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

**Jyoti Sharma**
Department of Bioscience and Biotechnology, Banasthali Vidyapith, Banasthali (Rajasthan), India

**Gaurav Pant**
Department of Biotechnology, Institute of Applied Science & Humanities, GLA University, Mathura (Uttar Pradesh), India

**Alka Singh**
Jawahar Navodaya Vidyalaya, Kondagaon, Chhattisgarh

**Rashmi Tripathi***
Department of Bioscience and Biotechnology, Banasthali Vidyapith, Banasthali (Rajasthan), India

*Corresponding Author: E mail: trashmi@banasthali.in

**Article Info**
https://doi.org/10.31018/jans.v13i3.2600
Received: March 2, 2021
Revised: August 9, 2021
Accepted: August 26, 2021

**How to Cite**
Sharma, J. *et al.* (2021). A study on chromium accumulation in *Labeo rohita* in the river Yamuna ecosystem in Mathura-Agra region in Uttar Pradesh, India. *Journal of Applied and Natural Science*, 13(3), 944 - 953. https://doi.org/10.31018/jans.v13i3.2600

**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*) values were above the critical level at both the sampling sites-Vrindavan (38) and Agra (28). The higher pollution indices (HPI, HEI, *C*) 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 (Luczyńska 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 alter 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 carcinogenic 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, Har- yana, 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) 27°15’05.4”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 HNO₃ 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, and 15 ml of diacid solution (HNO₃/HClO₄, 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 the inner wall of the flask, which 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...
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$_2$SO$_4$ was added. After 10 min of mixing, 1 ml H$_2$O$_2$ 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, $W_i$ stands for the reciprocal value of $S_i$, $S_i$ is the permissible limit for drinking water by Bureau of Indian Standards (2012), $Q_i$ refers to sub-indexing of $i^{th}$ parameter and calculated by Eq. (2) and number of parameters are represented by $n$.

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

Where $M_i$ is the observed heavy metal value $S_i$ means the parameter of $i^{th}$ in PPM ($\mu g / L$) 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).

$$MQI = \frac{\sum_{i=1}^{n} M_i}{S_i} \quad \text{Eq. (3)}$$
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 lead 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 expected daily intake of Cr is possible by using the Eq. (5).

\[
EDI = \frac{C \times FI \times BW}{1}
\]

--------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⁻¹day⁻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).

\[
THQ = \frac{EFQ \times ED \times FIR \times C \times 10^{-1}}{R \times D \times BW \times AT}
\]

--------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, R is the Dosage that evaluates the health risk of fish consumption (considered 0.003 μg/kg−1 day−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:

\[
HEI = \sum i = 1 - n \left( \frac{C_i}{MAC_i} \right)
\]

--------Eq. 7

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

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

\[
Cd = \sum_{i=1}^{n} CF
\]

--------Eq. 8

Where Cfi = (Ci/Cni)-1, here Cfi is contamination factor, Ci 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. laius, 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-
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 aquatic 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). Milivojevic, (2016) at Ugljesnica River, Serbia reported that HPI values greater than 100 are critical, and indicates

| 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)
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 surrounding 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 Vrindavan (Vihar Ghat) | Agra (Renuka Ghat) | MQI 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       | Water | Liver | Muscles | Gills | Kidney | Water | Liver | Muscles | Gills | Kidney |
|--------------|-------|-------|---------|-------|--------|-------|-------|---------|-------|--------|
| Vrindavan (Vihar Ghat) |       | 0.98  | 1       | 1     | 1      | 0.99  | 1     | 1       | 1     | 1      |
| Agra (Renuka Ghat)     | 1     | 1     | 0.99    | 1     | 1      | 1     | 1     | 0.99    | 1     | 1      |
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 samples, the concentration of Cr was found to be high in gills as compared to other tissues.

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

| Seasons | Fish Tissue | BCF |
|---------|-------------|-----|
| 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 |

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

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

| S.No. | Seasons | BAF | EDI | THQ |
|-------|---------|-----|-----|-----|
|       |         | Mathura | Agra | 70Kg−1 Body weight | 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 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.

**ACKNOWLEDGEMENTS**

The authors are grateful to GLA University, Mathura (Uttar Pradesh) and Banasthali Vidyapith, Banasthali 304022 (Rajasthan) for support in the present research. I would like to acknowledge Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, PUSA, New Delhi, for AAS analysis, and Fisheries Department, Mathura, Government of Uttar Pradesh, India for Fish identification.

**Conflict of interest**

The authors declare that they have no conflict of interest.

**REFERENCES**

1. Ali, H., Khan, E. & Ilahi, I. (2019). Environmental chemistry and ecotoxicology of hazardous heavy metals: Environmental persistence, toxicity, and bioaccumulation. *Journal of Chemistry*, 1-14. doi: 10.1155/2019/6730305
2. Bakan, G., Boke Ozkoc, H., Tulek, S. & Cece, H. (2010). Integrated environmental quality assessment of Kizilirmak River and its coastal environment. *Turkish Journal of Fisheries and Aquatic Science*, 10,453-462. doi: 10.4194/tjfas.2010.0403
3. Benson, N., Essien J., P., Williams, A., & Bassey, D. E. (2007). Mercury accumulation in fishes from tropical aquatic ecosystems in the Niger Delta, Nigeria. *Current

### 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)

### 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).
Science, 92(6), 781–785
4. Bureau of Indian Standards (2012). Indian Standard Drinking Water Specification. Bureau of Indian Standards (BIS), New Delhi.
5. Blinova, I., Bityukova, L., Kasemets, K., Ivask, A., Käkinen, A., Kurvet, I., Bondarenko, O., Kanarik, L., Sihmae, M., Aroja, V., Schwede, H. & Kahrù, A. (2012). Environmental hazard of oil shale combustion fly ash. Journal of Hazardous Materials, 229(230), 192–200. DOI: 10.1016/j.jhazmat.2012.05.095.
6. Briffa, J., Sinagra, E., & Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans. Heliyon, 6(9), 1-26. doi: 10.1016/j.heliyon.2020.e04691.
7. Farouk, A. E., Mansour, E. M. G., & Mekawy, M. T. (2020). Assessment of some heavy metals contamination and their pollution indices in water and fish organs of Oreochromis niloticus and Clarias gariepinus in Burullus and Edku lakes, (A comparative study). Egyptian Journal of Aquatic Biology and Fisheries, 24(5), 609 – 637. DOI:10.21608/ ejabf.2020.109886.
8. Federal Environmental Protection Agency (2003). Guidelines and Standards for Environmental Pollution Control in Nigeria, Federal Environmental Protection Agency (FEPA), p. 238.
9. Jain, C. K., & Sharma, M. K. (2001). Distribution of trace metals in the Hindon river system, India. Journal of Hydrology (Amsterdam), 253, 81–90. doi:10.1016/S0022-1694(01)00484-X.
10. Jain, C. K., Sharma, M. K., & Sharma, T. C. (2016). Assessment of heavy metal pollution index for Uglješnica River, Serbia. Bulletin of Environmental Contamination and Toxicology, 97, 737–742. doi:10.1007/s00128-016-1918-0.
11. Javed, M., & Usmani, N. (2013). Assessment of heavy metal (Cu, Ni, Fe, Co, Mn, Cr, Zn) pollution in effluent dominated rivulet water and their effect on glycoprotein metabolism and histology of Mastacembelus armatus. Springer Plus, 2, 390. https://doi.org/10.1186/2193-1801-2-390.
12. Kawaya, M., Yerima, H., Hamidu, H., Mohammed, Ibrahim A., Abdulnumimini, Nura Y.I., Adamu, Habiba, Grema, M., Dauda, M., Hallilu, F., Bello, A., & Kana, A. Mohammed (2019). Heavy metals pollution indices and multivariate statistical evaluation of groundwater quality of Maru town. Journal of Materials and Environmental Sciences, 10(1), 32–44. http://www.jmatenerenvirosci.com.
13. Lau, S., Mohamed, M., Yen, A.T. & Su'ut, S. (1998). Accumulation of heavy metals in freshwater mulluscs. Science of Total Environment, 214(1–3), 113-121. https://doi.org/10.1016/S0048-9697(98)00058-8.
14. Łuczynska, J., Paszczyk, B., & Łuczynski, M. (2018). Fish as a bioindicator of heavy metals pollution in aquatic ecosystem of Pluszne Lake, Poland, and risk assessment for consumer’s health. Ecotoxicology and Environmental Safety, 153, 60-67. DOI: 10.1016/j.ecoenv.2018.01.057.
15. Malik, N., Biswas, A.K., Qureshi, T.A., Borana, K. & Virha, Rachna (2010). Bioaccumulation of heavy metals in fish tissues of a freshwater lake of Bhopal. Environmental Monitoring Assessment, 160, 267–276. DOI 10.1007/s10661-008-0693-8.
16. Maskooni, E. K., Naseri-Rad, M., Berndtsson, R., & Nakagawa, K. (2020). Use of heavy metal content and modi-
29. Pal, R., Dubey, R.K., Dubey, S.K. & Singh, A.K. (2017). Assessment of heavy metal pollution through index analysis for Yamuna water in Agra region, India. *International Journal of Current Microbiology and Applied Sciences*, 6(12), 1491-1498. https://doi.org/10.20546/ijcmas.2017.612.166

30. Popkin, B., Adair, L. & Ng, S.W. (2012). Global nutrition transition and the pandemic of obesity in developing countries. *Nutrition Reviews*, 70(1), 1-21. doi: 10.1111/j.1753-4887.2011.00456.x

31. Renieri, E.A., Safenkova, I.V., Alegakis, A.K., Slutskaya, E.S., Kokaraki, V., Kentouri, M., Dzantiev, B.B. & Tsatsakis, A.M. (2019). Cadmium lead and mercury in muscle tissue of gilthead seabream and seabass: risk evaluation for consumers. *Food and Chemical Toxicology*, 124, 439-449. doi:10.1016/j.fct.2018.12.020.

32. Roesijadi, G. (1992). Metallothioneins in metal regulation and toxicity in aquatic animals. *Aquatic Toxicology (Amsterdam, The Netherlands)*, 22, 81–113. doi:10.1016/0166-445X(92)90026-J.

33. Showqi, I., Lone, F. & Naikoo, M. (2018). Preliminary assessment of heavy metals in water, sediment and macrophyte (Lemna minor) collected from Anchar Lake, Kashmir, India. *Applied Water Science*, 8(3). DOI:10.1007/s13201-018-0720-4

34. Singh, H., Pandey, R., Singh, K.S & Shukla, N.D. (2017). Assessment of heavy metal contamination in the sediment of the River Ghaghara, a major tributary of the River Ganges in Northern India. *Appl Water Sci*. 7:4133–4149. DOI 10.1007/s13201-017-0572-y

35. Strungaru, S., Nicoara, M., Teodosiu, C., Baltaig, E., Ciobanu, C. & Plavan, G. (2018). Patterns of toxic metals bioaccumulation in a cross-border freshwater reservoir. *Chemosphere*, 207, 192-202.

36. Tamasi, G. & Cini, R. (2004). Heavy metals in drinking waters from Mount Amiata (Tuscany, Italy). Possible risks from arsenic for public health in the Province of Siena. *Science of Total Environment*, 327(1-3), 41-51. doi: 10.1016/j.scitotenv.2003.

37. United States Environmental Protection Agency (1991). Guidelines for developmental toxicity risk assessment. Risk assessment forum United States Environmental Protection Agency (USEPA) II Washington, DC Federal Register, 56(234), 63798–63826

38. United States Environmental Protection Agency (2011). United States Environmental Protection Agency (USEPA), Regional Screening Level (RSL) Summary Table: November 2011. http://www.epa.gov/regshwmd/risk/human/index.htm.

39. Velma, V., Vutukuru, S.S. & Tchounwou, P.B. (2009). Ecotoxicology of hexavalent chromium in freshwater fish: a critical review. *Reviews on Environmental Health*, 24(2), 129-45. doi: 10.1515/reveh.2009.24.2.129.

40. World Health Organization (2011). Guidelines for drinking water quality (4th ed.p. 564). World Health Organization (WHO) Geneva.

41. Yadav, K.K., Gupta, N., Kumar, V. & Singh, J.K. (2017). Bioremediation of heavy metals from contaminated sites using potential species: A review. *Indian Journal of Environmental Protection*, 37, 65–84.

42. Yilmaz, A. B. (2005). Comparison of heavy metals of grey mullet (Mugil cephalus L.) and sea bream (Sparus aurata L.) caught in Iskenderun Bay (Turkey). *Turkish Journal of Veterinary Animal Sciences*, 29, 257–262. doi:10.1.1.465.6205&rep=rep1&type=pd

43. Yousafzai, A. M., Chivers, D. P., Khan, A., Ahmad, R. I. & Siraj, M. (2010). Comparison of heavy metals burden in two freshwater fishes, *Wallago attu* and *Labeo rohita* with regard to their feeding habits in natural ecosystem. *Pakistan Journal of Zoology*, 42(5), 537–544. http://zsp.com.pk/pdf/537-544%20

44. Yousafzai, A.M., Ullah, F., Bari, F., Raziq, Saumayya., Riaz, Mehreen., Khan, Khali., Nishan, Umar., Shananad, I.A., Shaheen, B., Shaheen, M. & Ahmad, H. (2017). Bioaccumulation of some heavy metals: Analysis and comparison of *Cyprinus carpio* and *Labeorohita* from Sardaryab, Khyber Pakhtunkhwa. *Bio Med Research International*, 1-5. https://doi.org/10.1155/2017/5801432