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RESEARCH ARTICLE

Determination of Harmful Metals in Water, Sediments and Fish from Vellar River, Tamil Nadu, India

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ABSTRACT

The present work deals with the metal analysis in water, sediment and selected freshwater fish in the Vellar river collected from January to December 2011. The distribution of metal concentration observed in the water and sediment samples was in the order of Cd > Cu > Pb > Cr > Fe > Zn > Mn, of which the levels of Cd 1.68 ± 0.076 mg/l was the highest and Mn 0.04 ± 0.002 mg/l was the lowest that were recorded in the water sample of the selected Vellar river water. The highest concentration levels of Cd 1.70 ± 0.068 mg/kg and the least concentration of Mn 0.20 ± 0.008 mg/kg were recorded in its sediment samples. The metal concentration distribution in the selected fish organ samples examined was in the order of Cd > Cu > Pb > Cr > Fe > Zn and Mn in liver > gill > kidney > intestine > muscle. The highest concentration levels of Cd 1.78 ± 0.053 mg/kg dry weight and the least concentration levels of Mn 0.04 ± 0.002 mg/kg dry weight were observed in the liver tissue of Mugil cephalus. The distribution of metal concentration was found to be in the order of magnitude as Mugil cephalus > Heteropneustes fossilis > Mystus vittatus > Etroplus suratensis > Anabas testudineus. Rise in agricultural, domestic and anthropogenic wastes in the investigated area might be the reason behind such increased accumulation of metal levels in these five fishes.

Keywords: Heavy metals, Sediment, Freshwater fish, Vellar river, Anthropogenic activities.

1. INTRODUCTION

The major environmental problem lies in fresh water ecosystem that is receiving various kinds of contaminants from the land. Majority of the industries at fresh water area discharge chemical effluents into the aquatic environment which in turn cause changes in habitat, species distribution, abundance, and bio-geo chemical cycles [1]. Wastes from urban, industries, and mining process are the potential sources of heavy metal pollution [2]. It is found out that the presence of heavy metals in natural water bodies tend to be a serious threat for biological sources and the living organism that depend on them [3, 4]. Due to spawning, commercially valuable shrimp and fishes are abundantly available in estuarine and coastal areas, and get influenced by this influx of chemical contaminants into the ecosystem [5]. Fishes occupy the topmost place in the aquatic food chain and huge amount of metals from water and sediments gets collected in them. [6] Sediments are known as "trace element traps", since they eventually bind almost all the contaminants which enter the aquatic environment. Heavy metals in sediments often lead to severe environmental problems when the contaminated sediments are suspended and such metals accumulate the filter feeders. Water

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system quality is based on sediments, and the sediments could be used to detect insoluble contaminants. Studies from field and laboratory experiments show that the building up of heavy metals in animal tissues depends mainly on metal concentration present in water. Heavy metals normally occurring in nature do not affect the environment, and they are essential for tissue metabolism and for the growth of plants and animals [7]. Metals like copper, zinc, iron, cobalt, molybdenum, nickel, silicon, and stannum are said to be toxic beyond a certain level, whereas vanadium, cadmium, lead, and mercury are prominently classified as toxic because of their detrimental effect even at low concentrations [8].

The fresh water selected for the present studies is biologically important and economic for the living beings, and it is getting contaminated by industries and human activities. These pollutants destruct the environmental food chain, and are harmful to marine environment and humans who stay nearby. As there is a limitation in extensive analysis with respect to the sediments and fishes around particular estuaries, we have formulated this work to determine the extent of heavy metal pollution in water sediments and consumable parts of fishes. The analysis of metals in the fish tissues in river and lakes was reported by many authors [9-13]. Hence this research was conducted to investigate the assessment of heavy metals such as, chromium, cadmium, copper, lead, iron, manganese and zinc in water, sediment and selected tissues of available freshwater fishes, Mugil cephalus, Heteropneustes fossilis, Mystus vittatus, Etroplus suratensis and Anabas testudineus collected from Vellar river at Cuddalore district, Tamil Nadu, India.

2. MATERIALS AND METHODS

2.1. Investigated area

The study area of the present investigation was Vellar river at Bhuvanagiri (Latitude 11.4667, Longitude 79.6333). It is a highly productive river that originates from Servarayan hills in Salem District, Tamil Nadu and flows over a distance of 480 km, forming an excellent river water system through Bhuvanagiri and it drains into the Bay of Bengal.

2.2. Collection of water, sediment and fish samples and analysis of heavy metals

$5cm^3$ of conc. HNO_3 was mixed with $250cm^3$ of water samples in $500cm^3$ beaker and then the mixture was evaporated to near dryness on hot plate. It was subjected to cooling, in which conc. HNO_3 was again mixed with the solution in the beaker enclosed with water glass. It was then mildly heated until the completion of digestion. The concentration was filtered and moved to $50cm^3$-standard flask, where distilled water was added [14]. Sediment samples were dried at normal temperature and crushed finely using mortar prior to filtering, and the samples were brought to less than 2mm mesh. The nitric-perchloric acid digestion system also suits the sediment analysis. The selected fish samples were kept in plastic bags, where low temperature is maintained, thus to satisfy the analytical holding time. These samples were weighed before and after they were cut into smaller parts and powdered finely to attain homogeneity, of which 5g was kept in a 125mL Erlenmeyer flask. It was mixed with 10mL of conc. HNO_3 and warmed on a hot plate until the solubilization of the tissues and the solution get changed to brown. It was cooled and then added with 5mL of conc. HNO_3 for repeated warming and cooling. An additional 2mL of nitric acid was mixed prior to heating of the hot plate until the reduction of sample to 10mL. After cooling, 2mL of 30% hydrogen peroxide was included and heated further till it reached 5mL. It was again allowed to cool, and 2mL of hydrogen peroxide was added followed by the addition of 10mL of hydrogen peroxide. It was again cooled and 2mL of conc.HNO_3 was added. It was then moved to the hot plate till the sample volume became 10mL. It was cooled again and shifted to a 100mL volumetric flask, and was then mixed with demonized water so as to carry out the ICP-OES analysis.

3. RESULTS

3.1. Metals analysis in water and sediments of Vellar river

The metal concentration in the Vellar river water and sediment samples is presented in figure B1. The distribution of metals concentration was observed in water and

sediment samples in the order of magnitude as Cd > Cu > Pb > Cr > Fe > Zn and Mn > water. The highest concentration levels of Cd 1.68 ± 0.076 mg/l and least concentration of Mn 0.04 ± 0.002 mg/l were recorded in the water samples of the selected Vellar river water. The highest concentration levels of Cd 1.70 ± 0.068 mg/kg and least concentration of Mn 0.20 ± 0.008 mg/kg were recorded in its sediment sample. Table A1 shows the mean concentration of heavy metals in water and sediments collected at Vellar river from January 2011 - December 2011

3.2. Metals analysis in selected fish organs of Vellar river

The metal concentration in Mugil cephalus is presented in figure B2. Among the metals analyzed in Mugil cephalus collected, its liver tissue showed the highest metal concentration levels of Cu 1.78 ± 0.053 mg/kg dry weight and muscle tissue showed the lowermost conc. of Mn 0.04 ± 0.002 mg/kg dry weight.

Figure B3 shows the metal concentration in Heteropneustes fossilis. In this, liver showed the highest metal concentration levels of Cu 1.74 ± 0.073 mg/kg dry and muscle tissue showed the least concentration of Mn 0.08 ± 0.002 mg/kg dry weight.

The metal concentration in fish Mystus vittatus is given in figure B4; where the liver tissue showed the highest metal concentration levels of Cu 1.72 ± 0.040 mg/kg dry weight and muscle tissue showed the minimal metal concentration of Mn 0.06 ± 0.002 mg/kg dry weight.

Figure B5 presents the metal concentration in Etroplus suratensis, in which the liver tissue showed the elevated levels of Cd 1.34 ± 0.056 mg/kg dry weight and muscle tissue showed minimal levels of Mn 0.07 ± 0.003 mg/kg dry weight.

The metal concentration in Anabas testudineus is illustrated in figure B6. Here, the liver tissue showed the elevated levels of Cd 1.50 ± 0.072 mg/kg dry weight and muscle tissue showed the declined levels of Cr 0.04 ± 0.002 mg/kg dry. Among the metals analyzed in figure B1-B6, the liver tissue of Mugil cephalus showed the highest metal concentration level of Cu 1.78 ± 0.053 mg/kg dry weight and the muscle tissue showed the lowest concentration of Mn 0.04 ± 0.002 mg/kg dry weight. The metal concentration distribution in the selected fishes analyzed was in the order of magnitude as Mugil cephalus > Heteropneustes fossilis > Mystus vittatus > Etroplus suratensis > Anabas testudineus. The distribution of metal concentration in the selected fish samples analyzed was in the order of Cd > Cu > Pb > Cr > Fe > Zn > Mn and liver > gill > kidney > intestine > muscle. The maximum concentration level of Cd 1.78 ± 0.053 mg/kg dry weight and the least concentration level of Mn 0.04 ± 0.002 mg/kg dry weight were found in the liver tissue of Mugil cephalus.

4. DISCUSSIONS

Figure B1 showed the peak and least mean concentration level of Cd 1.68 ± 0.076 mg/l and Mn 0.04 ± 0.002 mg/l respectively. The present study showed the highest mean concentration level of Cd 1.70 ± 0.068 mg/kg and the minimal concentration of Mn 0.20 ± 0.008 mg/kg in the sediment sample analysis.

The highest mean concentration level of Cd 1.78 ± 0.053 mg/kg dry weight in the liver tissue of Mugil cephalus is shown in figure B2 while the lowermost concentration of Cd 0.80 ± 0.023 mg/kg dry weight was recorded in the muscle tissue of Etroplus suratensis as in figure B5.

The highest mean concentration level of Cu 0. 98 ± 0.044 mg/kg dry weights in the liver tissue of Anabas testudineus was observed as in figure B6 while the least conc. of Cu 0.03 ± 0.002 mg/kg dry weight was recorded in the muscle tissue of Mugil cephalus as shown in figure B1. Figure B3 showed the highest mean concentration level of Pb 0.66 ± 0.028 mg/kg dry weight in the liver tissue of Mystus vittatus whereas the least conc. of Pb 0.06 ± 0.002 mg/kg dry weight was recorded in the muscle tissue of Mugil cephalus as illustrated in figure B1. The highest mean concentration level of Cr 0.38 ± 0.015 mg/kg dry weight in the liver tissue of Heteropneustes fossilis was noted as in figure B2 while the lowest conc. of Cr 0.02 ± 0.002 mg/kg dry weight was recorded in the muscle tissue of Mugil cephalus as in figure B1. Chromium bio-accumulation in fishes has proved to impair respiration and osmoregulation by structurally

damaging gill epithelium [15]. The high concentration of Cr contents in several freshwater fish parts attributing to waste water discharge is mainly because of domestic, agricultural and industrial wastes in the inspected area.

The highest mean conc. level of Fe 0.62 ± 0.004 mg/kg dry weight was observed in the liver tissue of Mystus vittatus as shown in figure B3 while the least conc. of Fe 0.10 ± 0.004 mg/kg dry weight was recorded in the muscle tissue of Mugil cephalus as in figure B1.

The highest mean concentration level of Zn 0.42 ± 0.017 mg/kg dry weight was observed in the liver tissue of Mugil cephalus as shown in figure B1 while the lowest conc. of Fe 0.03 ± 0.004 mg/kg dry weight was found out in the muscle tissue of Mugil cephalus as in figure B1.

Zn is the necessary element for embryo development and is important to reproductive organs [16]. The highest mean conc. level of Mn 0.24 ± 0.011 mg/kg dry weight was obtained in the liver tissue of Heteropneustes fossilis as shown in figure B2 whereas the least conc. of Mn 0.04 ± 0.002 mg/kg dry weight was recorded in the muscle tissue of Mugil cephalus as shown in figure B1. The level of metals is found to be high due to the increased mixture of agricultural and domestic wastes.

The result shows that cadmium concentration was the maximum followed by Cr > Cu > Pb > Fe > Zn > Mn. In earlier studies, the highest concentration level of cadmium was observed in liver tissue of Channa punctatus. The lowermost concentration level of manganese was noticed in muscle tissue of Channa punctatus in Gadilam river.

The highest concentration of heavy metals (Cu, Cd and Pb) was found in gill tissue of Mugil cephalus and Liza ramada, while the lowest concentrations was recorded in muscle tissue of Mugil Cephalus and Liza Ramada from Lake Manzala, Egypt [17]. The gonad tissue showed higher concentration of metals (Cu, Zn and Pb) than muscles, except for Cr of Oligosarcus hepsetus, Geophagus brasiliensis and Hypostomus in Tropical Brazilian river [18]. The liver is expected to be a target of toxic action since it contains metal binding proteins (metallothioneins) [19]. These proteins are responsible for the accumulation of significant level of metals. Gills are the most likely sites of metal uptake from the ambient environment due to their large surface area and close proximity with the external and internal environment. Tables A2-A6 show the mean concentrations of heavy metals in the selected fishes Mugil cephalus, Heteropneustes fossilis, Mystus vittatus, Etroplus suratensis and Anabas testudineus accordingly.

5. CONCLUSION

The highest mean concentration level of Cd 1.68 ± 0.076 mg/l and the lowest conc. of Mn 0.04 ± 0.002 mg/l were noted in the water sample of Vellar river. The highest mean concentration level of Cd 1.70 ± 0.068 mg/kg and the least conc. of Mn 0.20 ± 0.008 mg/kg were recorded in its sediment sample. Among the metal analyzed in the tissues of selected fishes, the highest mean concentration level of Cd 1.78 ± 0.053 mg/kg dry weight was observed in the liver tissue of Mugil cephalus whereas the lowermost conc. of Cd 0.80 ± 0.023 mg/kg dry weight was found out in the muscle tissue of Etroplus suratensis. The highest mean concentration level of Mn 0.24 ± 0.011 mg/kg dry weight was found in the liver tissue of Heteropneustes fossilis while the least conc. of Mn 0.04 ± 0.002 mg/kg dry weight was seen in the muscle tissue of Mugil cephalus. These metal levels in water, sediments and fish kinds might be a risk for human health in turn. Hence proper measures are ought to be initiated by both the individuals and the government.

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APPENDIX A

Table A1.Mean concentrations of heavy metals in water and sediment collected at Vellar river from January 2011 - December 2011

Samples	Heavy metals						
	Cd	Cu	Pb	Cr	Fe	Zn	Mn
Water (mg/l)	1.68 ± 0.076	0.62 ± 0.028	0.46 ± 0.021	0.28 ± 0.013	0.24 ± 0.010	0.20 ± 0.01	0.04 ± 0.002
Sediment (mg/kg)	1.70 ± 0.068	0.70 ± 0.029	0.60 ± 0.024	0.36 ± 0.014	0.42 ± 0.016	0.32 ± 0.012	0.20 ± 0.008

Table A2.Mean concentrations of heavy metals in the selected organs of freshwater fish Mugil cephalus caught at Vellar river from January 2010 - December 2011

Samples	Heavy metals (mg/kg dry weight)						
	Cd	Cu	Pb	Cr	Fe	Zn	Mn
Gill	1.64 ± 0.057	0.42 ± 0.019	0.26 ± 0.012	0.12 ± 0.003	0.20 ± 0.007	0.16 ± 0.006	0.18 ± 0.006
Liver	1.78 ± 0.053	0.52 ± 0.022	0.32 ± 0.012	0.16 ± 0.005	0.27 ± 0.012	0.20 ± 0.007	0.18 ± 0.008
Kidney	1.46 ± 0.037	0.38 ± 0.016	0.28 ± 0.007	0.08 ± 0.002	0.14 ± 0.005	0.12 ± 0.004	0.12 ± 0.004
Intestine	1.42 ± 0.040	0.28 ± 0.012	0.12 ± 0.004	0.06 ± 0.002	0.13 ± 0.003	0.06 ± 0.002	0.10 ± 0.004
Muscle	1.40 ± 0.052	0.03 ± 0.002	0.06 ± 0.001	0.02 ± 0.002	0.10 ± 0.004	0.03 ± 0.004	0.04 ± 0.002

Table A3.Mean concentrations of heavy metals in the selected organs of freshwater fish Heteropneustes fossilis caught at Vellar River from January 2010 - December 2011

Samples	Heavy metals (mg/kg dry weight)						
	Cd	Cu	Pb	Cr	Fe	Zn	Mn
Gill	1.56 ± 0.073	0.58 ± 0.020	0.30 ± 0.010	0.30 ± 0.013	0.30 ± 0.010	0.18 ± 0.009	0.15 ± 0.005
Liver	1.74 ± 0.073	0.60 ± 0.024	0.36 ± 0.017	0.38 ± 0.015	0.35 ± 0.016	0.22 ± 0.011	0.24 ± 0.011
Kidney	1.04 ± 0.042	0.50 ± 0.019	0.28 ± 0.011	0.20 ± 0.007	0.16 ± 0.007	0.15 ± 0.006	0.12 ± 0.005
Intestine	1.30 ± 0.049	0.42 ± 0.010	0.24 ± 0.009	0.18 ± 0.005	0.14 ± 0.006	0.12 ± 0.004	0.10 ± 0.002
Muscle	1.20 ± 0.042	0.40 ± 0.018	0.20 ± 0.009	0.13 ± 0.005	0.10 ± 0.003	0.10 ± 0.003	0.08 ± 0.002

Table A4.Mean concentrations of heavy metals in the selected organs of freshwater fish Mystus vittatus caught at Vellar River from January 2010 - December 2011

Samples	Heavy metals (mg/kg dry weight)						
	Cd	Cu	Pb	Cr	Fe	Zn	Mn
Gill	1.58 ± 0.046	0.93 ± 0.045	0.52 ± 0.024	0.12 ± 0.003	0.49 ± 0.022	0.26 ± 0.012	0.15 ± 0.006
Liver	1.72 ± 0.040	0.98 ± 0.036	0.66 ± 0.028	0.16 ± 0.007	0.62 ± 0.026	0.42 ± 0.017	0.18 ± 0.008
Kidney	1.52 ± 0.044	0.92 ± 0.037	0.48 ± 0.019	0.10 ± 0.003	0.47 ± 0.018	0.23 ± 0.008	0.12 ± 0.004
Intestine	1.36 ± 0.040	0.90 ± 0.038	0.50 ± 0.017	0.06 ± 0.002	0.46 ± 0.016	0.23 ± 0.006	0.10 ± 0.007
Muscle	1.30 ± 0.047	0.40 ± 0.012	0.80 ± 0.037	0.44 ± 0.013	0.02 ± 0.002	0.20 ± 0.009	0.06 ± 0.002

Table A5.Mean concentrations of heavy metals in the selected organs of freshwater fish Etroplus suratensis caught at Vellar river from January 2010 - December 2011

Samples	Heavy metals (mg/kg dry weight)						
	Cd	Cu	Pb	Cr	Fe	Zn	Mn
Gill	1.23 ± 0.055	0.76 ± 0.019	0.53 ± 0.014	0.29 ± 0.013	0.38 ± 0.017	0.24 ± 0.006	0.18 ± 0.007
Liver	1.34 ± 0.056	0.78 ± 0.021	0.58 ± 0.023	0.32 ± 0.013	0.44 ± 0.018	0.26 ± 0.012	0.22 ± 0.009
Kidney	1.08 ± 0.043	0.74 ± 0.025	0.46 ± 0.017	0.24 ± 0.008	0.34 ± 0.014	0.16 ± 0.006	0.14 ± 0.005
Intestine	0.94 ± 0.036	0.70 ± 0.032	0.42 ± 0.013	0.18 ± 0.005	0.30 ± 0.011	0.15 ± 0.005	0.10 ± 0.003
Muscle	0.80 ± 0.023	0.62 ± 0.029	0.26 ± 0.008	0.16 ± 0.004	0.25 ± 0.007	0.10 ± 0.004	0.07 ± 0.003

Table A6.Mean concentrations of heavy metals in the selected organs of freshwater fish Anabas testudineus caught at Vellar River from January 2010 - December 2011

Samples	Heavy metals (mg/kg dry weight)						
	Cd	Cu	Pb	Cr	Fe	Zn	Mn
Gill	1.34 ± 0.062	0.94 ± 0.024	0.48 ± 0.012	0.12 ± 0.005	0.42 ± 0.011	0.28 ± 0.013	0.18 ± 0.004
Liver	1.50 ± 0.072	0.98 ± 0.044	0.54 ± 0.015	0.14 ± 0.005	0.44 ± 0.012	0.30 ± 0.012	0.22 ± 0.010
Kidney	1.28 ± 0.044	0.90 ± 0.034	0.44 ± 0.013	0.08 ± 0.002	0.36 ± 0.011	0.24 ± 0.009	0.16 ± 0.006
Intestine	1.19 ± 0.045	0.72 ± 0.024	0.40 ± 0.014	0.08 ± 0.002	0.25 ± 0.010	0.20 ± 0.007	0.14 ± 0.005
Muscle	1.02 ± 0.037	0.60 ± 0.019	0.32 ± 0.010	0.04 ± 0.002	0.20 ± 0.009	0.10 ± 0.003	0.10 ± 0.003

All the values are expressed as mean ± S.D of twelve observations.

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APPENDIX B

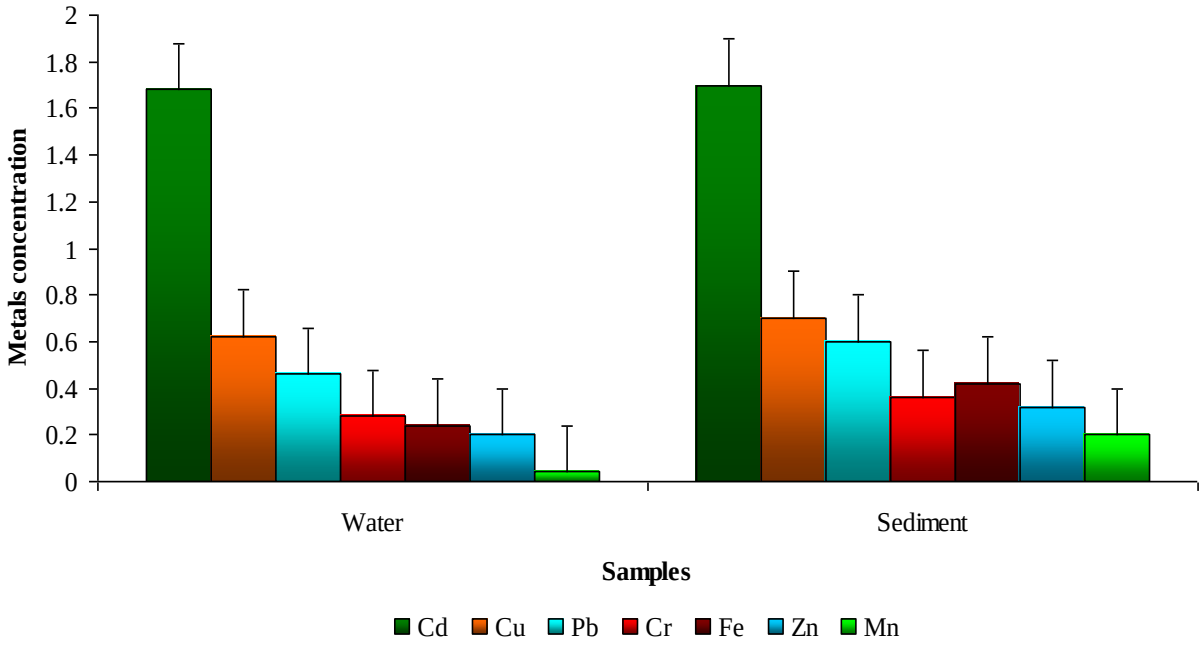

Figure B1.Mean concentrations of heavy metals in water and sediment caught at Vellar river from January 2011 – December 2011

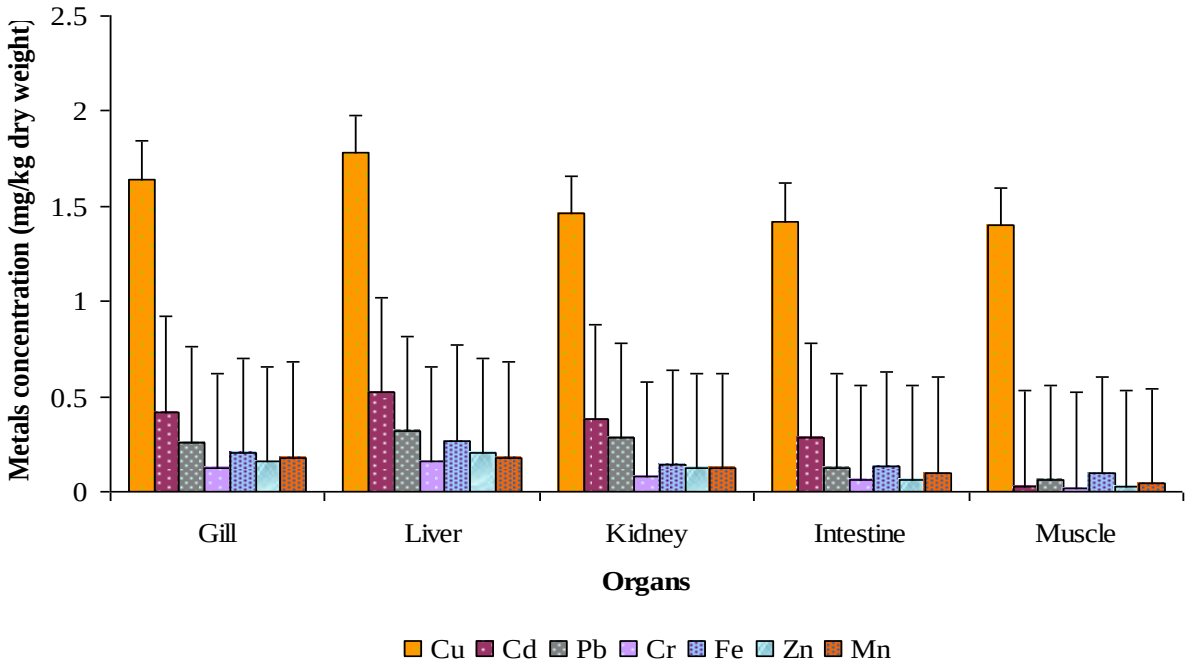

Figure B2.Mean concentrations of heavy metals in the selected organs of freshwater fish Mugil cephalus caught at Vellar River from January 2011-December 2011

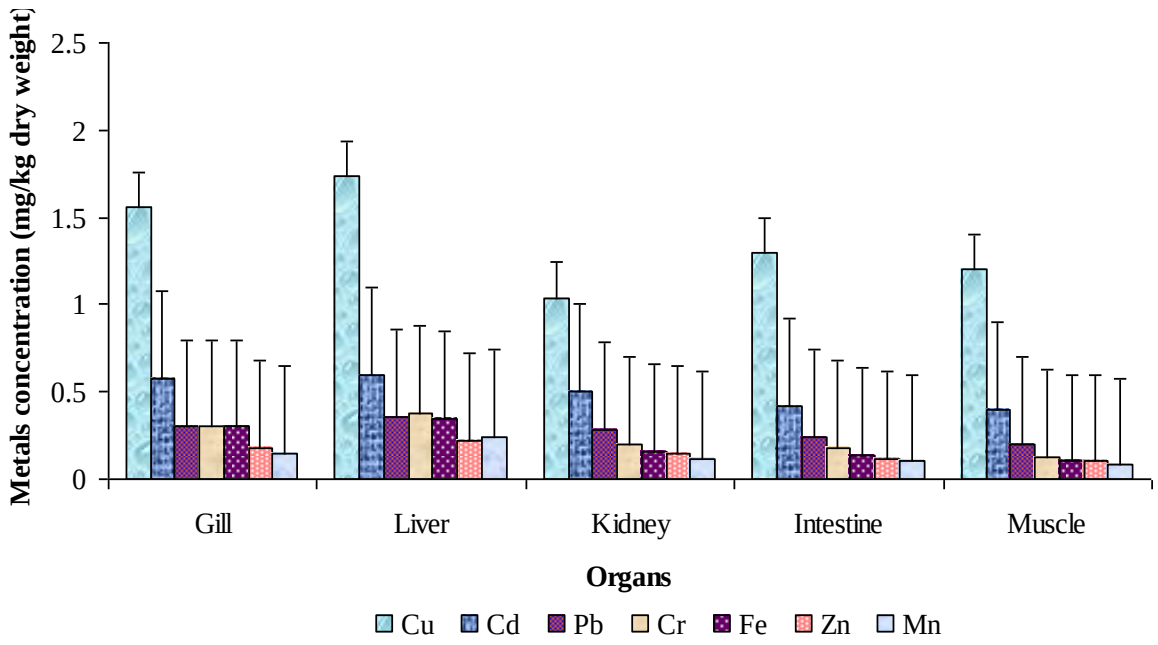

Figure B3.Mean concentrations of heavy metals in the selected organs of freshwater fish Heteropneustes fossilis caught at Vellar River from January 2011-December 2011

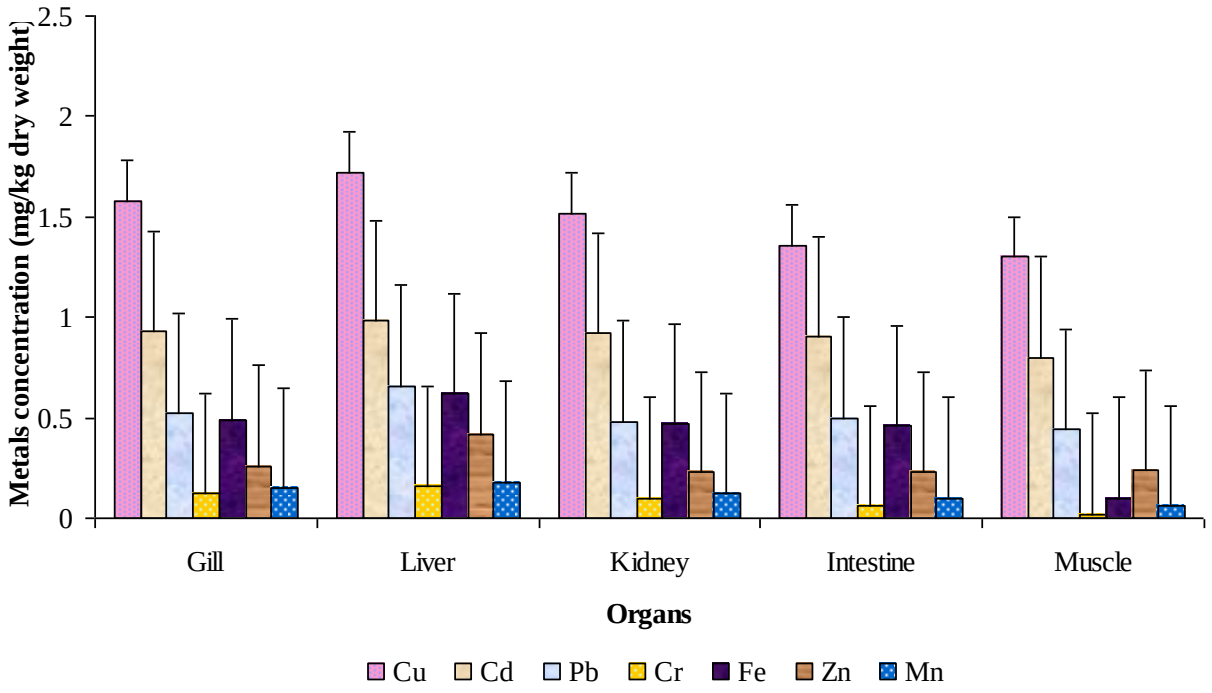

Figure B4.Mean concentrations of heavy metals in the selected organs of freshwater fish Mystus vittatus caught at Vellar River from January 2011 - December 2011

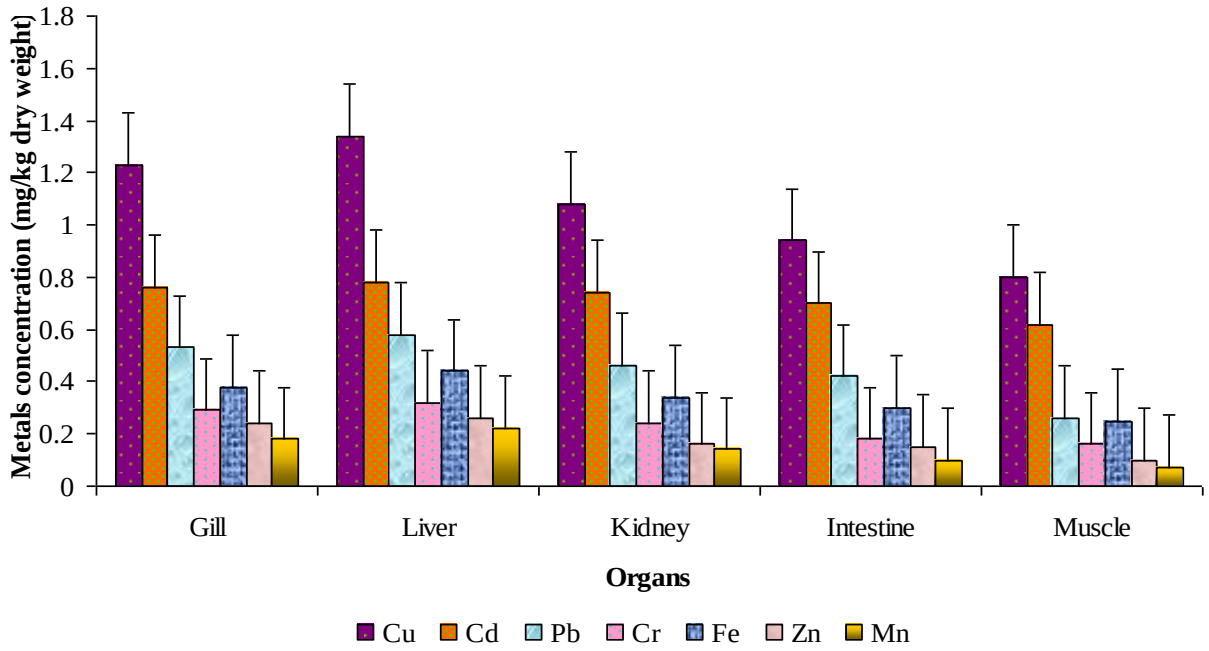

Figure B5.Mean concentrations of heavy metals in the selected organs of freshwater fish Etroplus suratensis caught at Vellar river from January 2011 - December 2011

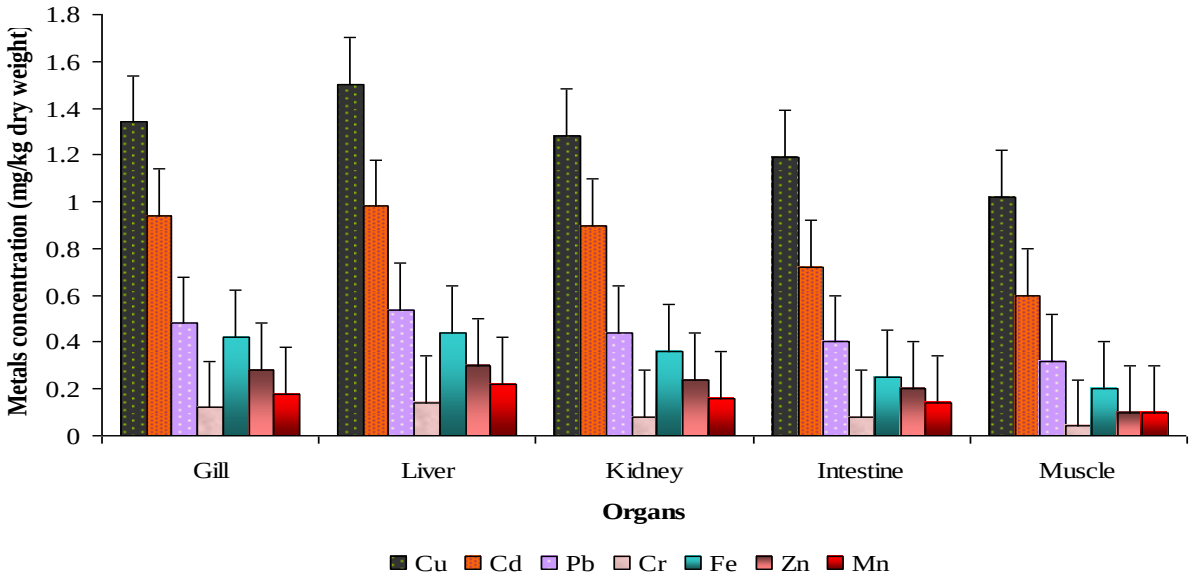

Figure B6.Mean concentrations of heavy metals in the selected organs of freshwater fish Anabas testudineus caught at Vellar River from January 2011 - December 2011