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The Bioaccumulation of Heavy Metals in Kollidam Estuary Edible Fish *Mugil cephalus*

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Abstract: ***The objective of this study was find out the concentrations of Zn,Cu,Pb and Cr in the muscles, gills, and liver of Mugil cephalus from the Kollidam estuary, Tamilnadu. Results were shown that metal bioaccumulation in the liver was higher than in the gills and muscles for all metals, and Zn concentration was higher than Cu, Pb, and Cr in all the tissues studied. The accumulation of heavy metal gradually increases in organs during different month period. The order of heavy metal concentrations of estuary water in the each site was higher levels to Cu<Pb<Zn and < Cr. Both results were statistically significant at p < 0.05. Bioaccumulation rate were indirect to estuary water. In all heavy metals, the bioaccumulation of Zinc and copper proportion was significantly increased in the tissues of edible fish.***

Keywords: Heavy metal, fish tissues, Estuary water

1. Introduction

The attendance of heavy metals in the aquatic environment is a major concern because of their toxicity and threat to plant and animal life, thus disturbing the natural ecological balance (Bhattacharya *et al* ., 2008). Heavy metals are naturally occurring elements that have a high atomic weight and a density atleast 5 times greater than that of water (Tchounwou *et al.*,2012). Even though, many heavy metals are considered as essential macro and micro elements especially at non adverse effect levels, they can exert negative effect on concentrations encountered in polluted environment (Dimari *et al.*, 2008) both acting singly or jointly in mixtures form. Several author reported that rate of heavy metals increase entry into the aquatic systems is alarming (Voegborlo *et al.*, 1999;Canli *et al.*, 1998; Dirilgen, 2001; Vutukuru, 2005). Heavy metals are normal constituents of marine environment that occur as a result of pollution principally due to the discharge of untreated wastes into rivers by many industries. Bioaccumulation of heavy metals in tissues of marine organisms has been identified as an indirect measure of the abundance and availability of metals in the marine environment (Kucuksegin *et al.*,2006).The toxic heavy metals in aquatic environment could be found to both natural and anthropogenic sources for changes arising from man made activities have taken place in aquatic ecosystem affecting the aquatic habitat (Olomukoro and Ezemonye, 2011; Mason, 1996; Ezemonye and Kadiri, 2000). Fish can absorb heavy metals through epithelial or mucosal surface of their skin, gills and gastrointestinal tract (Jovanovic *et a*l., 2011), since heavy metals and organic compounds can bioaccumulated in aquatic biota (USEPA, 1991) and biomagnifying in food chains. Bhattacharya *et al.*, (2009) resulted that bioaccumulation is the net biomolecule build-up of substances from water in an aquatic organism as a result of enhanced uptake and slow elimination.

The heavy metals are conservative pollutants and they are broken down over such a long time scale that they effectively become permanent additions to the aquatic environment (Mason, 1996; Roux, 1994; Ezemonye *et al.*, 2006).Bioaccumulation measurements to studies on methods of monitoring the uptake and retention of pollutants like metals or pesticides in organs or tissues of organisms such as fish and shell fish (Roux, 1994).George *et al.*, (2013) reported that most of these toxic chemicals when present in a concentration above the recommended standard will result in chemical pollution. Different fish species was especially the benthos have been found to bioaccumulations most of these heavy metals in their tissue (Zn, Cu, Cd, Pb, Fe). Effects of heavy mental in fish life cycle was affected. Nwaedozie, (1998) reported that zinc contamination affects the hepatic distribution of other trace metals in fish. The characteristic feature of heavy metals is their strong attraction to lipid content in the tissue andin general their slow elimination from biological systems (Nwani *et al.*, 2009: Ishaq *et al.*, 2011).

After that they remained metals tend to accumulate in sediments from where they may be released, moving up through the food chain (Nabawi *et al.*, 1987). Little is known about the bioavailability of sediment associated contaminants to marine organisms (Berge and Brevik, 1996). However it is becoming increasingly important to understand metal accumulation within food webs, because once these heavy metals reach man, they may produce chronic and acute ailments (Nabawi *et al.*, 1987). However, the toxicity of a metal to aquatic organisms is not directly proportional to its total concentration in the environment, but strongly depends on its chemical speciation (Blust *et al.*, 1995; Nair and Robinson, 2001).

Hand over information suggested that the concentration of toxic metals in many ecosystems is reaching unprecedented levels. Due to the steady load of contaminated dust in over crowded cities, the ambient concentrations of toxic metals are now among the highest ever being reported. Therefore, the purpose of this research was to quantify the levels of some heavy metals (Cu, Zn, Cr, andPb) in bone, liver and gills of a commercially important species of fishes (*Mugil cephalus*) with a view to determine the safety of its consumption by man.

2. Materials and Method

The study area and samples collection

The fish samples were caught by normal fishnet between 33 to42 m depths in Kollidam estuary, Tamilnadu. The area located between 79º45'46.08''to 79º49'47.48''E longitude. Based on the salinity gradient, the actual distance of Kollidam estuary was measured as 7.5 kilometers. All sample sites were selected along the length of the Kollidam estuary. The distances between the two adjacent sites are equal, which is 1.5 kilometers in distance. It receives a number of rivers and waste waters are mixed in the Estuary and it borders of bar mouth (fig.1). A total of 05 samples site were fish collected twice a month from different locations in Kollidam estuary (one year study period from January to December, 2016). Ten samples from fish species were obtained from the sampling area. Each sample site, the fish species average of 108.60 ± 2.13g mean weight and 15.41 ± 1.08 cm mean length were recorded. Then samples were placed in labeled polyethylene bags and stored at -20ºC until processing for metal analysis.

Water samples were collected for determination and analysis of the heavy metals levels. Samples were taken at the surface layer (<50 cm) using 1000 ml sterile glass bottles and stored at below 10ºC in an isothermic box during transportation and at 4°C in a refrigerator upon receipt in the laboratory. Samples were processed within 12 hours after collection for heavy metals analysis.

Importance of fish *Mugil cephalus*

The above mention fish is living at temperatures ranging from 8-24°C in calm waters close to shore, around mouths of streams and inlets, and brackish bays and harbors. Usually found in over sand or mud bottom, it feeds on zooplankton, benthic organisms, algae and small invertebrates. It feeds occasionally at the surface and can be used in aquaculture if stock is collected from the sea. This fish is commonly used by all types of people in their diet, and it is in high demand as it fetches high value in market. It is distributed in Western Atlantic, Nova Scotia, Canada to Brazil, Cape Cod to Southern Gulf of Mexico and Canadian Atlantic and Indian coastal waters. This species is found at depths of 120 m and often enter estuaries and rivers. It spawns in the sea from July to October, scatters 5- 7 million eggs into the open water/ substratum and so they are easily available in plenty during monsoon period in Indian marine regions

Preparation of samples and Analysis of heavy metals

After sample fish were immediately store in the ice chest containing ice cubes and brought to the laboratory for heavy metals analysis. In the laboratory, Composite samples of liver and edible tissues of each fish species (10 fishes from each species) were separated and store further analysis. Each sample of liver and edible tissues was weighed separately in clean, labeled petri-dishes and dried for several days at 70ºC to constant weight. Pulverization and homogenization were achieved by grinding the tissue samples in a Teflon mortar and analyzed for heavy metals according to UNEP/FAO/IAEA/IOC (1984).

An exact weight of dry sample (triplicate, each of 1g) was placed in a Teflon vessel and 4 ml of nitric acid was added. The vessels were tightly covered and allowed to predigest at room temperature over night. The digestion block was placed on a preheated heat at 80ºC for three hours. The samples were cooled at room temperature and then were transferred to 25 ml volumetric flask. The water used was distilled and deionized. All digested solutions were analyzed by Flame Atomic Absorption Spectrophotometer (Perkin-Elmer, Model 2380).

Statistical Tools

For data analysis, one-way analysis of variance was employed using SPSS 15.0Windows Software for finding out statistical differences among various parameters. Statistical significance was defined at $p<0.05$.

3. Results

The mean concentrations of heavy metals in accumulation of muscles, gills and liver of *Mugil cephalus* samples are given in Table 2-5. Results show that heavy metal concentrations in the fish samples decreased in the sequence for the muscle as Zn > Cu > Pb > Cr, for the gills as Zn > Cu > Pb > Cr for the liver as Zn > Cu > Pb > Cr were statistically significant ($P<0.05$).Table 2a-5a results show that different site estuary water samples (5 site) according to analysis reported, the following outcomes were found for the concentration ranges of the metals: Cr: KSW I 291.75 – 228.84 to KES v 154.1-224.41mg/L; KES I Cu: 152.65 – 168.4 to KSW v 180.12-184.12 mg/L; Zn: 152.65 – 168.4 to KESv 180.12-184.12mg/L and KESI Pb: 41.78 – 44.15 and KESv 69.4-67.38mg/L were found. Heavy metal concentrations varied each sites of the estuary water were decreased in the sequence of Cu > Pb > Zn> Cr.

4. Discussion

Ever increasing human populations and economic development have significantly contributed to the current worldwide worsening in water quality, including periodic accumulation of metals such as Cu, Zn, Cr and Pb from Kollidam estuary (Zhang *et al*.,2015; Varol, 2013: Rajesh Kumar *et al*.,2002). Heavy metals and metals have been confirmed to accumulate along the trophic chain in estuary ecosystems (Uysal *et al*., 2008; Wang *et al*., 2018). Heavy metals are not known to play any metabolic function although as a consequence to their bioaccumulation in fish, these metals can be toxic for humans, even at very low concentrations-permissible limit (Anwar *et al*., 2009). The metals concentration in fish is important both with admiration to nature and human consumption.. Though, the concentrations may be raised in coastal ecosystems due to the release of industrial, agricultural and domestic sewage waste and anthropogenic activities etc. As a results, aquatic organisms and surface water were increased concentration of metals from calculated every two month interval these variation due the bio accumulation of metal in the tissues of fish (Kalay and Canil, 1999; Sankar *et al*., 2009).

The aquatic organisms exposed to heavy metals from the run-off water tend to accumulated it in their body but fishes are more commonly affected than other species (Guven *et* *al*., 1999; Henry *et al*., 2004). Metal bioaccumulation is influenced by multiple routes of exposure (diet and solution) and geochemical effects on bioavailability (Luoma *et al*., 2005). As metals are not metabolized, moreover the bioaccumulation of metals and metalloids is of particular value as an biological indicator. Similarly, bioaccumulation is often a good integrative exposure of the chemical accumulated in the estuarine organisms in polluted water bodies. All trace metals are toxic at some bioavailability (Luoma *et al*., 2008).

According to Chi *et al*. (2007) reported that the excessive Zn intake is harmful to human health and can cause poisoning, diarrhea and fever. The mean value of Zn for O. *niloticus* tissue samples examined in 0.434 mg/kg. The high Zn concentration detected in Tilapia (0.43 mg/kg) could be due to their feeding on benthic worms and crustaceans. The mean Zn concentration from fish in was lower than other studies including Abdulali *et al*. (2003) in Langat river (20.58ug/g) and Muiruri *et al*. (2013) in Kenya (28-49.5mg/kg). MFA permissible level of Zn for human consumption is 100 mg/kg wet weight (MFA, 1983). In this studies heavy metal concentrations varies each sites and were decreased in the sequence of Cu > Pb > Zn> Cr. But in heavy metal concentrations in the fish samples were high in the three different tissues. Among several contaminants, metals pose some of the greatest threats to organisms because of their persistence and possible bioaccumulation and bio- magnification in the food chain (Ebrahimpour *et al*., 2011, Roie *et al*., 2013). Some metals, such as Fe, Cu, and Zn, are essential nutrients since they play an important role in living organisms, while As, Pb, and Cd are non-essential metals and have no biological role (Wood et al., 2012; Paudel *et al*., 2016). However, the toxicity of a metal to aquatic organisms is not directly proportional to its total concentration in the environment, but strongly depends on its chemical speciation (e.g. Blust *et al*.,1995; Nair and Robinson, 2001).

Heavy metals concentration in aquaculture organism can increase several times over the environmental levels which demonstrate their potential as accumulators of heavy metals. Hugget, *et al*. (1973) reported that purpose of these studies in the heavy metal harmful and toxic substances in water sediments and biota gives direct information on the significance of pollution in the aquatic environment. The present studies reveals that the levels of heavy metals found in the estuary are relatively compared with Kollidam fish tissue that different were statistically significant. These were related to both in the diluting effects of the huge volume of water and sediment in the estuary and a shorter period of industrialization (Zhang *et al*., 2001).

This study is in agreement with (Rao and Padmaja, 2000; Ambedkar and Muniyan, 2012) who reported that accumulation of heavy metal is varied at different levels in difference organs of the fish tissues. Metal concentration in fish organs depends on pollution and many different for various fish species living in the estuary water body also (Jezierska and witeska, 2006). Copper (Cu) plays a vital role in enzymatic processes and are essential for the synthesis of haemoglobin. However, high intake will cause health hitches (Demirezen and Uruc, 2006; ATSDG, 2004).The concentration of Cu in fish samples varied between 0.01 and 0.05mg/kg. The highest concentration of Cu was detected in *H. macrolepidota* (0.05 mg/kg) and the lowest value was detected in *C. apogon* (0.01mg/kg). The concentrations of Cu in all the samples were below the MFA and FAO limits. The observed values of Cu in fish tissues were lower than those by Kah *et al.* (2015) (0.16–0.27mg/kg) and Abdulali *et al*. (2003)for *O. niloticus* (1.46-1.69 µg/g).

The gills are an important site for the entry of the heavy metals (Vinodhini and Narayanan, 2008) and are the first target organ for exposure in fish. The high concentration of metals in the gills of *P. fluvidraco* and *C. carpio* is due to the metals complication with the mucus, which is difficult to be removed completely from the tissue before the analysis. The concentration of metals in the gill reflects the level of the metals in the waters where the fish live, whereas the concentration in liver and kidney represents storage of metals (Romeoa *et al*., 1999; Rao and Padmaja, 2000;Heier *et al*., 2009). Moreover, gill surface serves as metal-binding ligands and metal bioaccumulation in particular can occur due to positively charged metal species in the water to negatively charged sites on the gills (Teien *et al*., 2006; Terra *et al*., 2008; Playle *et al*., 2011). Thus, the gills in fish are more often recommended as environmental indicator organs of water pollution than any other fish organs (Obasohan *et al*., 2008; Yilmaz, 2009).Understanding the relationship of metals in sediments to bioaccumulation in aquatic organisms is important to understanding the fate of metals in coastal ecosystems from pristine to contaminate. Sediment metal concentrations are considered to be important routes of exposure in coastal food webs (Luoma and Rainbow, 2008).

Paudel *et al*. (2016) found that the levels of Cr in commercial fish were slightly above the permissible limits, suggesting that predators or scavengers would be at risk from chromium if they ate them in the wild. The liver is reported to be the primary organ for bioaccumulation and thus, has been extensively studied in regards to the toxic effects of xenobiotics (Hinton & Laurén, 1990; De Boeck *et al*., 2003; Yilmaz *et al*., 2007; Van dyk *et al*., 2007; Simonato *et al*., 2008; Madureira *et al*., 2012; Nunes *et al*., 2015). According to Mohamed (2009) the liver is also a target organ due to its large blood supply which causes noticeable toxicant exposure. In addition, according to Hinton & Laurén (1990) it is a detoxification organ and it is essential for both, the metabolism and the excretion of toxic substances in the body. The present report were compare in both, chromium concentration have similar in all the tissues and kollidam estuary water. This pattern was positive correlation. The kidney is the main organ involved in the maintenance of body fluid homeostasis. The morphology and function of the kidney have been modified through evolution to fulfill different physiological requirement and the widest range of kidney types is found in fishes (Hentschel & Elger, 1989).

Lead (Pb) is a neurotoxin that causes behavioral deficits in vertebrates (Weber and Dingel, 1997) and can cause decreases in survival, growth rates, learning, and metabolism (Eisler, 1988; Burger and Gochfeld, 2002). The present studies in the bioaccumulation of lead in the gills, liver and muscles of edible fish were observed throughout the year and during all the six seasons in the present study. Low accumulation of lead was observed in the first month sample for the years. However, there was an increase during month interval through the year. Lead accumulation during last samples was high for fish species studied. Random fluctuation in the accumulation of lead in the gills, liver and muscles of fish were observed during the years with no set pattern. The estuarine water Pb concentrations variation based on distance of site and month interval, this variation due to inlet of contaminated water. This may be due to the varying accumulation capacity of the fish or due to the fluctuation in the inflow of the heavy metal or it may also be a combination of both these factors (Dhinamala *et al*., 2017).

Five sites of estuaries water of Kollidam were evaluated for potentially mobile heavy metals concentrations, through the application of acid digesting. The potential heavy metal bioavailability in water sample as results followed the descending order Cr < Pb < Cu< Zn. On the other hand, some authors suggested that the tissues of some benthic organisms of already contain levels above the secure concentrations, reinforcing the importance of the heavy metal bioavailability evaluation in the area (Cajaraville *et al*., 2000; Dhinamala *et al*., 2017). Since most of the pollutants gets varied and becomes suspended as solid and bottom sediment through sedimentation, the estuary becomes a potential sink for these pollutants effects for a long period of time (Morrisey *et al*., 2003). But fish tissues concentration different between different month interval levels. The negative estuaries showed to be significantly more contaminated then the positive. Thus, results obtained in the present research represent one more step in the heavy metal accumulation comprehension in the study sit (Carlos *et al*., 2017). Notwithstanding, more and different approaches must be applied for better understanding of the heavy metal loading in the kollidam estuarine sites. More attention should be given for the speciation of heavy metals which will give a clear idea of how much threat was imposed to the aquatic life.

5. Conclusion

The health status and the biological diversity of the Indian estuarine ecosystems are deteriorating slowly through anthropogenic activities and, dumping of massive quantities of sewage into the estuary has radically reduced the population of the aquatic biota. It has also caused considerable ecological inequity and brings about in the large-scale disappearance of their flora and fauna. Further, in the outline of untreated municipal waste-water and industrial effluents into these aquatic bodies has led to serious water pollution including heavy metal pollution, which gets biomagnified and reaches man through food chain implications.

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Table 1: Bioaccumulation of Chromium in different tissues of *Mugil cephalus* in Kollidam estuary (mg/g dry wt)

Mon/Sites	Heavy metal in fish tissues	Five different site of Kollidam estuary in Tamilnadu				
		KSW I	KSW II	KSW III	KSW IV	KSW V
Feb	Muscles	0.58	0.57	0.61	0.63	0.64
	Gills	0.64	0.67	0.71	0.77	0.77
	Liver	1.17	1.23	1.31	1.47	1.52
Apr	Muscles	0.91	0.89	0.94	0.95	0.98
	Gills	0.96	0.97	0.9	1.01	1.13

	Liver	1.81	1.75	1.87	1.92	1.97
Jun	Muscles	1.2	1.31	1.44	1.65	1.77
	Gills	1.26	1.37	1.65	1.78	1.91
	Liver	2.1	2.28	2.31	2.38	2.45
Au	Muscles	1.77	1.89	1.94	1.21	2.17
	Gills	1.95	1.99	2.1	2.21	2.36
	Liver	2.17	2.23	2.31	2.42	2.49
Oct	Muscles	0.76	0.8	0.81	0.83	0.83
	Gills	0.85	0.91	0.94	0.94	0.97
	Liver	1.51	1.58	1.63	1.64	1.7
Dec	Muscles	2.22	2.24	2.32	2.56	2.87
	Gills	2.18	2.35	2.47	2.68	2.75
	Liver	3.47	3.51	3.6	3.67	3.92

Table 1 (a): Chromium metal concentration in the different sites of Kollidam estuary Water (µg/L)

Months	Chromium metal concentration in kollidam estuary water µg/L					
Sites	JF	MA	MJ	JA	SO	ND
KSW-I	219.73	115.43	117.65	170.89	215.18	228.84
KSW-II	244.19	131.67	130.15	178.94	232.44	245.57
KSW-III	243.82	186.77	123.55	175.58	235.21	246.51
KSW-IV	168.23	135.55	117.58	170.73	213.45	222.08
KSW-V	154.91	125.65	107.54	158.36	217.09	224.41

Table 2: Bioaccumulation of Lead in different tissues of *Mugil cephalus* in Kollidam estuary (mg/g dry wt)

Mon/ Sites	Heavy metal in fish tissues	Five different site of kollidam estuary in Tamilnadu				
		KSW I	KSW II	KSW III	KSW IV	KSW V
Feb	Muscles	0.71	0.71	0.73	0.74	0.76
	Gills	0.8	0.84	0.87	0.9	0.92
	Liver	1.1	1.31	1.35	1.4	1.52
Apr	Muscles	1.56	1.84	1.97	2.1	2.21
	Gills	1.24	1.38	1.49	1.57	1.89
	Liver	2.11	2.32	2.38	2.41	2.43
Jun	Muscles	3.17	3.25	3.38	3.74	3.87
	Gills	3.28	3.34	3.41	3.85	3.95
	Liver	4.12	4.56	4.61	4.79	4.88
Au	Muscles	4.33	4.47	4.51	4.69	5.87
	Gills	4.47	4.56	4.66	4.72	5.92
	Liver	5.66	5.71	5.75	5.88	5.97
Oct	Muscles	4.15	4.32	4.54	3.78	4.89
	Gills	4.3	4.45	4.62	4.75	4.87
	Liver	6.12	6.37	6.38	6.47	4.66
Dec	Muscles	6.03	6.102	6.287	6.59	6.87
	Gills	6.09	6.108	6.312	6.6	6.914
	Liver	7.56	7.68	7.89	7.94	7.99

Table 2 (a): Lead metal concentration in the different sites of Kollidam estuary Water (µg/L)

Months	Lead metal concentration in kollidam estuary water µg/L					
Sites	JF	MA	MJ	JA	SO	ND
KSW-I	41.78	24.63	20.56	25.87	36.13	44.15
KSW-II	47.8	24.78	20.75	31.89	36.85	59.13
KSW-III	66.5	34.25	27.45	32.53	39.65	63.65
KSW-IV	60.62	27.96	27.41	37.6	50.45	68.25
KSW-V	69.4	39.52	34.65	42.32	55.75	67.38

Table 3: Bioaccumulation of copper in different tissues of *Mugil cephalus* in Kollidam Estuary (mg/g dry wt)

Mon/Sites	Heavy metal in fish tissues	Five different site of kollidam Estuary in Tamilnadu				
		KSW I	KSW II	KSW III	KSW IV	KSW V
Feb	Muscles	34	36.25	37.54	40.56	42.33
	Gills	39.21	41.23	43	45	47.56
	Liver	43	48.21	52.13	58.98	61.25
Apr	Muscles	45	45.78	46.99	47.45	48.5
	Gills	48.31	48.26	49.87	52.36	53.11
	Liver	51	53.89	55.47	62.55	69.87
Jun	Muscles	52.33	53.89	54	55.65	58.66
	Gills	56.21	59.47	64.25	65.23	70.58

	Liver	68.55	73.43	79.25	82.79	90.54
Au	Muscles	63.67	67.58	70	72.4	73
	Gills	68.1	72.5	77.25	77.12	78.45
	Liver	76.5	79	81.23	84	86.98
Oct	Muscles	84.67	86.33	87.33	88	89.97
	Gills	86.54	89	91.58	91.89	96.1
	Liver	88	90.23	94.25	94.85	96.33
Dec	Muscles	95.33	97.21	99.26	99.89	102.94
	Gills	101	107	109.23	111.54	113.56
	Liver	93.21	95.4	95.25	97.87	101.38

Table 3 (a): Copper metal concentration in the different sites of kollidam estuary Water (µg/L)

Months	Copper metal concentration in Kollidam estuary water µg/L					
Sites	JF	MA	MJ	JA	SO	ND
KSW-I	6.76	2.71	2.8	6.76	6.49	7.25
KSW-II	8.21	2.75	3.15	8.43	8.52	8.43
KSW-III	7.05	2.1	1.73	6.46	6.74	7.38
KSW-IV	6.76	1.52	1.23	6.7	6.84	7.23
KSW-V	7.59	2.72	2.53	7.51	8.04	8.3

Table 4: Bioaccumulation of Zinc in different tissues of *Mugil cephalus* in Kollidam estuary (mg/g dry wt)

Mon/ Sites	Heavy metal in fish tissues	Five different site of kollidam Estuary in Tamilnadu				
		KSW I	KSW II	KSW III	KSW IV	KSW V
Feb	Muscles	347	368	488	559	564.67
	Gills	365	371	512.45	564.21	574
	Liver	456	468	475	489	492.3
Apr	Muscles	359	387	410	479	588
	Gills	360	367	381	410	432
	Liver	472	479	485	487	492
Jun	Muscles	415	487.56	541	580.12	628.33
	Gills	425	431	438	457	512
	Liver	496	499.96	512	528	540
Au	Muscles	441	455	552.6	610	654.67
	Gills	450.23	462	480.98	512	640
	Liver	514	526.45	541	569.55	584
Oct	Muscles	497.33	524	598	645.25	705.67
	Gills	481	486.78	495.45	499	513.35
	Liver	553	587	610	618	633
Dec	Muscles	532.33	590	678.53	721	743
	Gills	540.63	610.23	628	690	710.56
	Liver	760.52	798	845	867	896

Table 4 (a): Zinc metal concentration in the different sites of Kollidam estuary Water (µg/L)

Months	Zinc metal concentration in kollidam estuary water µg/L					
Sites	JF	MA	MJ	JA	SO	ND
KSW-I	152.65	119.52	102.58	128.48	154.28	168.94
KSW-II	180.48	107.65	93.15	140.95	167.37	188.51
KSW-III	249.25	87.79	83.52	174.89	212.69	266.58
KSW-IV	222.54	103.25	85.46	155.52	195.26	228.36
KSW-V	180.12	117.89	99.98	151.49	171.58	184.12