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Research Article

Bioaccumulation of Heavy Metals in Different Organs of *Catla catla* Reared in Coal Mine Water

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ABSTRACT

In the aquatic ecosystem, heavy metals are considered as the most important pollutants; it is present throughout the ecosystem and is detectable in critical amounts. In abandoned coal mine water the fishes were analysed for heavy metals. Heavy metals, such as Cd, Cr, Cu, Ni, Pb, Fe, Mn, and Zn, are the most important pollutants that affect the aquatic environment and fish. This study measures the accumulation of heavy metals in different body parts i.e, Liver, Kidney, Gills, and Muscles of Catla catla.

Keywords: *Heavy metals, Bioaccumulation, Mining area, Aquatic ecosystem.*

INTRODUCTION

Industrialization, along with mining activities, is the main source of contamination of heavy metals in the aquatic as well as terrestrial ecosystems (Wang et al., 2005). The pollution has in all the components of ecosystems viz. air, water, plants along with the soil. Presently the heavy metal contamination of plants, soil, and water is a very serious threat to living being because heavy metals above their normal ranges are extremely threatened (Nazir et al., 2015) several studies indicated that its lead to human health problem.. The heavy metal entered in the aquatic food chain through direct consumption of water or biota and through non-dietary routes such as uptake through absorbing epithelia (i.e., gills in the case of fish). Fish is one of the best sources of proteins (Burger & Gochfeld 2005) due to the rich amount of proteins; it is also one of the key parts of the food chain. Which is finally consumed by the human becomes a serious health concern due to metals accumulation by organisms with consequent transfer to human food chains, creating a potential health risk. Non – essential metals like lead & Cadmium can accumulate gradually in the human body, The coal mining sector plays a crucial role in industrial development, human income generation, employment, and economic growth (Jerome 2003; & Oelofse et al., 2008).

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India has been actively engaged in solid mineral exploitation for decades. It is endowed with deposits of more than 34 solid minerals, including coal, tin, gold, lead, zinc, thorium, lignite, uranium, and tantalum in more than 450 locations across the country (Mining Journal 2006).

Heavy metals are also accumulated through the discharge of agriculture municipal, residential, industrial waste products. Coal combustion is an important anthropogenic emission source of trace elements and an important source of several metals (Wagner & Boman, 2003).

The heavy metals content of coal varies by coal seam & geographic region. A variety of chemicals (mostly metals) are associated with coal. After termination of the mining activities the pit created is full of mine water. These mine water has been used for fish culture and the bioaccumulation of heavy metals were studied. The levels of metals in fish increase with the increment of the metal level in water, sediment & fish food organism. Fish can uptake and concentrate metal directly from the surrounding water or indirectly from other organisms such as small fish, invertebrate & aquatic vegetation. Fish also accumulate pollutants preferentially in their fatty tissues like the liver & the effect became apparent when concentrations in such tissue attain threshold level (Omar et al., 2014). However, this accumulation depends upon their intake, storage & elimination from the body (Abdallah & Morsy, 2013). This means that metals with high intake & low elimination rates in the tissue of the fish are expected to be bioaccumulated to a higher level (Kalay & Canli, 2000; Idriss & Ahmad; Drevnick et al., 2006; & Sfakianakis et al., 2015).

The bio-accumulation of heavy metals and its toxicity in fish are influenced by season, temperature, hardness, salinity & pH of water microhabitat utilization, feeding habit, age, sex, & species of fish the accumulation pattern of metals. Metallic interaction and the presence of organic & inorganic ligands in the aquatic system are further important for bioaccumulation of metals in fish (Kotze, 1999, Giessing 1981, Numan & Mcintosh 1983, Graney et al., 1984 & Unlu & Fowler, 1997).

Project site

The experiment was conducted in three sites,

Site 1: Sangam coal void: Sangam void is under Saunda Colliery, Bhurkunda,Ramgarh district, of Jharkhand (India). The coal void is 1000m long, 300 m wide, water depth about44m and freeboard 15m. It is undrainable, and the primary source of water is sky feeding and runoff from nearby the colonies. The coal void is abandoned since1995.

Site 2: Saunda coal void: It is the almost square shape of area 10 ha of depth 67 m.

Site3: Patratu dam, a natural reservoir.

MATERIALS AND METHODS

Sediment samples were collected from the depth of 90 feet at site 1 and 2 and 40 feet at site 3. The Catla were collected from selected site. The samples were rinsed with distilled water. Each fish was dissected to collect Liver, Kidney, Gills & Muscles tissues. Tissues were washed with Distilled water & were dried on filter paper at 60^0C for 24 hr. Dried fish tissue were homogenized by mortal & pestle & 0.2 g of homogenate was digested in 65% HNO_3& 30% H_2O_2 (7:1) by microwave digestion system. All the digested liquors were diluted to 50 ml in volumetric flask with double distilled water & stored in acid washed polyethylene bottle. The sediments samples were digested using concentrated HNO_3 & HF (7:1). A blank digestion was also carried out in the same way. The concentrations of heavy metal in the samples were determined by Atomic Absorption Spectrophotometer (Varian model no. AA280FS).

RESULT AND DISCUSSION

Table 1 represent the levels of metals in water samples of three sites. The table shows that Mn and Fe is high in Site 1, Cu, Ni, Zn, and Pb are almost the same as in site 3. Mn and Fe at site 1 are higher than permissible limits. Mn is higher may be due to discharge of waste from the nearby colonies (Siebe et al., 2010, &

Singh et al., 2017). Iron is the second-most abundant metal on the earth's crust. Elemental Iron is rarely found in nature, as the iron ions, $Fe^{2+}$and Fe^{3+} readily combine with oxygen- and sulfur-containing compounds to form oxides, hydroxides, carbonates, and sulfides. Iron is most commonly present in nature in the form of its oxides (WHO 2004).

The heavy metals concentration in the sediments is summarized in Table. The order of heavy metals concentration in sediment in site 1 is in order Fe>Mn>Zn>Ni>Cu> Cr>PB>Cd in site 2 Fe> Mn>ZN Cu>Ni>Cr >Cd>Pb and in site 3 Fe>Mn>Zn>Cu >Ni>Cr>Pb>Cd. The accumulation is almost similar in three sites. The Fe & Mn concentration is high in site 3 i.e. 40345 mg/Kg & 697.5 mg/Kg and 25269.9mg/kg & 2847.9mg/kg respectively at site 1. The heavy metals concentration is not in order as in soil in site 1. The heavy metals concentration is in the order Mn>Fe>Cr>Cu>Zn>Pb>Ni>Cd in site 1, and in site 2 Cr> Fe>Mn>Cu>Zn> Ni>Pb>Cd, and in site 3 it is Fe>Cr>Mn >Cu>Zn>Ni>Pb>Cd.

The heavy metals bioaccumulation order in Liver, Kidney, Gills and Muscles is presented in Table 2. It has been found that the heavy metals concentration is low in muscles in comparision to other organs. The maximum concentration of Nickel was found in Kidney, Copper and iron more in Liver, Manganese Chromium, Zinc and Lead in Gills, and Cadmium in muscles.

Zinc

Accumulation of heavy metals in tissues mainly depends upon the concentration of metals in water and exposure period, although some other environmental factors such as salinity, pH, hardness, and temperature also play significant roles in metal bioaccumulation (Blackmore & wang, 2003). When Zinc enters the bodies of these fish, it can biomagnify up in the food chain. "The Zinc concentrations in fish tissue decreased meaningfully with the increasing length of the fish, "which is regarded as a controversial subject (Toth & Brown, 1997). Zinc, an essential element, is one of the most common heavy metal pollutants. Zinc could cause sub-acute effects that change fish behaviors, i.e., deficiency in balance, restless swimming, air guzzling, periods of dormancy and death (Kori & Ubogu, 2008).

Zinc is a potential toxicant to fish (Vosyliena & Jankaita, 2006) which causes disturbances of acid-base and ion regulation, disruption of gill tissue and hypoxia (Murugan et al., 2008). The main target of waterborne Zn toxicity is the gills (Hogstrand, 2011), where the Ca^{2+}uptake is disrupted, leading to hypocalcemia and eventual death (Niyogi & wood, 2006). In present study, zinc has been observed gills> liver> kidney> muscles at site 1and 3, while in site 2 it was in order liver> kidney> gills> muscles. The higher concentration (434.88mg/kg) at site 1 in catla fish and lower concentration (32.36mg/kg) was found at Site 2.

Cadmium

Cadmium is a non-essential toxic metal that is widely distributed in the aquatic environment, and earth crust municipal waste and burning of fossil fuels are the largest source of cadmium release in the environment (such as coal and oil). According to some authors (Handy, 1992, & Calamari 1982) liver and Kidney are the primary sites of storage of this metal. This heavy metal has been shown to accumulate mainly (about 75 %) in Kidney, liver, and gills of freshwater fish. It can also be deposited in the hearts and other tissues and cause pathological changes of varying severity in the organs mentioned above. Once accumulated, the metals is slowly eliminated from the body through gills, skin, and Kidney. The concentration of Cadmium in catla fish at Site 1 was observed in order gill>liver>muscles> Kidney. In Site 2 it was muscles>kidney>gills>liver in the same species, and in Site 3 it was recorded in the order liver>muscles>gills> Kidney. The maximum values (87.59mg/kg) were observed in Site 2, and minimum value (0.658mg/kg) was recorded liver of catla fish at Site 1.

Lead

Lead is a naturally occurring substance; its environmental concentrations are significantly increased by anthropogenic sources, which include base metal mining, battery manufacturing. In water, lead may come from industrial and smelter discharges, from the dissolution of old lead plumbing, lead-containing pesticides, through precipitation, the fallout of lead dust, street runoff, and municipal wastewater (Handy, 1992, & Calamari 1982). Pb concentration and bioaccumulation is mainly dependent on the absorption into the sediments and the natural organic matter content of the water as well as the pH, alkalinity, and hardness (Sepe et al., 2003). Aquatic organisms bio accumulate Pb from water and diet, although there is evidence that Pb accumulation in fish, is most probably originated from contaminated water rather than diet (Creti et al., 2010). Lead deposits in various fish organs: liver, kidneys, and spleen, but also digestive tract and gills (Jezierska & Witeska, 2006). Accumulation of lead in different fish species has been determined in several works (Castro-Gonzalez & Mendez-Armenta, 2008), leading to disorders in fish body. Lead concentration in catla fish was observed from Site 1 in order glls>kidney>liver>muscles. In Site 2 it's in order gills>liver> kidney>muscle and in Site 3 in order muscles> gills>kidney>liver. The maximum values (163.63mg/kg) were found in gills of catla fish at Sangam coal void.

Chromium

The toxicity of Chromium to aquatic life is strongly influenced by the form of Chromium and quality of water. The toxicity towards Chromium considerably varies between groups of organisms. Invertebrate and phytoplankton are more sensitive than fish. In aquatic ecosystem, Chromium enters through the effluents discharged from leather tanneries, textiles, electroplating, metal finishing, mining, dyeing and printing industries, ceramic, photographic and pharmaceutical industries etc. (Arunkumar et al., 2000). In surface water, the most stable forms of Chromium are the oxidation states trivalent Cr (III) or (Cr^{3+}) and the hexavalent Cr (VI) or (Cr^{6+}). Hexavalent Chromium (Cr^{6+}) is considered to be toxic (i.e., carcinogenic) because of its powerful oxidative potential and ability to cross cell membranes (WHO, 1990). Fish assimilate Cr by ingestion or by the gill uptake tract, and accumulation in fish tissues, mainly liver, occurs at higher concentrations than those found in the environment (Pacheco et al., 2013). Impact chromium on organs like gill, Kidney, and liver may seriously affect the metabolic and physiologic activities and impair the growth and behavior of fish. Chromium compounds also cause renal failure leading to the loss of osmoregulatory ability and respiration in fish (Arillp & Melodio, 1988). In the present study, accumulation of Chromium in the tissues of the studied organ is in order kidney> gills > liver> muscles were observed at Site 1. In contrast, at Site 2 recorded in order gills> muscles> kidney> liver, and in Site 3, it has been found in order of kidney> liver> gills> muscles.

Iron

The highest bioconcentration of Iron in fish tissues was reported in the liver and gonads, decreasing in brain, muscle, and heart. Fe has several vital functions in the body. It serves as a carrier of oxygen to the tissues from the lungs by red blood cell hemoglobin, as a transport medium for electrons within cells, and as an integral part of critical enzyme systems in various tissues (FAO/WHO, 1998). Recently, Omar et al., in their study, proved that the fish liver is the target organ for Iron. Respiratory disruption due to physical clogging of the gills is suggested as a possible mechanism for iron toxicity. Because the gill surface of the fish tends to be alkaline, soluble ferrous Iron can be oxidized to insoluble ferric compounds, which then cover the gill lamellae and inhibit respiration. Ferrous Iron (Fe^{2+}) is considered to be more toxic to fish than the ferric (Fe^{3+}) form. The iron concentration recorded in different organs in order liver >kidney > gills> muscles in site 2 and 3 fish, respectively, while in site 1 kidney>liver > gills> muscles. The maximum value (735.75mg/kg) was observed in the site2 while minimum value (22.5mg/kg) has been found in fish from site 3.

Copper

Copper is an essential trace element required in the synthesis of oxidative enzymes such as catalase, peroxidase, cytochrome oxidase, and hemoglobin. Copper is an abundant element that occurs as a natural mineral with a widespread use. Copper pollution is through extensive use of fungicides, algaecides, molluscicides, insecticides, and discharge of wastes. Fish can accumulate copper via diet or ambient exposure, even at low environmental concentrations, the copper shows a distinct affinity to gather in the fish liver. Copper deficiency in animals is not merely dependent upon copper intake but depends on the dietary level of Zn, Fe and Ca (Fostner & Wiltmann, 1981). Copper-induced histological alterations are found in the gill, kidney hematopoietic tissue, mechano receptors, chemoreceptor, and other tissues. The concentration of Cu in different tissue was recorded in order liver> kidney> gills> muscles respectively at all selected sites in the same order. The maximum value (325.33mg/kg) in was observed at site 2, while minimum value (<0.03mg/kg) has been found in fish from site 3.

Nickel

The nickel toxicity may be due to nickel being in contact with the skin (body surface), penetrating the epidermis, and combining with body protein (Nielson, 1977). Nickel is an essential element at low concentrations for many organisms; it is toxic at higher levels (Magyarosy et al., 2002). Nickel is released by oil-burning power plants, coal-burning power plants, and trash incinerators (Al-Attar, 2007). The concentration of Ni in the studied organ was recorded in order gills> muscles> liver> Kidney in site 1, kidney > muscles> liver> gills at site 2, and in site 3 in order gills> liver> muscles> Kidney. The maximum value (16.5mg/kg) were recorded at site 2 and minimum value (3.92mg/kg) was recorded in site 3.

Manganese

Mn belongs to the essential elements with considerably higher liver concentrations than in muscle tissue due to its function as a cofactor for the activation of several enzymes (Wagner & Boman, 2003). The concentration of Mn in the studied organ was in order gills> liver> kidney> muscles have recorded in site 1 and 2 catla fish. At the same time, at site 3 liver> kidney> gills>muscles. The maximum value (214.75mg/kg) were observed in site 1, and minimum value (0.02mg/kg) has been found in site 3.

Table 1: Heavy metal concentration in Sediment and water

Sl.no	Heavy metals	Site 1		Site 2		Site 3	
		Soil (mg/kg)	**Water** (mg/l)	**Soil** (mg/kg)	**Water** (mg/l)	**Soil** (mg/kg)	**Water** (mg/l)
1	Cr	11	0.049	16.3	0.054	12.5	0.061
2	Cu	23.5	0.028	26.4	0.027	30	0.027
3	Mn	2847.9	1.209	1477.9	0.044	697.5	0.035
4	Fe	25269.9	0.581	19706.8	0.053	40345	0.151
5	Ni	81.9	0.01	24.2	0.01	22.5	0.01
6	Zn	572.47	0.019	184.4	0.016	67.5	0.022
7	Pb	<0.005	0.012	<0.005	0.007	4.25	0.009
8	Cd	<0.0005	0.001	0.7857	0.001	0.92	0.004

Table 2: Heavy metal bio accumulation sequence in different organs of fish

Heavy metals	Liver			Kidney			Gills			Muscles		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Cr	17.5	18.88	80.75	23.33	23.25	261.0	18.25	33.5	11.5	16.63	27.0	0.04
Cu	210.0	325.33	160.92	71.63	19.63	125.0	10.25	9.25	7.5	7.5	8.25	0.03
Mn	43.67	31.17	37.63	43.42	13.95	30.0	214.75	75.67	19.15	8.83	7.25	0.02
Fe	382.3	735.75	359.58	482.42	249.97	120.75	149.08	238.17	82.17	42.25	44.67	22.5
Ni	7.0	14.75	5.25	6.67	16.5	3.92	11.0	12.75	5.38	7.88	16.25	5.0
Zn	204.66	324.67	68.11	144.17	154.51	50.85	432.88	127.7	77.9	33.82	32.36	35.73
Pb	2.78	3.5	0.05	34.05	2.86	2.88	167.09	10.0	7.64	1.05	2.41	15.99
Cd	1.63	0.66	77.38	1.37	3.58	2.08	3.18	2.55	41.66	1.6	87.59	4.69

Table 3: Heavy metal concentration in different organs of fish (mg/kg wet wt)

	Site 1	Site 2	Site 3
Liver	Fe>Cu>Zn>Mn>Cr> Ni>Pb>Cd	Fe>Cu>Zn>Mn>Cr>Ni>Pb>Cd	Fe>Cu>Cr>Cd>Zn>Mn>Ni>Pb
Kidney	Fe>Zn>Cu>Mn>Pb>Cr>Ni>Cd	Fe>Zn>Cr>Cu>Ni>Mn>Cd>Pb	Cr>Cu>Fe>Zn>Mn>Ni>Pb>Cd
Gills	Zn>Mn>Pb>Fe>Cr>Ni>Cu>Cd	Fe>Zn>Mn>Cr>Ni>Pb>Cu>Cd	Fe>Zn>Cd>Mn>Cr>Pb>Cu>Ni
Muscles	Fe>Zn>Cr>Mn>Ni>Cu>Cd>Pb	Cd>Fe>Zn>Cr>Ni>Cu>Mn>Pb	Zn>Fe>Pb>Ni>Cd>Cr>Cu>Mn

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