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Research Article

A study on chromium accumulation in *Labeo rohita* in the river Yamuna ecosystem in Mathura-Agra region in Uttar Pradesh, India

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Abstract
The study investigated chromium (Cr) in the Yamuna river at Mathura - Agra region in Uttar Pradesh, India. The water and fish samples were collected quarterly from the sites, i.e. Vrindavan (Vihar ghat) and Agra (Renuka ghat) from October 2018 to January 2020.The average Cr concentration in water at the Vrindavan site was observed to be maximum (2.27 mg/l) than the Agra site (1.93 mg/l) in the month of April 2019 compared to its BIS /WHO standards (0.05 ppm). Among the samples of fish organs like gill, liver, muscle and kidney, maximum Cr concentration was found in the samples of gills from Vrindavan (Vihar ghat) site (9.63µg/g) and from Agra (Renuka ghat) site (7.78 µg/g) being above the standards values (1 µg/g by European union commission; 0.15 µg/g by Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO). The Cr concentration in the samples was in the order of gill > liver > muscle > kidney. The lower Bio-concentration factor (BCF) and target hazard quotients (THQ) in the muscles indicated fish to be safe for consumption. Heavy metal pollution index (HPI) and Pearson's correlation coefficient analysis indicated more HPI (2676.67) and a positive correlation between all the samples. The contamination degree (C_d) values were above the critical level at both the sampling sites-Vrindavan (38) and Agra (28).The higher pollution indices (HPI, HEI, C_d values) indicated higher degree of contamination in water samples. Hence strategies need to be formulated to check the rising concentration of heavy metals and ensure the safety of the people in the nearby areas.

Keywords: Bio-concentration factor, Chromium, Fish organs, Heavy metal pollution index, Metal quality index, Water

INTRODUCTION

Food is the ultimate source of energy and as the human population is increasing day by day, so is the demand for food. In South Asian countries, every fourth of children are born with low body weight (Popkin *et al.*, 2012). Land for agriculture is limited and therefore poses a great problem to food security, so dependence on alternatere sources of food has also increased. Fish is a rich source of proteins, omega 3 long-chain fatty acids and many other important vitamins like A and D. Fish and other seafood are consumed by the human in almost every part of the world. But due to various anthropogenic activities, the freshwater lakes, seas and other water bodies have been contaminated by various toxicants and heavy metals like chromium (Cr) , lead (Pb), mercury (Hg), etc. affecting the population of aquatic animals to a large extent (Bakan *et al.*, 2010). These toxicants follow various paths and get accumulated into the tissues and cellular levels of organisms, maybe, because of the complex levels of hierarchy (Strungaru *et al.*, 2018).
The presence of heavy metals for a long duration leads to its bioaccumulation and keeps on magnifying in quantities as it moves further in the food chain. Some heavy metals are essential to the body for physiological

and biochemical functioning, such as iron (Fe), cobalt (Co), and manganese (Mn), whereas metals like cadmium (Cd), nickel (Ni), Arsenic(As) are toxic (Yadav *et al*., 2017, Maurya *et al*., 2019, Renieri *et al*., 2019). Aquatic species, primarily fishes, are good water quality indicators (Łuczyńska *et al*., 2018). But due to a higher quantity of heavy metals in water, people feeding on fish can directly get some concentrations of these heavy metals. These metal toxicants have been a major threat to human health (Ogbomida *et al*., 2018). Exposure to these heavy metals for a longer period can lead to various disorders in the human body related to the brain, kidney, liver, lungs, etc. and sometimes may lead to carcinogenic effects (Jaishankar *et al*., 2014 and Briffa *et al*., 2020).

Industrial effluents and wastes discharged directly into water bodies usually alters the physical and chemical properties of water, and increasing concentration in relation to the kind of effluent being disposed (Blinova *et al*., 2012). Cr is present in effluents of industries like electroplating, tannery, and dye which is discharged into water bodies and has become a grave concern because hexavalent chromium is highly fatal to organisms as for its capacity to generate reactive species of oxygen inside living cells, enters the food chain and subsequently reaches into human in a biomagnified form and hence can cause many fatal diseases to humans and other organisms once it enters the food chain (Mitra *et al*., 2017).

Cr being one of the most common pollutants does not occur naturally in metallic form, rather present in divalent Cr (II), trivalent Cr (III) and hexavalent Cr (VI), oxidation states, of which Cr (III) and Cr (VI) being the stable forms. Hexavalent chromium is a toxic industrial pollutant and is a defined carcinogen leading to mutagenic and other congenital and physical abnormalities (Velma *et al*., 2009). The effects of Chromium (VI) interaction with the environment are due to its persevering persistence and capacity to induce a varied number of adverse effects in biological and ecological systems, including fish and aquatic life (Velma *et al*., 2009 and Ali *et al*., 2019).

L. rohita is one of the most important fish used for aquaculture in the South Asian region as it contains a high protein value, including Omega 3 fatty acids and vitamin A, B and C (Mensoor and Said, 2018). In India, it is extensively consumed as food in different states like Tripura, Nagaland, Odisha, West Bengal, Assam, Andhra Pradesh and parts of Uttar Pradesh.

Mathura is located on the banks of the river Yamuna and is popular as one of industrialized towns in Uttar Pradesh, India. Many industries, including food and beverage, dyeing, and oil refineries, add pollutants to the river, affecting its water quality. This study was carried out to determine the contamination level of Cr in the water and different organs of *L. rohita,*a freshwater fish from the Cyprinidae family.

MATERIALS AND METHODS

Study area

Yamuna river, the largest tributary of river Ganga, originates from Yamunotri glaciers of the lower Himalayan region (6320m a.s.l). The river passes through various states, including Uttarakhand, Himachal Pradesh., Haryana, Rajasthan, Delhi and Uttar Pradesh. The quality of water becomes highly polluted as it flows through Delhi, followed by the cities like Mathura and Agra. The samples of water for Cr analysis were collected from two sites- Vrindavan (Vihar Ghat) 27°35'04.7" N 77˚41'28.8"E and from Agra (Renuka Ghat) 27º15'05.4"N 77˚52'31.2"E quarterly in the year October 2018 to January 2020 (Fig.1).

Collection of water and fish samples

The water samples were collected from mid-stream, at a depth of 10-15 cm from the river's surface. The samples were collected in sterilized screw-capped polyethylene bottles following the standard method of Moyo and Rapatsa (2019) and transported to Ganeshi Lal Agarawal (GLA) University Mathura. The matured fish samples of *L. rohita,* the most common edible fish, were collected and that of the water were collected from the two sampling sites - Vrindavan (Vihar ghat) and Agra (Renuka ghat) as per the guidelines of the Committee for the purpose of control and supervision of experiments on animals (CPCSEA). The fishes were of the average length and weight 35.88±2.5 cm; 626.66±72.2 gms and; 34.21±2.0 cm and 674.16±68.5 gms respectively. All the samples were transported to the laboratory, GLA University, Mathura, in a Styrofoam box preserved with ice. The fish samples were washed with deionised water and freshly dissected for the organs of gill, liver, muscle and kidney for further processing.

Atomic absorption spectrophotometric (AAS) analysis of water samples and fish samples:

1 lt of water sample collected from each site was taken in a conical flask and 3 ml of 1N HNO_3 was added for digestion, followed by mixing and filtration with Whatman filter paper (No.42). In a conical flask 100 ml of filtered water sample was taken, and15 ml of diacid solution (HNO_3/$HClO_4$, 9:4) was added (USEPA, 1991). The conical flask was heated until the solution was fully evaporated, then the flask was cooled at room temperature. The powdery deposition was noticed on complete evaporation, 100 ml of triple distilled water was introduced in the powdery deposit to each conical flask to completely dissolve it before the AAS analysis (Showqi *et al*., 2018).

The fish organ samples such as liver, kidney, gills,and

Fig. 1. *Showing sampling stations of the study sites at river Yamuna of Mathura -Agra region: (A) Vrindavan (Vihar ghat), (B) Agra (Renuka ghat).*

muscles were washed with 0.9 % saline water. The samples were taken in a clean, dry test tube and 5 ml HNO_3 followed by 5 ml H_2SO_4 was added. After 10 min of mixing, 1 ml H_2O_2 was added to it and left overnight. Then it was kept in the oven at 105˚C for 2 h for digestion. The samples were cooled and filtered with the help of Whatman filter paper (No.42). After filtration, the volume was made to 25 ml with deionised water and stored in the sterile container at 4˚C (Mohammed *et al*., 2017).

Instrumental analysis

The Cr analysis of all the samples was performed at The Division of Soil Science and Agricultural Chemistry, Central Soil, and Plant Analysis Laboratory, ICAR-Indian Agricultural Research Institute, New Delhi, using Z-Express 8000 model of AAS.

Pollution index analysis

To assess the Heavy Metal Pollution Index (HPI), the river's water quality was evaluated by taking the weighted arithmetic average of the concentrations of various samples. The HPI value of 100 is considered fundamental (Mohan *et al.,*1996). It was computed with the help of Eq. 1

$$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i} \quad \text{.....Eq. (1)}$$

where, Wi stands for the reciprocal value of Si, Si is the permissible limit for drinking water by Bureau of Indian Standards (2012), Qi refers to sub-indexing of i^{th} parameter and calculated by Eq. (2) and number of parameters are represented by n.

$$Q_i = \sum_{i=1}^{n} \frac{M_i}{S_i} \times 100 \quad \text{.....Eq. (2)}$$

Where Mi is the observed heavy metal value Si means the parameter of ith in PPM (µg / L) as standard. An increased concentration of metal above their permissible limit shows the worst quality of samples. MQI value >1 is a threshold of warning (Bakan *et al.,* 2010). The MQI is calculated by Eq. (3) (Tamasi and Cini, 2004).

$$MQI = \sum_{i=1}^{n} \frac{M_i}{S_i} \quad \text{.....Eq. (3)}$$

The overall results from the above equations were analyzed statistically by using SPSS 2.0 statistical software package to determine the average, standard deviation, and Pearson's correlation coefficient with the level of significance $p < 0.05$. The data were carried out in triplicate form and it's mean was taken as results.

Bio- accumulation factor (BAF)

It is defined as the ratio of the concentration of chromium in tissues of fish with respect to water and is calculated by Eq. (4) recommended by (Lau *et al*.,1998; Javed and Usmani, 2013)

$$BAF = \frac{\text{Cr Concentration in fish tissues}}{\text{Cr Concentration in water}}$$ …………Eq. (4)

Quantitative risk assessment of human health

Generally, humans eat the muscles of edible fishes. Therefore, an estimated daily intake (EDI) of Cr and target hazard quotients (THQ) is used to assess human health risk. we have used the fish muscles only for this analysis.

Estimated daily intake (EDI) of Cr

The calculation of estimated daily intake of Cr is possible by using the Eq. (5).

$$EDI = \frac{C \times FIR}{BW}$$ …………………………..Eq. (5)

Where C is the mean Chromium concentration in fish muscle tissues (μg / g). Conversion factor 4.8 is taken for conversion from dry weight to wet weight. FIR (Food intake Rate) is the daily intake of freshwater fish g^{-1} (grams per day per capita). The average FIR was person^{-1}day^{-1} India Nutrition security freshwater fish. BW is the mean body weight for adults, i.e., 70 kg.

Target hazard quotient (THQ)

THQ is the non-carcinogenic level of risk estimated due to exposure to heavy metals. It is calculated using Eq (6).

$$THQ = \frac{Efq \times ED \times FIR \times C \times 10^{-3}}{RfD \times BW \times AT}$$ …………………Eq. (6)

where EFQ (Exposure frequency) is 365 days per year, ED is the Exposure Duration i.e. 70 years (as set for this study), FIR and C are already defined earlier, RfD is the Dosage that evaluates the health risk of fish consumption (considered 0.003 μg/kg−1day−1 by the United States Environmental Protection Agency), and AT is the time for non-carcinogenic average exposure (365 days × No. of exposure years).

Heavy metal evaluation index (HEI)

In metal assessment, if there is a higher concentration value from its standard limits, it indicates the samples' bad quality. MI value > 1 is the threshold of warning. Metal Index is calculated by the following formula:

$$HEI = \sum i = \quad 1 - n\left(\frac{Ci}{MACi}\right)$$ …………… Eq.7

Where Ci represents observed concentration of metal and MAC is showing maximum allowable limit (permissible limit).

Contamination degree (C_d)

Contamination degree provides overall degree of contamination in the selected sampling sites (Bello *et al*.,2015).

$$C_d = \sum_{i=1}^{n} CF$$ -----------------Eq.8

Where Cfi =(Coi/Cni)-1, here Cfi is contamination factor,Coi is representing observed value and Cni is the normative value which is same as MAC value.

RESULTS AND DISCUSSION

The Cr concentrations of the water samples and the fish organs samples of *L. Rohita* collected from the study sites of Vrindavan (Vihar ghat) and Agra (Renuka ghat) during October 2018 to January 2020 are given in Table 1. The concentration of Cr in water varied between 0.6 to 1.93 mg/l, and was above the permissible limits of World Health Organization (2011) and Bureau of Indian Standards (2012) for drinking water (0.05 ppm); and FEPA and WHO (0.15 μg/g) for fish. The Cr concentration in fish tissue ranged between 9.63 to 1.25 μg/g, and was significantly above the permissible limits proposed by FEPA, and WHO (0.15 μg/g) for fish tissues. Maurya *et al*., (2019) has reported that the values of Cr accumulation in all the fish tissue samples were above the permissible limits proposed by EU (1μg /g) in the tissues of common edible fish species *C. mrigala*, *C.catla*, *L.rohita*, *C. latius*, *C.garua*, and *M. tengara*.

The maximum concentration of Cr in the water samples was in the month of April 2019, in Mathura (1.9 mg/l), followed by Agra (1.4 mg/l). In contrast, minimum concentration was observed in October of 2018 in Mathura (0.8 mg/l) and in Agra (0.6 mg/l). The more concentration of metals during summer was also reported by Jain and Sharma (2001) in Uttar Pradesh (India) from the water samples of river Hindon and by Malik *et al*. (2010) from water and tissues of *L. rohita* and *C. idella* in Upper Lake of Bhopal.

The Cr concentration was observed to be higher in all the samples of fish tissues like gills,liver,muscles and kidney (Table1). The maximum Cr concentration was found in the month of April 2019 (summer) in the gills from Vrindavan (Vihar ghat) site (9.63 μg/g) when compared to the Agra (Renuka ghat) site having 7.78 μg/g. The higher Cr accumulation in gills was possibly due to the reason that gills were the first target organ for expo-

Table 1. Showing quarterly Cr concentrations (mg/l) in the water and tissue samples (µg/g) of *L. rohita.*

Month	Sample	Study Sites	
		Vrindavan (Vihar Ghat)	Agra (Renuka Ghat)
Oct 2018	Water	0.8	0.6
	Liver	3.75	3.04
	Muscles	2.50	2.02
	Gills	4.75	3.85
	Kidney	1.25	1.01
Jan 2019	Water	1.3	0.9
	Liver	4.43	3.59
	Muscles	2.91	2.30
	Gills	5.61	4.54
	Kidney	1.47	1.18
April 2019	Water	1.9	1.4
	Liver	7.60	6.16
	Muscles	5.07	4.10
	Gills	9.63	7.78
	Kidney	2.53	2.04
July 2019	Water	1.5	1.1
	Liver	5.90	4.79
	Muscles	3.93	3.19
	Gills	7.40	6.01
	Kidney	1.96	1.59
Oct 2019	Water	1	0.96
	Liver	3.67	4.36
	Muscles	2.70	2.57
	Gills	5.07	4.59
	Kidney	1.41	1.15
Jan 2020	Water	1.63	1.4
	Liver	5.18	5.00
	Muscles	3.33	3.17
	Gills	6.23	5.96
	Kidney	1.67	1.90

*All the values are mean values of three replicates; Standards of drinking water as per WHO and BIS (2012): 0.05 mg/standards of Cr concentration of fish samples as per EU (1 µg/g); and FEPA and WHO: (0.15 µg/g)

sure in fish and remain much more exposed to the aquatic surrounding as reported by Roesijadi, (1992) and Malik *et al*., (2010).The metal mucus complex formed in the gills cannot be completely removed that may also be the cause for higher accumulation in gills of the fishes as also reported by Yousafzai *et al.* (2010), Norena *et al.* (2012) and Yousafzai *et al*. (2017). Thus, the exposure and contact with the toxicant may be the reason for more accumulation of Cr in these tissues. The affinity of metals with the protein metallothionein leads to higher concentration as the protein plays a significant role in detoxification of the metals and increases in the liver and gills on being exposed to metal toxicants, as reported by Negi and Maurya, (2015) for *L.rohita* and *Hypophthalmichthys molitrix*. The higher accumulation of the toxicant has also been reported previously in gills and liver of the fishes aqutic ecosystems in Iskenderun bay Turkey and Nigeria in different species of fish (Yilmaz, 2005; Benson *et al.,* 2007).

The HPI is a very valuable tool for assessing all heavy metal pollution in water bodies.The mean HPI for the water and the fish samples was found to be very high i.e. 2676.67 and 208.2 respectively, indicating elevated chromium contamination in the Yamuna ecosystem for Vrindavan (Vihar ghat) region, while for the Agra (Renuka ghat) region, these values were comparatively lower i.e. 2120 and 178.9 respectively (Table 2). Milivojević, (2016) at Uglješnica River, Serbia reported that HPI values greater than 100 are critical, and indicates high pollution load and is mainly due to industrial and domestic wastes . In present study, HPI for both the water and fish tissue samples was high that was mainly due to industrial (Pipe industries, chemical industries, tanneries, electroplating); domestic wastewater (from local drains); pesticides, inorganic fertilizers, agricultural effluents (local from crop fields) which are discharged near both ghats into river and used by locals and tourists due to their religious values. The higher values at Vihar ghat in comparison to Renuka ghat indicated greater industrial and anthropogenic activities, leading to greater wastewater discharge into river as also reported earlier for river Yamuna (Pal *et al.,* 2017). These prominent Ghats were being regularly used by a massive population for their religious rituals. The Vihar Ghat is a site situated in Vrindavan, where contaminated water from Delhi enroutes to Vrindavan area and also from the petroleum oil refineries situated in Mathura whereby the Yamuna water flows through, and Renuka Ghat is present in Agra region (57 km from Vihar ghat) where industrial activities are comparatively lesser. This may be the probable reason for the quite large variation in heavy metal pollution load between the two studied sites.

The metal quality index (MQI) values for the assessment of total Cr pollution in the Yamuna environment are given in Table 2. Both the sampling sites were severely threatened with Cr contamination. The MQI > 1 is critical, indicating high metal pollution as reported previously by Pal *et al.,* (2016 and 2017) for Mathura and Agra regions, respectively. In present study, both the samples of water and fish, the MQI values were observed to be higher than the critical value as 26.8 (water) and 1.7 (fish tissue) for the Vrindavan (Vihar Ghat) region and 21.2 (water) and 1.4 (fish tissue) for the Agra (Renuka Ghat) region showing Vihar ghat site as more contaminated than the Renuka ghat site.

There was a remarkable positive correlation of Cr metal with water and fish with higher significance at ($p < 0.05$). A positive and strong correlation (r=1) was exhibited between water and fish tissues of *L.rohita* for Vrindavan (Vihar ghat) and Agra (Renuka ghat)(Table 3). The strong positive correlation between water and fish tissues from both the sampling sites indicated an interaction between the absorption of the metal and common sources of pollutants has also been reported earlier (Miller and Miller, 2002; Pal *et al*.,2017).

BCF of Cr in fish tissues is the ratio of the Cr in tissue to surrounded water. In the present study, the BCF of the Cr concentration in the specific fish tissues, i.e., gill, liver, muscles, and kidney, showed an appreciable chance of bioaccumulation of the Cr in body organ tissues of the fish (Table 4). The gills of fish species showed a higher BCF (6.4167) in October 2018, while liver, muscle, and kidney showed a lower BCF value for both the sites. The BCF showed that the concentration of the Cr in the tissues followed the order of gill > liver > muscle > kidney. The BCF was higher in liver and gills which are metabolically active. The higher accumulation in gills than the liver may be due to its direct contact and high vascular nature. The bioaccumulation was lower in the liver as it is the centre for the detoxification in the body was reported by Norena *et al*., (2012) and Yousafzai *et al*., (2017).

Table 2. Showing HPI and MQI of water and fish of *L. rohita* collected from the sampling sites of river Yamuna.

S. No.	Sample	HPI		MQI	
		Vrindavan (Vihar Ghat)	**Agra (Renuka Ghat)**	**Vrindavan (Vihar Ghat)**	**Agra (Renuka Ghat)**
1	Water	2676.67	2120	26.8	21.2
2	Fish	208.2	178.9	1.7	1.4

Critical values: HPI >150; MQI>1; Source: Pal et al., 2017)

Table 3. Pearson's correlation analysis of Cr concentration in water and fish tissues of *L. rohita*.

Sample	Vrindavan (Vihar Ghat)					Agra (Renuka Ghat)				
	Water	**Liver**	**Muscles**	**Gills**	**Kidney**	**Water**	**Liver**	**Muscles**	**Gills**	**Kidney**
Water	1	0.98	1	1	1	1	0.99	1	0.97	1
Liver		1	1	1	1		1	1	1	1
Muscles			1	0.99	1			1	1	0.99
Gills				1	1				1	1
Kidney					1					1

Table 4. Bio-concentration factor (BCF) index of Cr concentration in fish tissues of *L. rohita*.

Seasons	Fish Tissue	BCF	
		Vrindavan (Vihar ghat)	Agra (Renuka Ghat)
Oct 18	Liver	4.6875	5.0667
	Muscles	3.1250	3.3667
	Gills	5.9375	6.4167
	Kidney	1.5625	1.6833
Jan 19	Liver	3.4077	3.9889
	Muscles	2.2385	2.5556
	Gills	4.3154	5.0444
	Kidney	1.1308	1.3111
Apr 19	Liver	4.0000	4.4000
	Muscles	2.6684	2.9286
	Gills	5.0684	5.5571
	Kidney	1.3316	1.4571
Jul 19	Liver	3.9333	4.3545
	Muscles	2.6200	2.9000
	Gills	4.9333	5.4636
	Kidney	1.3067	1.4455
Oct 19	Liver	3.6700	4.5417
	Muscles	2.7000	2.6771
	Gills	5.0700	4.7813
	Kidney	1.4100	1.1979
Jan 20	Liver	3.1779	3.5714
	Muscles	2.0429	2.2643
	Gills	3.8221	4.2571
	Kidney	1.0245	1.3571

Table 5. Quarterly values of BAF, EDI and THQ.

S.No.	Seasons	BAF		EDI 70Kg−1 Body weight		THQ	
		Mathura	Agra	Mathura	Agra	Mathura	Agra
1	Oct 18	3.82500	4.13333	0.06688	0.05421	0.02229	0.01807
2	Jan 19	2.76923	3.22222	0.07869	0.06339	0.02623	0.02113
3	Apr 19	3.26842	3.57857	0.13573	0.10950	0.04524	0.03650
4	Jul 19	3.20000	3.54545	0.10491	0.08524	0.03497	0.02841
5	Oct 19	3.21000	3.30208	0.07016	0.06929	0.02339	0.02310
6	Jan 20	2.51534	2.86429	0.08961	0.08765	0.02987	0.02922

Critical Values: BAF:< 1000: no probability; EDI: 0.003 μg/kg−1 day− 1; THQ>1 (Source: USEPA ,2011)

The human population generally consumes fish muscles. Therefore, evaluating the human health risk through an estimated daily intake (EDI) of Cr and target hazard quotients (THQ) values of the concentration of Cr in fish muscles were assessed and mentioned in Table 5. The accumulation of these heavy metals in freshwater fish is a matter of concern for the population of nearby areas taking fish as food on a regular basis. The acceptable guidelines for EDI 0.003 μg/ kg−1 day− 1 , and THQ are 1 as stated by USEPA, (2011). The EDI was quite less than the standard values, and THQ was observed to be below 1 in all the muscle samples of the fish. Therefore, at present the fish is safe for human consumption, but more accumulation of Cr in future can lead to public health risks.

HEI was found to be more in water samples of Vrindavan (Vihar ghat) site as 27.1 as compared to Agra (Renuka ghat) site as 21.2. The HEI indicates low pollution for values less <10, moderated for values between 10 – 20, and >20 for high pollution (Farouk *et al.*, 2020; Maskooni *et al.*, 2020). The values were above the critical values at both places indicates the water to be polluted. The water at Vrindavan (Vihar ghat) site is more polluted than the site at Agra. However, in the fish

Table 6. Heavy metal evaluation index (HEI) of Cr concentration in water and fish tissues.

Site	Vrindavan (vihar ghat)	Agra (Renuka ghat)
Water	27.1	21.2
Fish	2.08	1.79
Overall	2.24	1.91

HEI values < 10 indicates low; 10 - 20 moderate and HEI>20 indicates high pollution (Source: Farouk *et al.,* 2020)

samples, the HEI values were found to be low compared to critical values, but higher in the fish from Vrindavan (2.08) site than the fish from Agra (1.79) (Table 6).

The degree of contamination (C_d values) is important as an indicator of the contamination of water. From the C_d values, a very high degree of contamination in water samples was observed (Table 7). The values less than < 3 indicates low contamination, medium contamination for values between 1-3 , and > 3 for high contamination (Kwaya 2019; Farouk *et al*., 2020).The maximum C_d value (38) was an indication of the contamination of the water samples was taken from Vrindavan site during summer. The C_d values in the water samples from Agra site (28) were also above the critical value but less contaminated than Vrindavan.

The $C_d$values in the fish tissues in most cases were above the critical values except kidney. The values in the gills of the fish were found above the critical level during the summer (4.81) from Vrindavan region. The C_d values are also reported to be high in aquatic animals as they are exposed to elevated levels of heavy metals (Singh *et al*., 2017).

Conclusion

The study of the Cr concentration in Yamuna river water and fish, *L. rohita* at the two sampling sites Vrindavan (Vihar Ghat) and Agra (Renuka Ghat), showed a high concentration of Cr in water and fish organs viz. gills, liver, muscles and kidney. The maximum accumulation was found in the gills and liver of *L. rohita*, and is a good biological marker for the aquatic ecosystem. HPI for both the water and fish tissue samples was high, mainly due to waste discharged into rivers. BCF index was also high in the gills and in the liver and low in the muscles, and kidney. The lower value of BCF and THQ's were observed in muscles as these are the edible parts. This is also indicative that the consumption of *L. rohita* will not be a threat to human health. The higher values of the water pollution indicated a higher degree of contamination. The water was unfit for consumption and strategies need to be formulated for water pollution control, and flow from industries need to be regulated.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Table 7. Quarterly determination of Contamination degree (C_d) index of Cr in different samples of water and fish tissues at study sites.

S.No.	Seasons	Mathura					Agra				
		Water	Liver	Muscles	Gills	Kidney	Water	Liver	Muscles	Gills	Kidney
1	Oct 18	16	1.87	1.25	2.37	0.62	12	1.53	1.01	1.92	0.51
2	Jan 19	26	2.21	1.45	2.80	0.73	18	1.79	1.15	2.27	0.59
3	Apr 19	38	3.80	2.53	4.81	1.26	28	3.08	2.05	3.89	1.02
4	Jul 19	30	2.95	1.96	3.70	0.98	22	2.39	1.59	3.01	0.79
5	Oct 19	20	1.83	1.35	2.53	0.70	19.2	2.18	1.28	2.29	0.58
6	Jan 20	32.60	2.59	1.67	3.11	0.83	28	2.50	1.59	2.98	0.95

C_d< 1 indicates low; C_d =1-3 indicates medium and C_d>3 indicates high contamination degree (Source: Farouk *et al.,* 2020).

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