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QUANTIFICATION OF HEAVY METAL ACCUMULATION IN WATER AND EDIBLE FISH TISSUE SAMPLES COLLECTED FROM THE RIVER TAWI, JAMMU, INDIA

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Abstract

The present study estimated the concentration (in ppm) of heavy metals of Zn, Fe, Cu and Pb in water samples and edible tissue of *Labeo boga*; both collected from the non polluted (Station I) and polluted (Station II) locations of river Tawi, Jammu, India. The mean concentration of heavy metals (Zn, Fe, Cu, Pb) at Station I were 0.048±0.008 (ppm); 0.016±0.001 (ppm); 0.157±0.002 (ppm) and 0.0001±0.0001 respectively; while at Station II, these values were 0.133±0.001 (ppm); 0.022±0.002 (ppm); 0.206±0.002 (ppm) and 0.002±0.001 (ppm) respectively; the statistical difference between the stations were significantly higher ($p<0.05$). The order of heavy metal load obtained in water samples at both the stations was found to be Fe>Zn>Cu>Pb. Also, the mean bioaccumulation of heavy metals *viz*. Zn, Fe, Cu and Pb in the edible tissue of fish at Station I was found to be 0.374±0.011 (ppm), 0.105±0.02 (ppm); 0.094±0.04 (ppm) and0.001±0.0001 (ppm) respectively; on the other hand, mean bioaccumulation was 0.539±0.013 (ppm); 0.156±0.04 (ppm); 0.121±0.023 (ppm) and 0.0013±0.0001 (ppm) respectively at Station II. Even though bioaccumulation of the heavy metals in the experimental sites did not exceed the acceptable limits recommended by the agencies like FAO and WHO, the present results showed an increasing trend of the accumulation, which definitely poses a serious threat to the survival of aquatic organisms in the study area.

Key words: Heavy metals, *Labeo boga*, Edible tissue, Bioaccumulation; Pollution

Introduction

River water forms the lifeline of all living organisms. Heavy metal pollution has become a global problem due to their environmental toxicity, persistence, bioaccumulation and biomagnification in food chain (Kumar and Seema 2016, Kumar et al. 2017, Xu et al. 2018, Ali et al. 2019). High level of heavy metals in fresh water bodies makes them unsuitable for human consumption, livestock watering and irrigation (Edokpayi et al. 2017). Heavy metals are distributed in the environment through natural processes *viz*. volcanic eruptions, spring water, erosion and bacterial activity; also many anthropogenic activities such as industrial effluents, sewage sludge, domestic waste, agricultural run off etc. are the prime sources of heavy metal contamination of water bodies (Zhang et al. 2014, Banaee et al. 2015, Singh et al. 2016, Farsani et al. 2019). Heavy metals can be easily converted into more toxic organic forms by microbes, some of which can be harmful to humans and aquatic organisms (Hu et al. 2013, Xu et al. 2016, Zhao et al. 2016). The heavy metal pollution may possess serious health concerns for human beings *viz*. renal failure, cardiovascular diseases, liver damage (IARC 2012, Rahman et al. 2012, Ying et al. 2018, Kim et al. 2019).

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In recent years, consumption of fish has increased rapidly and hence awareness of its nutritional and therapeutic benefits (Bawuro et al. 2018, Kumar et al. 2020). Fish is a complete food source and highly valuable in the diet because they provide good quantity of protein and lipid of higher biological value (Gandotra et al. 2017, Rajeshkumar et al. 2018, Sumia et al. 2020). The concentration of heavy metals in fish tissue reflects the past or present exposure of fish to these contaminants (Henry et al. 2004). Edible fish present in the aquatic bodies form an important group of organisms as heavy metal accumulated in fish tissue could act as potential carrier of metal ions along the food chain. At the end, directly or indirectly, the metal ions in the aquatic medium reach to the man (Jitesh and Radhakrishnan 2017). Fish is widely used to biologically monitor the degree of metal pollution in aquatic ecosystems (Brumbaugh et al. 2005, Al-Sayegh et al. 2012, Mahurpawar 2015). As heavy metals are known for their potential toxicity and the detrimental effects on animal and human health, thus there is a growing concerns that bioaccumulation of heavy metals in fish tissue may represent a health risk (Burger and Gochfeld 2009, Ling et al. 2009, Olusola and Festus 2015).

Heavy metals like iron (Fe), zinc (Zn), copper (Cu) etc are included in the group of essential trace elements required for maintaining the cellular function and are integral components of numerous metal containing enzymes (Rajkowska and Protasowicki 2013, Jia et al. 2017). These trace metals can be taken up by the fish through the food chain and from the water; and ultimately end up in the fish, where they accumulate in various organs and tissues.

The river Tawi is an important lifeline for Jammu City and its outskirts, which serves as a source of drinking water as well as a source of some local fishes to the residents of Jammu region but the river is increasingly getting polluted due to discharge of untreated sewage and dumping of municipal solid wastes, agricultural and industrial wastes and their run offs. The pollution of Tawi with heavy metals is increasing day by day which is a matter of great concern. Thus the present study was designed to quantify the level of heavy metals in the water and edible tissue samples of the fish *Labeo boga,* both collected from the river under study. Also such studies help in predicting pollutants transfer probability and possible health consequences to humans.

Material and Methods

Study area

Water and fish samples were collected from the two sections of the River Tawi *viz*., upstream section: Nagrota - latitude 32º 46’, longitude 74º 54’ (Station I) with non-polluted, clear and fast flowing water and downstream section: Gujjarnagar- latitude 32º 43’, longitude 74º 52’ (Station II) with slow-moving and polluted water due to sewage discharge, cremation wastes, religious wastes, ill-treated drainage, agricultural wastes.

Assessment of heavy metals

For heavy metal assessment, water samples were collected in polyethylene bottles (washed with HNO_3 previously). Also, samples (20±1.5 cm; 140±1.0 cm) of fresh water fish *Labeo boga* Hamilton 1882 (Cypriniformes: Cyprinidae) were collected during autumn through monsoon seasons and were dissected to obtain muscle tissues. The separated tissues were dried at 120° C in the petri dishes until a constant weight was obtained. The edible tissue (1 mg) was then placed in digestion flask and ultrapure nitric acid (8 ml) was added. The digestion flask was then heated at higher temperature in microwave digester until all the material was dissolved. The digest was then diluted with double distilled water and the presence of heavy metals namely, Zn, Fe, Cu and Pb in the samples was quantified using an atomic absorption spectrophotometer (AAS-aa 7000). Element specific cathode lamps and flame absorption mode was used to approximate the metal concentration in parts per million (ppm) both in water and tissue samples. Blank and standard solutions for the devices were used as controls.

Statistical analysis

Mean ± SD values were estimated from the raw data. Moreover, Karl Pearson's product-moment co-efficient of correlation values (r) were calculated using SPSS software to find linear relationship, if any, between the quantitative variables W (heavy metal concentrations in water) and M (heavy metal concentrations in fish muscles) at both selected Stations I and II.

Results

Results for the heavy metal concentration in water samples (Table 1) revealed that maximum mean concentration of heavy metals was observed during summer season, while minimum values were observed during winter season. The order of accumulation of heavy metals in water samples was observed to be Fe>Zn>Cu>Pb. Thus results indicated that Fe was maximally and Pb was least accumulated in the river. Also, results inferred higher accumulation of heavy metals in water at downstream section (Station I) as compared to upstream section (Station II).

Also in the present study, mean bioaccumulation (Fig. 1) of heavy metals (Zn, Fe, Cu and Pb) in the muscle (edible) tissue of fish at Station I was found to be 0.374±0.01 (ppm); 0.105±0.02 (ppm); 0.094±0.04 (ppm) and 0.001±0.0001 (ppm) respectively. Similarly at Station II (Fig. 2), mean bioaccumulation of Zn, Fe, Cu and Pb in edible tissue was 0.539±0.02 (ppm); 0.156±0.04 (ppm); 0.121±0.023 (ppm) and 0.002±0.0001 (ppm) respectively. The order of accumulation of heavy metals in fish edible tissue was observed as Zn>Fe>Cu>Pb. Thus, zinc (Zn) was observed to be highest in fish edible tissue as compared to other heavy metals at both the stations. Similar observation has been reported by Maurya and Malik (2016), Singh and Kumar (2017) and Kumar et al. (2020). Seasonal bioaccumulation variation trend in fish edible tissue was observed to follow the order as summer>monsoon>autumn>winter. Also, increased values of heavy metal bioaccumulation were observed in edible tissue of fish at downstream section (Station II) as compared to upstream section (Station II).

Table 1. Concentration of heavy metals (Zn, Cu, Fe and Pb) in both non polluted station (Station I) and polluted station (Station II) of river Tawi

Sampling seasons	Heavy metal concentrations in ppm							
	Zn		Fe		Cu		Pb	
	Sta. I	Sta. II	Sta. I	Sta. II	Sta. I	Sta. II	Sta. I	Sta. II
Autumn	0.058 ±0.013	0.079 ±0.016	0.148 ±0.024	0.216 ±0.026	0.017 ±0.002	0.026 ±0.006	0.001 ±0.0001	0.003 ±0.0007
Winter	0.011 ±0.008	0.023 ±0.015	0.049 ±0.020	0.084 ±0.008	0.016 ±0.004	0.020 ±0.005	BDL of 0.0001	0.002 ±0.0006
Summer	0.081 ±0.018	0.242 ±0.084	0.265 ±0.132	0.327 ±0.106	0.024 ±0.004	0.031 ±0.006	0.001 ±0.0007	0.002 ±0.0013
Monsoon	0.042 ±0.019	0.179 ±0.142	0.173 ±0.192	0.145 ±0.236	0.007 ±0.006	0.013 ±0.007	0.001 ±0.0011	0.002 ±0.0018

Values expressed as Mean ± SD (n = 3), Sta. = Station.

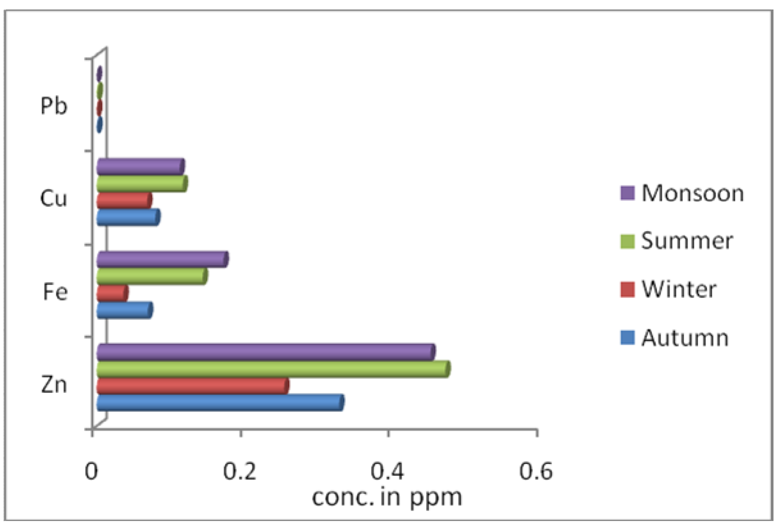

Fig. 1: Mean bioaccumulation of heavy metals (Zn, Fe, Cu and Pb) in edible tissue of *L. boga* at Station I.

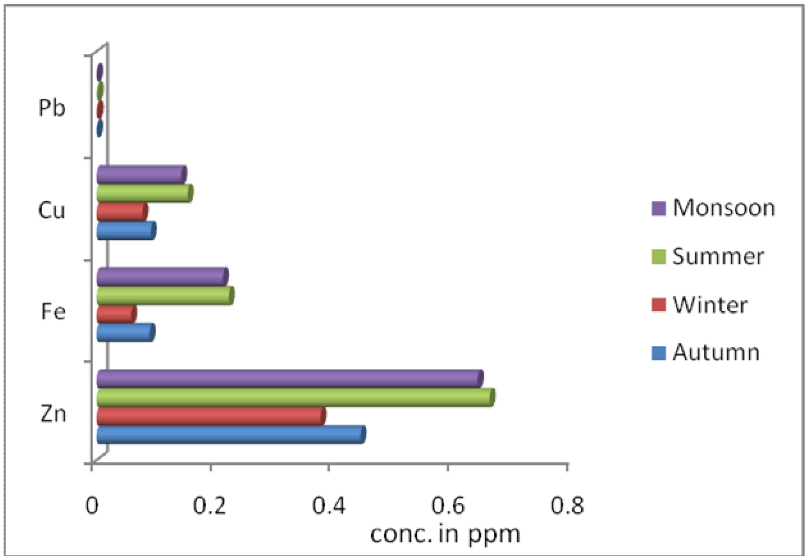

Fig. 2: Mean bioaccumulation of heavy metals (Zn, Fe, Cu and Pb) in edible tissue of *L. boga* at Station II.

Table 3. Correlation matrix for heavy metals in water samples (W) and fish edible tissue (M) at Station I

	Zn W	Fe W	Cu W	Pb W	Zn M	Fe M	Cu M	Pb M
Zn W	1	0.940*	0.528	0.582	0.741	0.548	0.674	0.820
Fe W		1	0.373	0.819	0.914	0.770	0.880	0.965*
Cu W			1	-0.095	0.005	-0.266	-0.015	0.272
Pb W				1	0.973*	0.973*	0.992**	0.923*
Zn M					1	0.961*	0.992**	0.960*
Fe M						1	0.965*	0.854
Cu M							1	0.956*
Pb M								1

Co-efficient of correlation (r) values; *= p <0.05 (2-tailed); ** = p <0.01 (2-tailed).

Table 4. Correlation matrix for heavy metals in water samples (W) and fish edible tissue (M) at Station II

	Zn W	Fe W	Cu W	Pb W	Zn M	Fe M	Cu M	Pb M
Zn W	1	0.753	0.265	0.304	0.949*	0.912	0.927*	0.260
Fe W		1	0.801	0.714	0.528	0.436	0.467	0.331
Cu W			1	0.572	-0.048	-0.151	-0.114	0.543
Pb W				1	0.156	0.082	0.095	-0.337
Zn M					1	0.994**	0.997**	0.066
Fe M						1	0.999**	0.023
Cu M							1	0.054
Pb M								1

Co-efficient of correlation (r) values; *= $p < 0.05$ (2-tailed); ** = $p < 0.01$ (2-tailed).

Pearson correlation matrix shown in Table 3 and 4 depicts relationship between heavy metals in water and heavy metals in fish edible tissue. At upstream section (Station I), iron (Fe) in water showed positive correlation with lead (Pb) in muscle ($r = 0.965$; $p < 0.01$); zinc (Zn) in muscle showed strong positive correlation with copper (Cu) in muscle ($r = 0.992$; $p < 0.05$). Also at downstream section (Station II), zinc (Zn) in water showed positive correlation with copper (Cu) in muscle ($r = 0.927$; $p < 0.01$); zinc (Zn) in muscle showed strong positive correlation with iron (Fe) in muscle ($r = 0.994$; $p < 0.05$) and with copper in muscle ($r = 0.997$; $p < 0.05$).

Discussion

In the present study, the highest concentration of heavy metals in water samples observed in summer season followed by post monsoon. Such increase in conc. of heavy metals during the summer season could be due to increased leaching movement of heavy metals from the sediments to the surface water under the effect of high temperature; also due to fluctuations in the amount of sewage and domestic discharge into the water body. Similar types of results reported by Ellahi and Hossain (2011), Zhao et al. (2016), Jitesh and Radhakrishnan (2017) and Bhuyan and Bakar (2017). Also, the elevated level of heavy metals in water at downstream section could be due to increased downward flow of water (Karabassi et al. 2008); also due to increased waste discharge from various sources along the stretch of Station II. Similar trend of variation in heavy metal concentration at downstream and upstream stations of river has been reported by Andotra (2014) and Kumar et al. (2020). Iron and zinc were found to be present in high levels in water samples (in present study) as compared to the copper and lead. Zinc is discharged in rivers in the form of effluents from electroplating industries, sewage discharge, immersion of painted idols. Zinc toxicity causes vomiting, diahrrhoea, liver and kidney damage (Boxall et al. 2000, Gautam et al. 2015). Iron comes into water from natural geological sources, industrial waste, domestic discharge etc. Excess of Iron may cause coagulation in blood vessels, drowsiness, hypertension. Lead is present in paints, storage batteries, glass etc. Higher levels of lead leads to cognitive impairment in children, development delays (Kaur 2012, Malik et al. 2014).

Copper sources into water body may include copper smelting, ore processing activities, windblown dust etc and it usually causes headache, nausea, vomiting, diarrhea, kidney damage etc (Gautam et al. 2015). Similar, studies on the determination of heavy metal load in river water so as to assess water quality has been conducted by several researchers (Gulfraz et al. 2001, Paliwal et al. 2007, Malik et al. 2014, Mohamed et al. 2014, Ahmed et al. 2015, Singh et al. 2019, Mishra et al. 2020).

Fish serves as standard organism to determine the bioaccumulation and impact of heavy metal pollution. The bioaccumulation of heavy metals in different fish tissues has been estimated by several investigators (Mohamed 2000, Subartha and Karuppasamy 2008, Javed and Usmani 2011, Malik et al. 2014, Shaikh 2014, Noor and Zutshi 2016, Jia et al. 2017, Mubarakh and Ali 2020). At station II, increased bioaccumulation of heavy metals in edible tissue could be due to higher level of heavy metals in surrounding water as compared to Station I and hence resulted into more absorption/ accumulation in fish body. It is mostly assumed that metals are taken up in ionic form and are influenced by various environmental factors such as pH and temperature (Ibrahim and Omar 2013). The metal contamination in river water can be absorbed into algae and aquatic plants via roots resulting in their accumulation mainly in stem and leaves and finally metals can be accumulated in herbivore fish including *Labeo boga* after being fed (Soulivongsa et al. 2020). Also, during the present study, increased bioaccumulation of heavy metals in fish tissue has been reported during summer season. Increase in temperature also increases the toxicity as due to depletion of dissolved oxygen, energy demand increases causing rise in the respiration rate in organism, which leads to rapid assimilation of wastes (Salem et al. 2014). Also, increased water temperature in summer increases the metabolic rate and feeding activity of fish, resulting in an increase in metal uptake and accumulation in tissues, inturn leading to higher values for the heavy metal (Obasohan 2008). Such trend of seasonal variation in tissue bioaccumulation of heavy metals has been supported by findings of Khaled (2004), Bahnasawy et al. (2009) Bahnasawy and Khidr (2011) and Ibrahim and Omar (2013).

To assess the public health risk of consuming fish from river Tawi, metal concentrations in water samples and fish edible tissue were compared with Maximum Permissible Limits (MPL) for human consumption as set by various organizations (USEPA 1976, FAO 1983, WHO 2008/2011). Results suggested the heavy metal concentrations in water samples and edible tissue of fish were found to be satisfactorily lower than standard limits, except for iron (Fe) concentration in water samples which was found to be high as per standards proposed by USEPA 1976 (0.3 ppm for Fe).

Conclusion

The main motive behind conducting the present study was to quantify the toxicity levels of some common heavy metals in water and fish tissues and hence to determine the suitability of water and fishes for human consumption. The results revealed that consuming fishes from the River Tawi may not be harmful to consumers because the observed concentrations of the heavy metals were much below the permissible limits recommended by FAO/WHO. However, trace metallic loads in the water bodies should be continuously monitored as their rising levels might cause potential damage to the aquatic organisms and human health in the near future.

Conflict of interest

The authors hereby declare no conflict of interest regarding the publication of this article.

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