Nadu, India

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Abstract

This study is an attempt to ascertain the nature of the effluents, and wastewater released from the industries located at Mettur, Salem District, Tamil Nadu State, India for a period of one year, from January 2015 to December 2015. Cadmium concentration in water and sediments during the study showed pronounced spatio-temporal variations. The higher level of Cd accumulation in the gill and liver were due to their entry via water and food and due to its close contact, with mucous secretion and specific mode of nutrition and feeding habits respectively, while in liver and kidney, it was due to their physiological mechanisms. The decreased concentrations were due to the decreased rate of accumulation. Even though Station-I is less polluted when compared to Station-II, the histopathological changes in the tissues of fish collected form it were severe because of their migration from the highly polluted Station-II. The fish seems to be under severe pollution stress and there is a serious matter in the point of fishery resources of the river Cauvery and socio-economic condition of the surrounding fishermen.

Keywords: Cadmium, Cauvery River, spatio-temporal variations, fishery resources, histopathological changes.

Introduction

Information on heavy metal toxicity is an important parameter for the ecological risk assessment of pollutants through the investigation of water, sediments and fish parts. Among the heavy metals, Cadmium (Cd) is most notorious metal pollutant in aquatic environments. The increasing of Cd contaminations in aquatic ecosystem due to various industrial and agricultural activities is worldwide environmental problem. Due to the high solubility of Cd in water, it is easily accumulated in plant parts including grains causing contamination of food chain ending with humans (Chen *et al.*, 2007). This metal is considered as potentially toxic and poses a serial risk for human health when it enters the food chain (Mensi *et al.*, 2008). Monitoring of heavy metal contamination in the river systems by using water, sediment and fishes is indicating the potential heavy metal concentration in different strata of aquatic ecosystem (Jaffar and Asharaf, 1998). Fishes are often used to investigate the effect of chemical wastes in the aquatic environment since fishes are very sensitive to a wide variety of toxicants (John and Tresa, 1998), they are primarily used as pollution indicators in water quality management (Mathivanan, 1988). Many researches were performed to evaluate the heavy metal toxicity for aquatic organisms by examining acutely toxic concentrations or the effects of exposure to single metals (Allen, 1993; Baatrup, 1991).

Kalman *et al.* (2010) reported the effects of Cd on *S. aurata* and determined the metal accumulation in different tissues. Heavy metals accumulate in fish through the following five routes (i) food or non-food (ii) particles, (iii) gills, (iv) water and (v) skin then flow into the blood and storage in liver for its transformation or storage. Moreover, these parts of fish have been identified as the main storage sites for heavy metals (Kim *et al.*, 2004). The aim of present study was to determine the Cd accumulation in water, sediment and fish (*Catla catla*) parts of Cauvery River, Mettur, Tamil Nadu, India, in addition, it was verified as to whether these species could be used as environmental indicators of aquatic ecosystems.

Materials and methods

Study area: In the study area, two stations were selected in the river Cauvery, as Station-I and Station-II. Station I: The inflow of water before entering into the Mettur Dam i.e., Pannavadi (from here to Mettur, the distance is 20 Kms). Station II: Outflow of water from Mettur dam i.e., discharge of water, with the above industrial effluents, i.e., Sankali Muniappan Koil areas is a small village 6 Kms from the Mettur dam.

Sample collections: The studies were carried out over a period of 12 months i.e., from January 2015 to December 2015.

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Table 1. Accumulation of Cadmium in water (mg/L) of River Cauvery, Mettur during Jan 2015 to Dec 2015

Months		Station-I	Station-II
January		2.33 ± 0.021	24.49 ± 2.021
February		2.24 ± 0.046	25.77 ± 3.032
March		3.46 ± 0.047	22.78 ± 0.873
	Average	**2.67**	**24.34**
April		3.76 ± 0.038	23.76 ± 0.476
May		3.27 ± 0.041	28.87 ± 0.489
June		3.22 ± 0.035	23.42 ± 0.638
	Average	**3.41**	**25.35**
July		3.63 ± 0.026	22.23 ± 0.018
August		2.38 ± 0.029	23.28 ± 0.003
September		2.31 ± 0.030	21.79± 0.058
	Average	**2.77**	**22.43**
October		3.29 ± 0.029	20.38 ± 0.029
November		2.48 ± 0.039	21.89 ± 0.062
December		0.39 ± 0.034	19.76 ± 0.075
	Average	**2.72**	**20.67**
	Annual average	**2.89**	**23.19**
	Level of significance 5%		

Monthly samples of water, sediment and fish tissues were collected over a period of one year from Jan to Dec 2015 comprised of four seasons. Fresh fishes were collected and brought to the laboratory in ice box. The tissues were subjected to analysis of heavy metal concentration in gill, liver and kidney. Water samples were collected from the intertidal region of the rivers in the precleaned and acid washed polypropylene bottles of 1L capacity and immediately kept in an ice box and transported to the laboratory to avoid contamination. The water samples were then filtered through a millipore filtering unit using Millipore filter paper (mesh 0.45µ). The filtered water samples were preconcentrated with Ammonium Pyrolidine Dithiocarbamate (APDC), Methyl Iso-Butyl Ketone (MIBK) extraction procedure (Brooks *et al.*, 1967). Sediment samples were collected at monthly intervals using a precleaned and acid washed polythene bags which were sealed and kept in ice box until further analyses. Immediately after returning to the laboratory, the sediment samples were then washed with deionized water in the laboratory and dried in a hot air oven at 105°C for about 6 h; ground to powder in a glass mortar and stored in pre-cleaned polythene bags.

Heavy metals analysis: Analysis of metals was continued by retrying the samples from which 500 mg was taken and digested with a mixture of 1 mL of conc. H_2SO_4, 5 mL of conc. HNO_3 and 2 mL of conc. $HClO_4$. A few drops of HF (Hydrofluoric acid) were added in order to achieve complete dissolution of the materials. The mixture was boiled, evaporated to near dryness and then resuspended in 10 mL of 2N HCl. This was passed through a paper filter and made up to 25 mL with metal free distilled water.

The resulting solution was then stored in washed borosil vials or HG and polythene container for other metals. The digested material was then made up to 25 mL with deionised water and aspirated into the standard Atomic Absorption Spectrophotometer (Perkinelmer model, 373) (APHA, 1989).

Statistical analysis: Statistical analysis of the data were interpreted using single factor analysis of variance (one way–ANOVA, $p<0.05$ (SPSS Version 15.0)) to analyze the difference of physicochemical properties and heavy metal levels at different stations.

Results

Accumulation of Cadmium in the water, collected at Station-I and II

Station-I: Monthly variation at Station-I for all four seasons is represented in the Table 1. The annual average Cd content of river Cauvery is 2.89 mg/L and 23.19 mg/L from Station-I. The Cd content in water at both Stations and all months are statistically significant at 5% level.

Station-II: The seasonal fluctuations of Cd at both the stations of Mettur River Cauvery are given in Table 1. During the study period, the registered Cd content recorded from Station-I are 24.34, 25.35, 22.43 and 20.67 mg/L and for Station-II respectively. Among the four seasons, the higher Cd value is recorded in summer and lower value is noted during the monsoon season at both the stations of river Cauvery.

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Table 2. Accumulation of Cadmium in sediment (mg/g) of River Cauvery, Mettur during Jan 2015 to Dec 2015

Months		Station-I	Station-II
January		15.33 ± 0.019	42.28 ± 0.045
February		14.44 ± 0.029	57.32 ± 0.051
March		18.27 ± 0.034	62.37 ± 0.037
	Average	**16.01**	**53.99**
April		16.23 ± 0.019	69.45 ± 0.081
May		17.22 ± 0.023	82.37 ± 0.061
June		19.24 ± 0.029	83.47 ± 0.043
	Average	**17.56**	**78.43**
July		18.38 ± 1.362	53.49 ± 0.006
August		15.23 ± 0.031	61.39 ± 0.049
September		15.22 ± 0.020	44.33 ± 0.023
	Average	**16.27**	**53.07**
October		14.28 ± 0.046	51.28 ± 0.074
November		14.44 ± 0.035	33.74 ± 0.059
December		16.48 ± 0.046	39.81 ± 0.058
	Average	15.06	41.61
	Annual average	16.22	56.77

Accumulation of Cadmium in sediment, collected at Station-I and II

Station-I: Variations in Cd content in the sediment at Station-I of river Cauvery ranged from 16.01, 17.56, 16.27, 15.06 mg/g (Table 2). Analysis of variance showed that the Cd content in sediment at different months and stations are statistically significant at 5 % level.

Station-II: The level of Cd in sediment at Station-II ranged to 53.99, 78.43, 53.07, 41.61 mg/g, respectively (Table 2) for four seasons. The annual average Cd in sediment is higher (56.77 mg/g) at Station-II than that (16.22 mg/g) of Station-I. Bioaccumulation of Cd in the Gill of fish, *Catla catla* at Station-I and II.

Station-I: The level of Cd accumulation in the gill tissues of fish, *Catla catla* ranged for four seasons as 11.51, 11.90, 11.86 and 10.82 mg/g at Station-I respectively. The annual average bioaccumulation in gills is 10.82 µg/g for Station-I. The maximum and minimum concentration of Cd in gills is recorded during summer and winter seasons. The level of Cd in gill of Catla collected between two stations and all months are statistically significant at 5 % level (Table 3).

Station-II: The level of Cd accumulation in the gill tissues of fish, *Catla catla* ranged for four seasons as 62.83, 66.22, 67.78 and 60.68 µg/g. at Station-II respectively. The accumulation of Cd concentrations in the gill is observed during the four seasons. The annual average of bioaccumulation is 64.37 µg/g. In general, Cd concentration is high at Station-II than at Station-I (Table 3).

Bioaccumulation of Cadmium in the liver of fish, *Catla catla* at Station-I and II

Station-I: Accumulation of Cd in liver ranged from 17.21, 17.66, 16.82 and 16.81 µg/g for Station-I, respectively for four seasons (Table 3). In both the stations, higher level of metal accumulation is registered during summer and lower value is noted during winter season. The annual average bioaccumulation in liver is 16.81 µg/g for Station-I. The accumulation of Cd in the liver of *Catla catla* collected from both the stations and all months are statistically significant at 5 % level.

Station-II: The concentration of Cd in liver ranged from 56.63, 60.91, 57.57 and 51.68 µg/g at Station-II respectively. The average bioaccumulation of Cd is higher at Station-II, than at Station-I. The annual bioaccumulation of liver is 56.69 µg/g for Station-II (Table 3).

Bioaccumulation of Cadmium in the Kidney of fish, *Catla catla* at Station-I and II

Station-I: The bioaccumulation of Cd in the kidney of *Catla catla* ranged from 13.35, 14.10, 13.68 and 14.02 µg/g for Station-I. In both, the Cd is higher at Station-II and it is lower at Station-I. In both the stations, higher level of metal accumulation is registered during summer and lower value is noted during winter season. The annual average bioaccumulation in liver are 13.78 µg/g for fish collected from Station-I (Table 3).

Station-II: The annual average bioaccumulation in kidney is 37.63 µg/g for fish collected from Station-II.

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Table 3. Bioaccumulation of Cadmium (µg/g) in gill, liver and kidney of fish, *Catla catla* collected at Station-I and II during Jan 2015 to Dec 2015.

Month	Gill		Liver		Kidney	
	Station I	Station II	Station I	Station II	Station I	Station II
January	12.18±0.018	61.38±0.017	16.56±0.021	52.63± 0.016	12.69±0.032	39.67±0.024
February	11.48±0.023	62.84±0.019	17.52±0.021	57.68±0.039	13.16±0.024	37.43±0.015
March	11.89±0.024	64.29±0.018	17.56±0.074	59.58±0.028	14.22±0.047	37.24±0.017
Average	**11.51**	**62.83**	**17.21**	**56.63**	**13.35**	**38.11**
April	11.89±0.026	63.30±0.026	17.21±0.052	59.49±0.026	13.59±0.023	38.58±0.021
May	12.14±0.021	68.87±0.022	17.89±0.035	61.64±0.006	14.23±0.033	38.87±0.026
June	11.69±0.018	66.49±0.016	17.89±0.032	61.60±0.003	14.19±0.030	42.28±0.027
Average	**11.90**	**66.22**	**17.66**	**60.91**	**14.10**	**39.91**
July	11.39±0.018	68.29±0.035	17.48±0.060	57.39±0.047	14.38±0.040	37.29±0.025
August	12.42±0.025	65.59±0.022	17.10±0.035	59.54±0.028	13.49±0.039	38.29±0.027
September	11.79±0.035	69.17±0.021	15.89±0.044	55.49±0.021	13.19±0.026	41.31±0.029
Average	**11.86**	**67.78**	**16.82**	**57.57**	**13.68**	**38.96**
October	10.59±0.029	59.39±0.022	58.51±0.032	54.51±0.032	13.48±0.062	34.28±0.021
November	10.48±0.025	58.28±0.025	15.21±0.044	49.32±0.024	14.27±0.024	33.19±0.028
December	11.39±0.027	64.38±0.033	15.69±0.031	51.21±0.019	14.31±0.029	33.18±0.039
Average	**10.82**	**60.68**	**15.57**	**51.68**	**14.02**	**33.55**
Annual average	**11.52**	**64.37**	**16.81**	**56.69**	**13.78**	**37.63**

The accumulation of Cd in the liver of *Catla catla* at both stations and months are statistically significant at 5% level (Table 3). Bioaccumulation of Cd in the kidney of *Catla catla* ranged for 38.11, 39.91, 38.96 and 33.55 µg/g, respectively for four seasons at Station-II. The accumulation of Cd in the kidney of *Catla catla* at both stations and months are statistically significant at 5% level.

Discussion

Heavy metals may be accumulated in fish either through water or by food. In aquatic biota, the water route has been demonstrated to be more important (Power, 1999). In general, the accumulation of heavy metals found in various tissues of the fishes analyzed is quite low (Tariq, 1993). The main route of entry of Cd seems to be through the food, whereas it is through water by which the metal accumulation might have had occurred. The safe concentration of Cd, was determined according to Mathivanan (1988) following the application factor values as suggested by Indian Standard Institution. In this study, the uptake of Cd was evidenced in all the tissues of test fish, *Catla catla* collected from different Stations-I and II. Cadmium was predominantly accumulated in gill, liver and kidney of the test fish, *Catla catla*. This might be attributed to redistribution of the metal between tissues and/or excretion of the metal by gill independent of other tissues. The low concentration of metals in the fish gills suggest that gills may also be an important route for metal effluent in addition to kidney (Reddy and Singh, 1994). Industrial, agricultural and domestic wastes pollute the water bodies with heavy metals, which reach the human tissues through food chain, thereby proved to be chronic metal toxicants (Mathivanan, 2006).

In this study, it has been observed that the presence of Cd present in water, sediments and in different tissues of fish, *Catla catla* collected at two stations (unpolluted and polluted) from the river Cauvery of Mettur. Cd concentration in the water fluctuates much depending on various factors such as season, hydrological parameters, biological availability and other chemical complexes. The seasonal variation in the concentration of metals revealed the fact that, the concentration of Cd was high at pre monsoon, respectively at both the Stations-I and II. The observed low Cd values in water during summer and premonsoon season resulted due to the uptake of this metal by the organisms, adsorption on to the particulate matter and a fraction of metal could get stripped off, as described earlier by Alokam (2002). The concentration of metals in water, sediment and tissues of *Catla catla* collected from Station-II are highly polluted due to the entry of industrial effluents that may be the reason for the high accumulation of metals at Station-II. High accumulation of metal in water was recorded at Station-II than at Station-I, which could be attributed due to the mixing of industrial effluents through channels from the industries situated nearby the study area. The toxicity of heavy metals in water is affected by pH, hardness, alkalinity and organic materials. Higher level of hardness, pH and alkalination tend to reduce the toxicity of metals in water (Tamizhmalar, 2002). Cadmium concentration was maximum during the summer season at both the stations and minimum during post monsoon and monsoon seasons. Local fishing activity, anthropogenic influences and discharges of municipal sewage and sludges might have increased the Cd level in the sediments; minimum Cd concentration, recorded during the monsoon and post monsoon seasons, was probably due

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to the utilization by micro phytobenthic community (Pillai, 1994). According to Shrihari and Venkatesha (1994) who have suggested that the river formations are getting more polluted with heavy metals. This is also confirmed by this investigation on water and sediments of river Cauvery. Ananthan (1995) has also studied the high cadmium content in an estuary near Chennai region, Tamil Nadu. In this investigation, the accumulation of Cd in the organ of *Catla catla* has the following order of abundance at 2 stations of river Cauvery.

Gill > Liver > Kidney

The accumulation of Cd in the fish tissues may reflect the elevated level of Cd in water and sediment. Maximum Cd accumulation in kidney was reported earlier by Tamizhmalar (2002). The increased accumulation of Cd in the gill may be mainly due to the fact that the gills are one of the most permeable regions of body and are the principal sites of respiration, in addition to its transporting ions during osmosis regulation. All the heavy metal values were highly predominant during the summer season. This could be an account of heat flow conditions being observed during the summer as compared during winter and rainy season.

This result on metal concentration showed that although metal pollution in the river Cauvery (WHO, 1992). Hence, this study can confirm that the freshwater edible fish, *Catla catla* is a biological indicator organism to assess the level of pollution in the river Cauvery at Mettur, Salem District, Tamil Nadu.

Conclusion

In this study we can confirm that the freshwater edible fish, *Catla catla* is a biological indicator organism to assess the level of pollution in the river Cauvery at Mettur, Salem District, Tamil Nadu. These results are decided to frame the guidelines for proper treatment of industrial wastewater from various industries located in and around Mettur, Salem District. In addition, the recommendations were also made and they may be implemented for using the wastewater for Agriculture and Aquaculture practices in the near future to attain sustainability.

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