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Original Article

Distribution and bioaccumulation of heavy metal in water, sediment and fish tissue from the River Mahananda in Seemanchal zone, North Bihar, India

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Abstract: In the present study, distribution, and bioaccumulation of Cu, Zn, Cd, and Pb were analysed in water, sediment and freshwater fish tissues of *Catla catla* and *Mystus seenghala* which were seasonally collected from River Mahananda in Seemanchal zone. The results showed that except Pb, level of Cu, Zn and Cd in water were below than allowance limit of WHO (2008), while level of Cu, Zn and Cd in sediment was higher than a toxicity reference value (TRV) recommended by USEPA (1999), except Pb. Heavy metal concentration in water and sediment were recorded in the order: Cu>Pb>Zn>Cd and Zn>Cu>Pb>Cd, respectively. The seasonal variation of this metal in water was in the sequence: rainy>winter>summer, and in sediment summer>winter>rainy. Bioaccumulation of studied metal by different tissues of *M. seenghala* was maximum than *C. catla*, and found that following order of magnitude: liver>gill>muscle. The order of studied metal concentration in liver Zn>Pb>Cu>Cd, in Gills Zn>Pb>Cu>Cd, in muscle Zn>Pb>Cu. Pb was only metal whose concentration was higher than FAO, FAO/WHO and WHO standards in all examined tissues of both species. Bioaccumulation of Pb in different tissues of both fishes was observed maximum in summer followed by winter and rainy (monsoon) seasons. Bioaccumulation factor (BAF) of all four metals in organs of *M. seenghala* was higher than *C. Catla.* Metal index value (MI) > 1 for Cd and Pb in water suggests that worse quality of water. The levels of heavy metals accumulated in two fishes might be due to the increase in agricultural influx water, domestic wastes, poultry farm, municipal and some other anthropogenic activities. This study shows that River water in the studied zone is a serious concern of human health and selected fishes do not feed directly without proper treatment of the riverine ecosystem, and potential danger may occur in the future.

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Introduction

Heavy metal pollution in the aquatic system has attracted global attention due to their environment toxicity, persistence, bioaccumulation and biomagnifications in the food chain, which can pose adverse effect on living beings and the entire ecosystem (Kumar et al., 2015; Kumar and Seema, 2016; Kumar et al., 2017; Xu et al., 2018; Ali et al., 2019). Anthropogenic activities continuously increase the amount of heavy metal in the aquatic ecosystem (Xu et al., 2018; Kumar et.al, 2019). As heavy metals cannot be degraded, they are deposited, assimilated or incorporated in water, sediment and aquatic organisms and thus, causing heavy metal pollution in an aquatic ecosystem (Kumar and Kumar, 2018; Farsani, et al., 2019). In the light of the extreme human activity, natural sources of heavy metals are usually of a little importance (Xu et al., 2016a; Patel et al., 2018; Yan et al., 2018). Anthropogenic activities such as industrial effluent, sewage sludge, domestic wastes (Guatam et al., 2013; Mozumdar et al., 2015; Banaee et al., 2015; Arbind and Seema, 2016; Kumar et al., 2017; Farsani et al., 2019; Banaee and Tahari, 2019), atmospheric pollutants (Arbind and Seema, 2017) and agricultural runoff (Zhang et al., 2014; Singh et al., 2016, 2017) entering the water bodies are one of the prime sources of heavy metal toxicity, which deteriorates water quality and danger to human health and aquatic organisms (Xu et al., 2016a, b). In water bodies, metals can be in dissolved and particulate form (Farsani, et al., 2019), and their levels in water depend on some physiochemical parameter such as redox

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potential, pH, temperature, dissolve oxygen, salinity, conductivity and ionic strength (Hassan et al., 2015; Sim et al., 2016).

Sediments often act as carries potential sources for metals in the aquatic environment (Hassan et al., 2015; Sim et al., 2016). About 99% of the heavy metals entering into river from different sources have been found to ultimately precipitate onto the sediment (Sim et al., 2016; Singh et al., 2017; Xu et al., 2018). Their quality can indicate the states of water pollution (Zahra et al., 2014). The distribution of heavy metals in the sediments is affected by the chemical composition of the sediments, grain size and content of total carbon matter (Zhao et al., 2014; Azidi et al., 2018). The release of heavy metals from sediment to water bodies is affected by the overlying water conditions, pH, alkalinity, salinity, dissolved oxygen concentration and suspended solid (Simpon et al., 2004; Li et al., 2013) and found that physical disturbance of sediments released metals more rapidly than biological disturbance (Atkinson et al., 2007). The pH is an important factor of metal bioavailability in sediment (Li et al., 2013). Decreasing the pH, increases the competition between metal ion and H^+ for binding sites such as OH^- , CO_3^{2-}, SO_4^{2-}, Cl^-, S^{2-} and PO_4^{3-} in sediments, therefore absorption abilities and bioavailability of the metals in the sediments subsequently decrease and then increase the mobility of metal ions and may result in dissolution of metal complexes, thereby releasing free metal ions into the water system (Nowrouzi et al., 2014; Rajeskumar and Li, 2018). Contaminated sediments do not always remain at the bottom of the water body, anything that stirs up the water, such as dredging, can resuspend sediments. Resuspension may mean that all of the animals in the water, and not just the bottom-dwelling organism, will be directly exposed to the toxic contaminants (Begum et al., 2009). Thus, sediments can be a sensitive indicator to detect the quality of the aquatic system, and it may act not only as a sink but also as sources of contamination in aquatic bodies (Li et al., 2013; Rajeskumar et al., 2018; Ali et al., 2019).

In recent years, the consumption of fish has increased rapidly with an awareness of its nutritional and therapeutic benefits (Sioen et al., 2007; Bawuro et al., 2018). Fish contains high level of unsaturated acids and low levels of cholesterol and also has a high level of many essential nutrients (El-Mosclhy 2000; Kris-Etherton et al., 2002; Afshan et al., 2014; Bawuro et al., 2018; Rajeskumar and Li, 2018). Various researches have shown the adverse effect of heavy metals on human health, such as renal failure, cardiovascular diseases, liver damage and even death (Castro-Gonzalez and Armenta, 2008; Al-Bussaidi et al., 2011; Rahman et al., 2012). Bioaccumulation of heavy metal in freshwater fish depends upon the various factor such as fish characteristics and external environmental factors. The retention of heavy metal in the body of an organism depends on many factors such as the speciation of the metal concerned and the physical mechanism developed by the organism for the regulation, homeostasis, and detoxification of the heavy metal. The degree of bioaccumulation in different tissues of fish is generally different depending on the active tissue like liver, gills, and kidney have a higher accumulation of the heavy metal than other tissues such as skin and muscles (Maurya and Mallik, 2019; Ezekiel et al., 2019). Thus the presence of heavy metals in water and sediment would be primary source for the distribution and bioaccumulation of metals in the fish and cause adverse effect to those who consume the contaminated fish (Yu et al., 2012; Bao et al., 2015; Bawuro et al., 2018; Maurya and Mallik, 2019; Ezekiel et al., 2019). Therefore, this research aimed to evaluate the distribution, bioaccumulation and seasonal variation of Cu, Zn, Cd and Pb in water, sediment and freshwater fishes from River Mahananda in three districts of Seemanchal zone and monitoring the health risk of heavy metal in fish and people within the environment.

Materials and Methods

Study area: The River Mahananda originates 6 Kms north of Kurseong in the Darjeeling district of West Bengal in the Himalayan range, at the elevation of 2062 m. It has a powerful role in regulating overall economy of the catchment area, such as Darjeeling, Utter Dinajpur and Maldah districts of west Bengal and Kishanganj, Purnea and Katihar districts of Bihar. The River Mahananda starts its 360 kms long journey to the Ganga out of which 324 kms are in India and 36 kms are in Bangladesh. The total drainage area of this river is 24,753 sq kms, of which 5,293 sq kms are located in Nepal, 6,677 sq kms in west Bengal, 7,975 sq kms in Bihar and rest is located in Bangladesh, where it finally joins the Ganga (Padma) near Godagarighat in Nawabganj district. The River Mechi and Kankai flow through Nepal and form the boundary between India and Nepal and then flow through the Indian state of Bihar to join the Mahananda in Kishanganj district (Fig. 1).

Collection of water, sediment and fish samples: A total of 66 samples (water and sediment) were collected from Mahananda River during year 2017-2018 in summer, rainy (monsoon) and winter season, including 22 samples from each season and at 8 sites of each Kishanganj and Katihar and 6 sites of Purnia district of Seemanchal zone, Bihar (Table 1). About 500 mL water samples were collected at 0.5 meter below the water surface, filtered in pre cleaned bottle and preserved by adding 5 mL of 65% concentrated HNO_3 to it and then packed in ice bath (4°C) and brought to the laboratory for further digestion (APHA, 2005). About 500 g sediments samples were collected at a depth of 0-10 cm using a portable Ekman grab sampler by applying the method of US EPA (2001) and immediately transferred into polyethylene bags, which were already washed with 10% HNO_3 solution and successively rinsed with distilled water. At each site, three samples were collected and were subsequently well-mixed to get a composite mixture (Kumar et al., 2019). Five specimens of each species (*C. catla* and *M. Seenghala*) were also collected seasonally at each sampling sites, using a multifilament, nylon gillnet with help of local fisherman. These fish species represent different biotopes (Table 2) that were immediately preserved on ice in an ice chest and then transferred to the laboratory where they were weighed and their total length recorded, and kept frozen at -20°C. After identifying, all fishes were dissected into separate

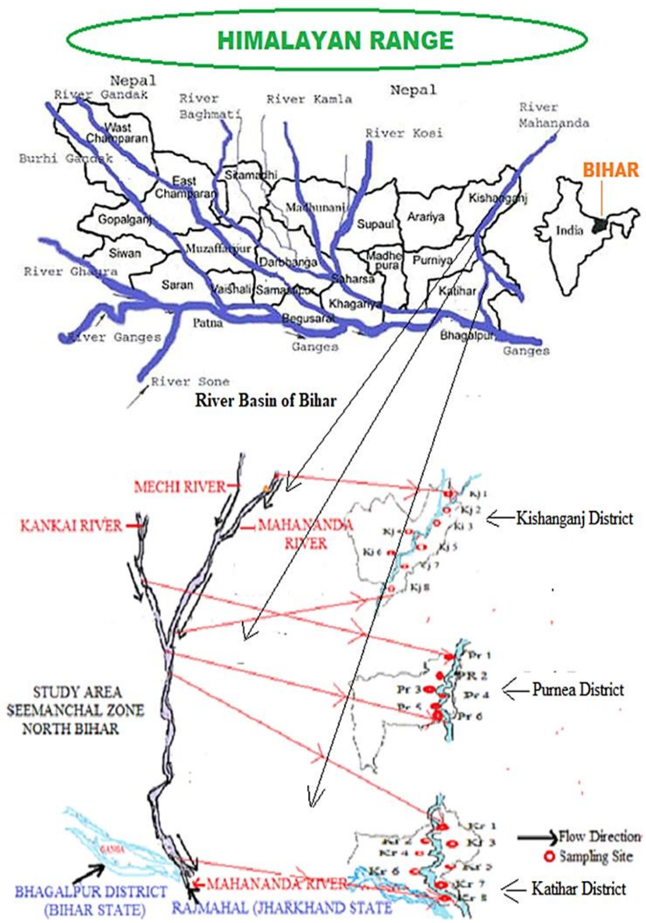

Figure 1. Map showing sampling location of River Mahananda in Seemanchal zone.

organs such as liver, gills and muscles using stainless steel instrument by applying the method of Voegborlo et al. (2012) and Al-Busaidi et al. (2011) and put in to Petri plate to dry at 120°C until reaching a constant weight.

Digestion of water, sediment, and fish samples: 100 mL water sample was taken in a conical flask, and 5 mL of concentrated HCl acid was added to it and then heated on the hot plate for two hours at 105°C to 25 mL. The concentrated water sample was then transferred into 100 mL volumetric flask, and distilled water was added to fill up to the mark and then analysed for Cu, Zn, Cd and Pb using Atomic Absorption Spectrophotometer. Each sediment sample was air dried and homogenized by grinding, using an agate mortar and pestle to pass through 63 µ mesh nylon sieve at room temperature. To estimate the heavy metal content, 2 gram of sediment sample

Table 1. Sampling sites, geographic coordinates and description of sampling sites.

Sampling site	Geographic Coordinates		Description
	Latitude	Longitude	
Kishanganj District			Upstream
Thakurganj (Kj-1)	26.4272^{0} N	88.1254^{0} E	Few factories too have been established in this region in the recent decades. The water body receives a lot of water of wastes ranging from industrial, agricultural and domestic sources, which apart from adversely affecting the normal hydrochemistry of the river, also decreases its channel capacity at various points, and this has been largely responsible for flood disasters in the river. The main Rivers flowing through this district are Mahananda, Kankai, Mechi, Donk, Rauta, Sudhani and Ramzan.
Arrabari (Kj-2)	26.2703^{0} N	88.0363^{0} E	
Halamla (Kj-3)	26.3707^{0} N	88.2347^{0} E	
Palkoaikund (Kj-4)	24.2113^{0} N	87.8353^{0} E	
Balubari (Kj-5)	24.1490^{0} N	87.9126^{0} E	
Gobondpur (Kj-6)	26.1177^{0} N	87.8967^{0} E	
Chakandra (Kj-7)	26.1335^{0} N	87.8803^{0} E	
Kishanganj town (Kj-8)	26.07944^{0} N	87.93722^{0} E	
Purnea District			Midstream
Talbari (Pr-1)	26.0093^{0} N	87.7542^{0} E	The district is one of the fastest growing districts in the state and this can be seen in the increasing infrastructural facilities in the city. The Rivers also receives effluents from many small industries, textile battery producing unit and also agricultural runoff from its catchment area. Kankai River is major tributary of Mahananda River, when enters in Purnea district. There are four important rivers which traverse the city and also divide the district into four distinct zones. The rivers which traverse the city are Kosi in the west, Panar in the northeast, Mahananda in the east and Ganga in the south.
Surjapur (Pr-2)	25.9680^{0} N	87.7640^{0} E	
Amor (Pr-3)	25.95694^{0} N	87.72500^{0} E	
Khari (Pr-4	25.9385^{0} N	87.7640^{0} E	
Chanargaon (Pr-5)	25.1335 N	87.8193 E	
Bhasia (Pr-6)	25.8673^{0} N	87.7443^{0} E	
Katihar District			Downstream
Taiyabpur (Kr-1)	25.7117^{0} N	87.8206^{0} E	The main rivers of the district are Ganga, Kosi and Mahananda. This district shares boundary with two states i.e. Jharkhand at the southern side and West Bengal at the eastern side. The Bangladesh lies around 80 km east of Katihar town and Nepal lies around 100 km north of Katihar town. The River receives allochtonous input of organic matter from the surrounding vegetation derived through runoff from the surface of soil. Solid wastes are produced daily from domestic uses in Katihar city and about 65% of them are dumped in the river. The right portion of River Mahananda at Bagdob known as Jhawa branch, when enters in Katihar district of Seemanchal zone,
Majhok (Kr-2	25.6970^{0} N	87.8380^{0} E	
Jhawa R.S.(Kr-4)	25.6134^{0} N	87.7755^{0} E	
Meena R.S. (5)	25^{0} 35'00" N	87^{0} 51'00" E	
Mukuria (Kr-5)	25.6269^{0} N	87.8869^{0} E	
Lava (Kr-6)	26.1037 N	87.8457 E	
Singha (Kr-7)	26.1655 N	87.5634 E	
Gobindpur (Kr-8)	26.4976^{0} N	87.6519^{0} E	

Table 2. Fish species ecological characteristic.

Species	Common name	Habitant	Feeding behavior	No. of samples	Length (cm)	Weight (gr)
Catla catla	Catla	Surface and mid-water feeders	Mainly omnivorous	5	14-25	225-450
Mystus seenghala	Dariai Tengara	Middle bottom feeder	Carnivorous	5	20-30	205-420

collected from each site was digested separately with 25 mL of tri-acid mixture of HNO_3, H_2SO_4 and $HClO_4$ in the proportion of 5:1:1 respectively in Teflon measuring beaker at about 80°C for 4-5 h based on Allen et al. (1986) modified by Singh et al. (2017). After this digested, solution was filtered using Whatman No. 42 filter paper in pre-cleaned 100 mL measuring flask and volumes were made up to mark and then subjected to atomic absorption spectrophotometer for analysis of Cu, Zn, Cd and Pb. The dried fish tissues were digested by the method described by Voegborlo et al. (2012), modified by Bawuro et al. (2018). In this method one gram of each sample was digested separately with $HClO_4$ and HNO_3 in the ratio 1:1 followed by sulphuric acid, and the mixture was heated at 200°C for 30 min. After complete digestion, each digested mixture was cooled at room temperature and then transferred in to 50 mL volumetric flask. Distilled water was added to it to fill up to the mark and analysed for Cu, Zn, Cd, and Pb using Atomic Absorption Spectrophotometer.

Metal Index (MI): For assessing the water quality,

Table 3. Seasonal variation of heavy metal in water of River Mahananda in Seemanchal zone.

Metal	Location	Summer (M±SD)	Rainy (M±SD)	Winter (M±SD)	Total (M±SD)	Metal Index	WHO (2008)
Cu (mg/L)	Kishanganj, n=8	0.36±0.02	0.41±0.01	0.40±0.011	0.39±0.026	0.195	1-3 mg/L
	Purnia, n=6	0.38±0.01	0.49±0.14	0.45±0.05	0.44±0.056	0.22	
	Katihar, n=8	0.43±0.13	0.47±0.02	0.47±0.03	0.456±0.023	0.225	
Zn (mg/L)	Kishanganj, n=8	0.12±0.01	0.17±0.05	0.15±0.11	0.147±0.025	0.049	10-15 mg/L
	Purnia, Dt., n=6	0.15±0.15	0.21±0.01	0.17±0.01	0.176±0.030	0.051	
	Katihar, n=8	0.18±0.02	0.25±0.02	0.22±0.06	0.217±0.035	0.072	
Cd (mg/L)	Kishanganj, n=8	0.058±0.01	0.068±0.03	0.061±0.01	0.062±0.005	20.44	2 mgL
	Purnia, n=6	0.068±0.02	0.078±0.04	0.072±0.04	0.073±0.005	23.33	
	Katihar, n=8	0.065±0.02	0.075±0.01	0.065±0.02	0.068±0.006	22.78	
Pb (mg/L)	Kishanganj, n=8	0. 15±0.08	0.20±0.05	0.17±0.03	0.173±0.025	17.33	0.1-0.2 mg/L
	Purnia, n=6	0.25±0.02	0.35±0.02	0.31±0.04	0.303±0.05	30.33	
	Katihar, n=8	0.31±0.33	0.38±0.01	0.34±0.11	0.343±0.035	34.33	

Table 4. Seasonal variation of heavy metal in sediment of River Mahananda in Seemanchal zone.

Metal	Location	Summer (M±SD)	Rainy (M±SD)	Winter (M±SD)	Total (M±SD)	TRV (USEPA)
Cu (mg/L)	Kishanganj, n=8	65.32±7.32	58.72±7.63	60.38±8.61	61.47±3.433	16 mg/kg
	Purnia, n=6	65.73±9.24	58.92±9.28	60.09±21.9	61.58±6.641	
	Katihar, n=8	71.5±7.81	68.12±8.24	69.32±9.41	69.65±1.713	
Zn (mg/L)	Kishanganj, n=8	108.5±8.47	102.41±9.51	104.8±10.2	105.24±3.068	110 mg/kg
	Purnia, n=6	117.34±20.27	113.62±19.21	115.46±21.9	115.47±1.860	
	Katihar, n=8	119.43±9.81	116.71±9.55	117.35±10.08	117.83±1.422	
Cd (mg/L)	Kishanganj, n=8	0.921±0.11	0.82±0.101	0.864±0.118	0.868±0.0501	0.6 mg/kg
	Purnia, n=6	0.73±0.15	0.657±0.21	0.68±0.109	0.689±0.037	
	Katihar, n=8	0.79±0.12	0.78±0.12	0.712±0.103	0.755±0.053	
Pb (mg/L)	Kishanganj, n =8	23.23±4.12	21.46±3.71	22.95±4.34	22.55±0.951	31 mg/kg
	Purnia, n=6	24.47±4.43	22.67±2.81	23.95±3.62	23.67±0.926	
	Katihar, n=8	25.81±3.72	23.76±3.21	24.41±3.66	24.66±1.048	

metal index can be applied. It was calculated by the following equation, defined by Tamasi and Cini (2004) and described by Yehia and Sebaee (2012):

$$MI = \sum \frac{Ci}{(MAC)i}$$

Where Ci is the metal concentration in water sample and MAC is the maximum allowed concentration for each element in drinking water and subscript i is the i^{th} sample.

Bioaccumulation factor (BAF): BAF is inductive of the degree of accumulation of heavy metal in an organism relative to that in its habitant (water and sediment). It was calculated by the following equation described by Kalvins et al. (1998) and modified by Ali et al. (2019):

$$BAF = \frac{Cfish\ tissue}{C\ sediment}$$

Where $C_{\text{fish tissue}}$ is the metal concentration in fish tissue and C_{sediment} is the metal concentration in the sediment.

Statistical Analysis: All statistical analysis was performed on using the Microsoft Excel 2007. Similarly, the significance of differences between the concentrations of heavy metals in water, sediments and selected tissues were calculated using Casio calculator (made in China) fx-991 MS. A probability of $P<0.05$ was considered statistically significant.

Results

The seasonally variation of averages mean concentration with standard deviation of Cu, Zn, Cd, and Pb in water, sediment and selected organs *viz.* liver, gills and muscles of two *C. catla* and *M. seenghala* of River Mahananda in Seemanchal zone are presented in Tables 3 and 4, and 5-8, respectively.

Water: The average maximum mean concentration of Cu, Zn and Pb in water sample was found

Table 5. Seasonal variation of Cu concentration (mg/kg dry wt) in different organs of *Catla catla* and *Mystus seenghala* in River Mahananda.

Location	Organ	*Catla catla*				*Mystus seenghala*			
		Summer (M±SD)	Rainy (M±SD)	Winter (M±SD)	Total (M±SD)	Summer (M±SD)	Rainy (M±SD)	Winter (M±SD)	Total (M±SD)
Kishanganj	Liver	2.9±0.05	2.4±0.34	2.2 4± 0.26	2.51±0.344	4.8±0.21	5.1±0.11	4.7±0.06	4.83±0.152
	BAF	0.0444	0.0408	0.037	0.041±0.003	0.0734	0.0851	0.0778	0.0787±0.006
	Gills	1.33±0.02	1.35±0.012	1.28± 0.31	1.32±0.036	1.91±0.21	2.1±0.01	1.9±0.02	1.97±0.113
	BAF	0.0203	0.0229	0.0211	0.0214±0.001	0.0292	0.0357	0.0314	0.0321±0.003
	Muscles	0.92±0.23	0.85±0.15	0.82±0.31	0.853±0.051	1.21±0.06	1.09±0.11	1.06±0.21	1.12±0.079
	BAF	0.014	0.0144	0.0101	0.013±0.002	0.0185	0.0185	0.0175	0.018±0.0005
Purnea	Liver	5.5±0.41	5.1±0.03	4.1±0.34	5.133±0.351	5.2±0.32	4.8±0.21	4.1±0.08	4.70±0.556
	BAF	0.0836	0.0868	0.0798	0.0834±0.0035	0.0791	0.0814	0.0682	0.076±0.007
	Gills	3.2±0.131	2.9±0.31	2.6±0.13	2.9±0.32	3.7 ±0.41	3.2±0.05	3.01±0.02	3.3±0.356
	BAF	0.0499	0.0492	0.0432	0.0474±0.0037	0.0456	0.0543	0.0499	0.05±0.004
	Muscles	1.46±0.05	1.24±0.12	1.2±0.31	1.3±0.14	1.76±0.23	1.54±0.13	1.52±0.34	1.607±0.133
	BAF	0.0222	0.021	0.0199	0.021±0.0031	0.0267	0.0261	0.0252	0.026±0.0007
Katihar	Liver	15.3±0.34	14.4±	13.8±0.43	14.5±0.755	20.6±0.50	20.5±0.45	18.7±0.38	19.93±1.069
	BAF	0.2139	0.2113	0.199	0.208±0.008	0.2881	0.3009	0.2677	0.286±0.017
	Gills	4.5±0.01	2.8±0.01	3.75±0.03	4.35±0.5408	3.7±0.31	2.8±0.23	2.6±0.04	3.03±0.586
	BAF	0.0629	0.0704	0.054	0.0624±0.008	0.0517	0.0411	0.375	0.0434±0.007
	Muscles	2.65±0.34	2.25±0.02	2.04±0.41	2.313±0.309	1.78±0.07	1.52±0.21	1.48±0.25	1.593±0.162
	BAF	0.037	0.033	0.0294	0.033±0.004	0.0248	0.0223	0.0213	0.023±0.002

0.456±0.023, 0.217±0.035 and 0.343±0.035 mg/L, respectively at study point of Katihar (downstream), whereas Cd was 0.073±0.005 mg/L at location of Purnea district (midstream). Similarly, average lowest mean concentration of Cu, Zn, Cd and Pb were found 0.39±0.026, 0.147±0.025, 0.062±0.005 and 0.173± 0.025 mg/L, respectively at location of Kishanganj, upstream of River (Table 3). The order of heavy metal in the water of river was Cu>Pb>Zn>Cd. The results indicated that Cu was maximally and Cd was least accumulated in the water of the river. The results also indicated the greater values of heavy metals in water were found at downstream of river and seasonally higher concentration of these metals were detected in the rainy season followed by winter and summer season. The maximum MI of Cu, Zn and Pb in water samples was found 0.225, 0.072 and 34.33, respectively at the study point of Katihar and for Cd 23.33 at Purnea district of midstream of River Mahananda (Table 3).

Sediment: The average maximum mean concentration of Cu, Zn, and Pb in sediment of river was 69.65± 1.713, 117.83±1.422 and 24.66±1.048 mg/kg, respectively in downstream of river at Katihar, whereas Cd was 0.868±0.0501 mg/ kg at location of Kishanganj. Similarly, the average minimum mean concentration of Cu, Zn and Pb was 61.47±3.433, 105.24±3.068 and 22.55±0.951mg/kg, respectively at upstream of river at the location of Kishanganj, whereas Cd was 0.689±0.037 mg/kg at midstream of the river at Purnea zone. The order of heavy metal accumulation in sediment of River was Zn>Cu>Pb >Cd. The data also indicated that Zn was maximally accumulated and Cd got the least concentration in the sediment of each location of Mahananda River. The maximum concentrations of these metals in sediment were detected in summer, followed by winter and rainy season (Table 4).

Heavy metal content and BAF in fish tissues:

Copper: In the liver of *C. catla,* Cu recorded its highest mean concentration 14.5±0.755 mg/kg and in *M. seenghala* was 19.93±1.09 mg/kg at the same location of downstream of River at Katihar, whereas lowest mean concentration in *C. catla* was 2.51± 0.344 mg/kg at location of Kishanganj, and in *M. seennghala* was 4.7±0.556 mg/kg at location of Purnea (Table 5). Similarly, in gills, maximum mean concentration of Cu in *C. catla* was recorded 4.35±0.5408 mg/kg and in *M. seenghala* was 3.3±0.356 mg/kg at locations of River at Katihar and Purnia areas, respectively. Minimum concentration was 1.32±0.036 and 1.97±0.113 mg/kg, respectively, at the same study points of upstream of river at Kishanganj (Table 5). In muscles of *C. catla* and *M. seenghala*, the highest

Table 6. Seasonal variation of Zn concentration (mg/kg dry wt) in different organs of *Catla catla* and *Mystus seenghala* in River Mahananda.

Location	Organ	*Catla catla*				*Mystus seenghala*			
		Summer (M±SD)	Rainy (M±SD)	Winter (M±SD)	Total (M±SD)	Summer (M±SD)	Rainy (M±SD)	Winter (M±SD)	Total (M±SD)
Kishanganj	Liver	28.7±2.65	26.3±1.32	27.6 ±2.21	27.53±1.20	35.3±2.76	35.2±5.31	34.7± 6.01	35.07±0.3214
	BAF	0.2645	0.2568	0.2633	0.2615±0.004	0.3253	0.3437	0.3311	0.3333±0.009
	Gills	22.2±2.31	22.4±4.12	22.3± 1.42	22.3±0.01	36.7±3.21	36.6±3.25	35.7±3.54	36.33±0.5507
	BAF	0.2046	0.2187	0.2127	0.212±0.007	0.3474	0.3573	0.3406	0.3484±0.008
	Muscles	16.9±2.01	15.1±3.2	16.1±2.43	16.03±0.902	12.3±0.56	11.6±1.02	11.7±1.05	11.87±0.378
	BAF	0.1587	0.1474	0.1536	0.1532±0.005	0.1133	0.1132	0.1116	0.1127±0.009
Purnea	Liver	41.7±0.76	38.5±0.54	37.8±6.01	39.33±2.079	75.4±8.3	70.6±7.8	69.8±5.2	71.93±3.028
	BAF	0.3553	0.3388	0.3273	0.3405±0.014	0.6435	0.6231	0.6065	0.6243±0.0185
	Gills	24.7±4.32	22.5±3.54	22.7±2.12	23.3±1.216	40.1±3.23	39.2±5/42	39.4±2.03	39.9±1.044
	BAF	0.2104	0.198	0.1966	0.2016±0.007	0.3417	0.345	0.3369	03512±0.0040
	Muscles	12.5±0.42	12.1±0.6	11.8±1.01	12.13±0.351	16.6±2.1	17.3±3.32	17.4±2.11	17.1±0.4358
	BAF	0.1065	0.1064	0.1021	0.109±0.0025	0.1414	0.1522	0.1507	0.1481±0.0058
Katihar	Liver	65.7±5.98	63.7±8.32	62.3±5.48	63.9±1.708	45.2±6.30	46.6±4.32	47.8±1.23	46.53±1.301
	BAF	0.5501	0.5457	0.5308	0.5422±0.01	0.3984	0.3992	0.4073	0.4016±0.005
	Gills	37.3±4.31	36.4±3.03	35.6±2.01	36.43±0.850	48.1±3.21	46.3±1.95	45.1±2.01	46.5±1.509
	BAF	0.3123	0.3118	0.3033	0.309±0.005	0.424	0.3967	0.3843	0.4016±0.0203
	Muscles	19.2±0.98	17.5±1.06	17.1±1.83	17.93±1.115	22.3±2.56	23.7±2.13	25.6±4.10	23.86±1.6563
	BAF	0.1607	0.1499	0.1457	0.1521±0.007	0.1965	0.203	0.2181	0.2058±0.0111

mean concentration of Cu was 2.313±0.309 and 1.607±0.133 mg/kg at the station of Katihar and Purnia, respectively, whereas lowest mean concentration was 0.853±0.051 and 1.12±0.079 mg/kg at same station of Kishanganj (Table 5). The maximum BAF of Cu in the liver of *C. catla* and *M. seenghala* was 0.208±0.008 and 0.286±0.017, respectively at the same study point of River at Katihar, whereas minimum mean BAF value was 0.041±0.003 and 0.076±0.007 at the location of Kishanganj and Purnia district, respectively. In gills of *C. catla* and *M. seenghala* the maximum mean BAF value obtained was 0.0624±0.008 and 0.05±0.004 at the station of Katihar and Purnia, respectively, and minimum BAF was 0.0214±0.001 and 0.0321±0.003 at the same study point of Kishanganj. In muscle of *C. catla* and *M. seenghala* highest BAF value of Cu was 0.033±0.004 and 0.023±0.002, respectively at same location Katihar and lowest value was 0.013±0.002 and 0.018±0.0005, respectively at same location Kishanganj.

Zinc: The highest concentration of Zn in liver of *C. catla* and *M. seenghala* was 63.9±1.708 and 71.93±3.028 mg/kg at location of Katihar and Purnea, respectively, whereas lowest mean concentration was recorded 27.53±1.20 and 35.07±0.3214 mg/kg, respectively at same station of River at Kishanganj (Table 6). Also, at location of downstream of river at Katihar the gills of *C. catla* and *M. seenghala*, recorded the maximum mean concentration of Zn was 36.43±0.850 and 46.5±1.509 mg/kg, respectively and minimum mean concentration was 22.3±0.01 and 36.33±0.5507 mg/kg, respectively at upstream of river at Kishanganj (Table 6). In muscles of *C. catla* and *M. seenghala* the highest mean concentration of Zn was recorded 17.93±1.115 and 23.86±1.656 at the same location of Katihar, whereas minimum concentration was recorded 12.13±0.351 and 11.87±0.378 mg/kg at the stations Purnea and Kishanganj (Table 6). The maximum mean value of BAF for Zn in liver and gills of *C. catla* was 0.5422±0.01 and 0.309±0.005, respectively at same location of Katihar and in muscles was 0.1532±0.005 at location of Kishanganj, whereas in gills and muscles of *M. seenghala* highest BAF value for Zn was 0.4016±0.020 and 0.2058±0.0111, respectively at the same station of Katihar and in liver was 0.6243±0.0185 at Purnea location. The lowest value of BAF for Zn in liver and gills of *C. catla* was 0.2615±0.004 and 0.212±0.007and of *M. seenghala* was 0.3333±0.009 and 0.3484±0.008, respectively at upstream of River at Kishanganj. In muscle of *C. catla*

Table 7. Seasonal variation of Cd concentration (mg/kg dry wt) in different organs of *Catla catla* and *Mystus seenghala* in River Mahananda.

Location	Organ	*Catla catla* Summer (M±SD)	Rainy (M±SD)	Winter (M±SD)	Total (M±SD)	*Mystus seenghala* Summer (M±SD)	Rainy (M±SD)	Winter (M±SD)	Total (M±SD)
Kishanganj	Liver	0.928±0.11	0.925±0.04	0.92±0.01	0.924±0.004	0.996±0.06	0.985±0.06	0.958±0.04	0.979±0.019
	BAF	1.007	1.004	1.0033	1.005±0.002	1.081	1.069	1.0401	1.063±0.021
	Gills	0.256±0.01	0.242±0.03	0.31±0.12	0.269±0.035	0.891±0.04	0.856±0.03	0.865±0.06	0.870±0.018
	BAF	0.2779	0.2951	0.2905	0.2878±0.009	0.9674	1.0439	1.001	1.004±0.038
	Muscles	ND	ND	ND	ND	ND	ND	ND	ND
	BAF	ND	ND	ND	ND	ND	ND	ND	ND
Purnea	Liver	0.524±0.12	0.501±0.01	0.511±0.05	0.512±0.01	0.548±0.01	0.545±0.03	0.54±0.11	0.5443±0.004
	BAF	0.7178	0.7625	0.7514	0.7439±0.23	0.7506	0.8298	0.7941	0.7915±0.396
	Gills	0.472±0.02	0.451±0.02	0.45±0.03	0.4576±0.012	0.581±0.01	0.578±0.05	0.569±0.03	0.576±0.0062
	BAF	0.6465	0.6864	0.6617	0.6648±0.02	0.7958	0.8797	0.8367	0.8374±0.419
	Muscles	ND	ND	ND	ND	ND	ND	ND	ND
	BAF	ND	ND	ND	ND	ND	ND	ND	ND
Katihar	Liver	0.478±0.05	0.47±0.06	0.465±0.03	0.471±0.0065	0.562±0.04	0.521±0.03	0.52±0.01	0.534±0.0239
	BAF	0.605	0.6025	0.6568	0.6214±0.03	0.7113	0.6679	0.7303	0.7031±0.031
	Gills	0.46±0.021	0.392±0.03	0.402±0.04	0.418±0.0367	0.751±0.04	0.72±0.02	0.71±0.02	0.727±0.0213
	BAF	0.5822	0.5025	0.5646	0.5497±0.041	0.9506	0.923	0.9971	0.9569±0.037
	Muscles	ND	ND	ND	ND	ND	ND	ND	ND
	BAF	ND	ND	ND	ND	ND	ND	ND	ND

ND = Not detected

Table 8. Seasonal variation of Pb concentration (mg/kg dry wt) in different organs of *Catla catla* and *Mystus seenghala* in River Mahananda.

Location	Organ	*Catla catla* Summer (M±SD)	Rainy (M±SD)	Winter (M±SD)	Total (M±SD)	*Mystus seenghala* Summer (M±SD)	Rainy (M±SD)	Winter (M±SD)	Total (M±SD)
Kishanganj	Liver	14.2±1.2	13.1±2.2	12.7±2.31	13.33±0.776	14.78±3.32	15.4±2.12	15.1±5.2	15.09±0.310
	BAF	0.6612	0.6104	0.5523	0.6079±0.054	0.6362	0.7176	0.6579	0.6705±0.042
	Gills	6.4±0.45	6.1±1.34	5.7±0.47	6.066±0.351	9.3±2.38	8.7±1.61	8.6±1.23	8.866±0.378
	BAF	0.2755	0.2842	0.2483	0.2693±0.018	0.4003	0.4054	0.3747	0.3937±0.016
	Muscles	3.88±0.23	2.79±0.04	2.58±2.1	3.083±0.698	1.78±0.21	1.79±0.41	1.76±0.22	1.776±0.015
	BAF	0.167	0.13	0.1124	0.1364±0.02	0.0766	0.0834	0..0766	0.0788±0.003
Purnea	Liver	14.3±2.1	13.5±4.2	13.1±4.21	13.63±0.611	18.4±2.41	16.7±5.12	16.2±3.25	17.1±1.153
	BAF	0.5843	0.5955	0.5469	0.5755±0.02	0.7519	0.7366	0.6764	0.7216±0.04
	Gills	9.57±0.12	8.32±1.36	7.88±1.1	8.59±0.8767	1.25±0.32	11.7±0.45	11.81±0.27	12.0±0.4336
	BAF	0.591	0.367	0.302	0.42±0.1516	0.5108	0.5161	0.4931	0.5066±0.012
	Muscles	2.7±0.56	2.6±0.56	2.2±0.31	2.5±0.2645	3.7±0.33	3.6±0.51	3.1±1.1	3.466±0.321
	BAF	0.1103	0.1146	0.0918	0.1055±0.012	0.1512	0.1588	0.1294	0.1464±0.015
Katihar	Liver	30.5±5.61	30.1±7.1	28.2±4.27	29.2±1.229	32.51±7.13	31.4±4.34	32.2±5.41	32.03±0.572
	BAF	1.181	1.2668	1.155	1.201±0.058	1.2592	1.3215	1.3191	1.299±0.035
	Gills	16.5±3.81	15.3±2.4	15.4±2.36	15.73±0.665	24.3±2.23	24.6±4.21	24.4±3.01	24.43±0.152
	BAF	0.6392	0.6439	0.6308	0.638±0.006	0.9414	1.0353	0.7995	0.9254±0.11
	Muscles	8.5±1.31	8.2±0.37	8.01±2.41	8.236±0.247	7.6±0.56	7.1±0.392	7.2±0.51	7.3±0.264
	BAF	0.3293	0.3451	0.3277	0.334±0.009	0.2944	0.2988	0.2949	0.296±0.002

lowest BAF was recorded 0.109±0.0.0025 and of *M. seenghala* was 0.1127±0.009 at study point of Purnea and Kishanganj district, respectively.

Cadmium: The highest mean concentration of Cd in liver of *C. catla* and *M.seenghala* was 0.924±0.004 and 0.979±0.019 mg/kg, respectively at the same location of Kishanganj (upstream) and whereas lowest mean concentration 0.471±0.0065 and 0.534±0.0239 mg/kg was recorded at the same location of downstream of Katihar (Table 7). In gills maximum mean concentration in *C. catla* and *M. seenghala* was 0.4576±0.0124 and 0.870±0.0181 mg/kg at study point of Purnea and Kishanganj, respectively but minimum mean concentration was found 0.269±0.0359 and 0.576±0.0062 mg/kg at study point of Kishanganj and Purnia respectively (Table 7). Cd

Table 9. Heavy metals in fish's tissues (mg/kg dry wt) and Maximum Permissible Limits (MPL) International standard.

Metal	*C. catla*	*M. seenghala*	FAO (1983)	FAO/WHO (1989)	WHO (1995)
Cu	0.853± 0.051-14.5±0.755	1.12±0.079-19.93±1.069	30	30	30
Zn	12.13±0.351-63.9±1.708	11.87±0.378-71.93±3.028	30	40	100
Cd	0.269±0.036-0.924±0.004	0.534 ±0.024-0.979 ±0.02	0.05	0.5	1
Pb	2.5±0.264-29.2 ±1.2288	1.78±0.015- 32.03±0.572	0.5	0.5	2

was not detected in any concentration in the muscles of *C. catla* and *M. seenghala* at any location of river in Seemanchal zone. The maximum value of BAF for Cd in the liver of *C. catla* and *M. seenghala* was recorded 1.005±0.002 and 1.063±0.0211 at the same location of River (upstream), whereas minimum BAF value 0.6214±0.0306 and 0.7031±0.031 were found at same study point, downstream of River in Seemanchal zone. Like concentration of Cd in gills, maximum BAF value in galls of *C. catla* and *M. seenghala* was obtained 0.6648±0.0201 and 1.004±0.0383 at study point of Purnea and Kishanganj, respectively and minimum BAF value was obtained 0.2878±0.009 and 0.8374 ±0.419 at study point of Kishanganj and Purnia, respectively.

Lead: The highest mean concentration of Pb in liver, gills and muscles of *C. catla* was 29.2±1.229, 15.73±0.663 and 8.265±0.247 mg/kg respectively and of *M. seenghala* was 32.03±0.572, 24.43±0.152 and 7.3±0.264 mg/kg, respectively at the same location, downstream of River at Katihar (Table 8). The lowest mean concentration of Pb in the liver, gills and muscles of *C. catla* was 13.33±0.776, 6.066±0331 and 3.083±0.698 mg/kg and of *M. seenghala* was 15.09±0.310, 8.866±0.378 and1.776±0.0015 mg/kg respectively at the same location, upstream of river at Kishanganj (Table 8). The maximum mean value of BAF for Pb in liver of *C. catla* was 1.201±0.0581 at Katihar area and of *M. seenghala* was 1.299±0.035 at same location, whereas the minimum value of BAF for Pb in the liver of *C. catla* was 0.5755±0.02 at station Purnea and in *M. seenghala* was 0.6705±0.042 at Kishanganj district. In gills of *C. catla* and *M. seenghala*, the maximum mean value of BAF for Pb was 0.638±0.006 and 0.9257±0.11 at the same station of Katihar and the minimum value was 0.2693±0.018 and 0.3937±0.016 at same location of Kishanganj. In muscle of *C. catla* and *M. seenghala*, the highest value of BAF of Pb was 0.334±0.009, and 0.296±0.002 at same station of Katihar area, whilst the lowest BAF value was 0.1055±0.01 and 0.0788±0.003 at station Purnea and Kishanganj for the two types of fish's *C. catla* and *M. seenghala*, respectively.

Discussions

The results show that except Pb, the heavy metal load (Cu, Zn and Cd) in water was below than toxicity threshold level recommended by WHO (2008), whereas the concentration of Cu, Zn and Cd in sediment samples was higher and of Pb was lower than TRV recommended by USEPA (1999). The concentrations of Cu, Zn, Cd and Pb in the water system were found to be maximum during the rainy season, which may be due to extremely low alkalinity and pH of the aquatic phase (Battacharya et al., 2008). During the summer season, the concentration of Cu, Zn, Cd and Pb in water system attained their minimum value with high surface water temperature. The parameter like pH, alkalinity, TDS and turbidity value also reached their highest values during the summer season (Battacharya et al., 2008). The effect was also observed in the sediment phase with the highest heavy metal concentration in summer followed by winter and rainy season. The opposite trend of seasonal variation of heavy metals in water and sediment might be also due to as the decreased river flow in summer, the rate of sedimentation and consequently the concentration increase. On the other hand, in rainy season, increased river flow causes a dilution effect, and consequently, metal level in sediment decreases. Though at the one set of rainy season, the first flush effect may enhance the level, the dilution effect predominates as the season progresses. Similar observations were also recorded by Pandey et al. (2017). Similarly, higher levels of metal in winter than rainy season could be linked to decreased river flow during the winter season. Similar seasonal patterns have been reported in another research (Kumar et al., 2013). A high concentration of heavy metal in water and sediment at Katihar zone (downstream) may be due to urban release of sewage and industrial effluents together with agricultural runoff and atmospherically deposited substances also reach the river directly or indirectly through land surface runoff (Pandey et al., 2013; Pandey et al., 2017; Kumar et al., 2019). A high level of heavy metal in water and sediment in a downstream could be downward flow of water resuspension of deposited sediments under high flow rate of water tend to carry heavy metal in downstream. The elevated level of heavy metals, especially in the sediment can be a good indication of pollution and often can be attributed to anthropogenic influences, rather than a natural process, are also supported by work of Mustafa et al. (2007) and Karabassi et al. (2008). Higher concentrations of heavy metals in riverside sediments may pose an ecological risk to bottom-dwelling organisms (Decan et al., 2018).

The maximum mean concentration of Cu was recorded in liver (19.93±1.069 mg/kg), followed by gills (4.35±0.5408 mg/kg) and in muscle (2.313±0.309 mg/kg) and the level of Cu in the different tissue samples of the fishes were varied between 0.92±0.23-20.6±0.50 mg/kg in summer, 0.85±0.15-20.5±0.45 mg/kg in rainy and 0.82±0.31-18.7±0.38 mg/kg in winter, respectively. The mean concentration of Cu present in this study was exceeded the several folds than the literature (Ambedkar and Muniyan, 2012; Dhanakumar et al., 2014; Rajeshkumar and Li, 2018) and also exceeded the several folds than the permissible limit (3 mg/kg) recommended by WHO (2008), but lower the maximum permissible limit (MPL) recommended by FAO, FAO/WHO for human consumption. The highest levels of Cu in the different tissues of selected fish species may be due to domestic waste, agricultural and industrial wastes and also due to increased boating activities, recurrent usage of antifouling paint, oil dropping from boats, and commercial fishing in the study area. Several researchers have also observed the level of Cu in the liver and other fish tissues (Storelli et al., 2006; Frang et al., 2007; Uysal et al., 2009; Leung et al., 2014; Karunanidhi et al., 2017). Pyle et al. (2005) reported that in the liver, Cu concentration are usually regulated by homeostatic control below50 μm/g/drywt and can exceed this threshold only if the control mechanisms are overloaded. Cu is an essential element that serves as a cofactor in some enzymes system and necessary for the synthesis of haemoglobin (Sivaperumal et al., 2007), but any high intake of Cu can cause adverse health effect problems for most living organisms.

In the present study, Zn was observed the highest amount in both fishes' tissues in the order of magnitude as liver> gills>muscle and seasonal variation of Zn in the fish tissues were observed in the order of summer>winter≈rainy season. Similar trends were reported by some researches (Yehia and Sebaee, 2012; Maurya and Malik, 2016; Singh and Kumar, 2017). In these finding, Zn level was within the range of permissible limit (10-75 mg/kg) as recommended by WHO but lower than MPL, recommended by FAO, FAO/WHO for human consumption and approximately same as 13.08±0.30-78.15±2.04 and 58.44±3.67-26.67±1.37 mg/kg in liver, gills and muscle of different fishes as reported by Yehia and Sebaee (2012) and Maurya and Malik (2016), respectively. The sources of Zn in the study area may be geological rock weathering or human activities such as industrial and domestic wastes water discharges. Zn is an essential element as more than one hindered specific enzyme require for their catalytic function (Kayrak and Terkin, 2018). However, at higher levels, Zn produced adverse effects in fish by structural damage, which affects the improvement, growth, and survival of fish (Kori et al., 2008). Zn is a potential toxicant to fish (Vosylien et al., 2006), which causes ion regulation, disturbances, disruption of gill tissue and hypoxia (Murugan et al., 2008). In human beings, significant levels of Zn can cause prominent health problems, and high dose of Zn damage the pancreas and disturb the protein metabolism and cause arteriosclerosis (Afshan et al., 2014).

Among the studied metal, Cd was observed minimum amount in both types of fish tissues; it was also detected as lowest in water and sediment. The highest Cd concentration was found in liver followed by gills and not detected in muscle in both fishes. The same distribution pattern of Cd was reported by Jaric et al. (2011). The level of Cd was highest in *C. catla* and *M. Seenghala* in the summer followed by winter and rainy season. The level of Cd found in liver and gill of *C. catla* and *M. Seenghala* was exceeded than the MPL, recommended by FAO, FAO/WHO for human consumption, but were lower than 34.44±0.79, 1.6±0.068 mg/kg in liver and 30.89±.21, 1.35±0.061 mg/kg in gill of other fishes as reported by Ambedkar and Muniyan (2012) and Maurya and Malik (2016), respectively. In the study points, Cd enter into the fresh water by disposal of industrial, municipal and household waste and also agricultural runoff. Cd is the non-essential and most toxic heavy metal which is widely distributed in aquatic environment and earth's crust. The nutritive need of different tissues of fishes depends on their biochemical configuration of mineral contents, amino acids, protein and vitamins, etc. (Afshan et al., 2014).

The distribution of Pb in different tissues of *C. catla* and *M. seenghala* was in the order of liver>gill> muscle. The level of Pb found in liver, gill and muscle of *C. catla* and *M. seenghala* was approximately same as available in literature Yehia and Sebaee (2012) and Maurya and Malik (2016) and was exceeded several folds than the MPL, recommended by FAO, FAO/WHO for human consumption and also higher than 0.40±0.011-0.68±0.32 mg/kg as reported by Ambedkar and Muniyan (2012). Among the four metals, Pb was observed as the second major amount in both types of fishes in summer, followed by the rainy and winter season. Similar results have been reported in different fishes by Yehia and Sebaee (2012). Pb enter in water system through runoff, industrial and sewage waste streams. The high concentration of Pb in studied areas may be due to extended agriculture, textile poultry form, industrial and other activates near to study points. The sediments could be the primary sources of Pb contamination, and bottom-dwelling organisms may be directly affected by this deposited element (Rajeshkumar and Li, 2018). Pb is a nonessential element for a living organism, and also it possesses a severe adverse effect on a living organism. Fish and humans are primarily exposed to Pb by food ingestion and breathing. An increasing level of Pb in the water can cause generative damage in some aquatic life and cause blood and nervous changes in animals and fish. Pb accumulates in muscles, bones, blood, and fat. Newborns and young children are especially delicate to even low levels of Pb (Afshan et al., 2014).

The concentration of heavy metal in two type fishes was different, as distribution and bioaccumulation heavy metal have a direct link with the feeding habit of fish and fish niche in the water system (Shrivastava et al., 2001; Oguzie, 2003). Moreover, many factors such as age, sex, size, reproductive cycle, summing patterns, geographical location, as well as other factors like salinity, temperature and interacting agents can influence metal uptake (Mustafa et al., 2003; Yilmaz, 2005; Zhao et al., 2012). A higher level of metal in *M. seenghala* compared to *C. catla* is that *M. Seenghala* is a carnivorous and bottom feeder, while *C. catla* is omnivorous, herbivorous and surface, mid water feeder (Maurya and Malik, 2016; Adebayo, 2017; Rajeshkumar and Li, 2018). Seasonal variation of metal in fish may be due to varying seasonal growth rate, reproductive cycle, water salinity and temperature may be the cause of high metal accumulation of metal mainly during summer in comparison of winter and rainy season. A similar pattern was reported by Ebinger et al. (2015), Singh and Kumar (2017), Rajeshkumar and Li (2018) and Rajeshkumar et al. (2018). In this work, accumulation of metal in different tissues of *C. catla* and *M. seenghala* was liver>gill>muscle. Mormede and Devies (2001) have reported that the liver was the target organ, showing the detoxification and accumulation role of the liver. The muscle is generally considered to have weak accumulating potential (Erdogrul and Erbilir, 2007; Uysal et al., 2009). The liver is the preferred organ for metal accumulating, as could be deduced from the present study. A similar pattern has been observed in some other researches (Stprelli et al., 2006; Dural et al., 2007; Ploetz et al., 2007; Agah et al., 2009). The difference in the level of accumulation of metal in different organs of a fish can be attributed to the differences in the physiological role of each organ (Rajeshkumar and Li, 2018; Rajeshkumar et al., 2018). Regular ability, behaviour and feeding habits are other factors that affect the bioaccumulation differences in the different organs. The liver of the *C. catla* and *M. seenghala* obtained the highest level of all studied metals, while muscles appeared to be least. This finding is an agreement with those of other studies regarding fish tissue (Kir et al., 2006; Karaded and Unlu, 2007; Karaded-Akin, 2009; Mohamadi et al., 2011; Ebrahimpour et al., 2011; Liu et al., 2012; Rajeshkumar and Li, 2018). The liver is a vital organ in vertebrates and has a significant role in metabolism (Liu et al., 2012). The high accumulation of metals in the liver is due to the greater tendency of the element to react with the oxygen carboxylate, amino group, nitrogen, sulphur of mercapto group in the metallothionein protein, whose level is highest in the liver as supported by Al-Yousuf et al. (2000). Gill is an essential site for the entry of heavy metals (Vohodhani and Narayanan, 2008; Rajeshkumar and Li, 2018). In the present work, higher metal concentration in the gill is due to element complexation with the mucus, which is difficult to be obliterated from the tissue before analysis (Khalil and Faragallah, 2008). Thus, level of metals in the gill reflects the level of the metals in the water system where the fish lives, whereas the concentration in liver and kidney storage of metals (Vohodhani and Narayanan, 2009). Thus, the gills in fish are more often recommended as environment indicator organs of water pollution than any other fish organ. Level of metals was lower in muscle compared to liver and gill because at being inactive tissue in accumulating heavy metals (Karaded et al., 2004; Stprelli et al., 2006; Dural et al., 2007; Ploetz et al., 2007; Agah et al., 2009).

Health risk assessments for fish consumption: To assess the public health risk of Mahananda river fish consumption, metal concentrations in liver, gills, and muscles of the fishes in this study were compared with the Maximum Permissible Limits (MPL) for human consumption as set by various organizations. The concentrations of metals in the different tissues of *C. catla* and *M. seenghala* collected from River Mahananda in Seemanchal zone was found to be below the MPL for human use recommended by FAO (1993), FAO/WHO (1989) and WHO (1995) with few exceptions. The essential metals Zn and Cu were clearly below the MPL, for human consumption, whereas the nonessential metal Cd was lower and Pb was higher than MPL. Both fishes were contaminated by Pb and a threat to public health. This could be likely due to anthropogenic sources.

Conclusions

Based on experimental findings, it was concluded that metal index value (MI) for Cd and Pb in water was more significant than one; therefore, river water cannot be used for drinking purposes. In the sediment concentration of Cu, Zn and Cd exceeded the TRV suggest that adverse effects on sediment-dwelling organisms, and different fish species as well as the impact on human health, who consumed fish from the study area. The results also showed that metal accumulation in the fish varied between organs and species depending on species-specific factors like feeding behaviour, swimming patterns, and a genetic tendency or other factors like geographical distribution, age, and ambient concentration of metals in the water system. Metals accumulations were higher in the liver, followed by gills and muscles. The high level of Cu, Zn, Cd and Pb was observed in liver and gill and even though fish liver and gill are rarely consumed. The low-level of heavy metal in muscle is particularly important because muscle is the main part of the fish and directly influences human health. However, Pb in both types of fishes during all three seasons exceeded MPL, hence unsafe for consumption and therefore they pose a threat to public health.

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