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Research Article

Heavy Metals Accumulation in Water and Human Health Risk Assessment via the Consumption of *Labeobarbus intermedius* Samples from Borkena River, Ethiopia

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Concentrations of heavy metals, namely, chromium, lead, cadmium, and copper, were evaluated in the water samples and selected fish organs (*Labeobarbus intermedius*) from the Borkena River, Ethiopia. The concentrations of these metals were determined using ELICO's SL-176 double-beam atomic absorption spectrophotometer (AAS). The distribution of heavy metals in water samples analyzed was in the order of magnitude of Cu > Cr > Cd > Pb. The average heavy metal concentrations recorded in the water samples were below the maximum permissible limit established by international and national organizations (WHO, EPA, and USEPA), except for cadmium. Organ specificity was observed for accumulating the selected heavy metals in the order of liver > kidney > muscles. Pearson's correlation results revealed that Cr and Cd originated from similar sources. Hazard quotient (HQ) and total hazard index (THI) results showed that Cu, Cr, Cd, and Pb contents were safe and might not have adverse public health effects. From the point of carcinogenic risk, this study suggests that the observed Cr and Cd concentrations possibly pose a risk of developing cancer in the future. Controlling waste at the source and implementing remediation strategies should be done to reduce heavy metal pollution in the river.

1. Introduction

Water pollution is a common environmental problem causing crises in the existing water resources, making them unsuitable for the intended purpose due to contamination [1]. Water pollution is water contamination by excess substances that create significant threats to humans and the aquatic environment [2].

Among environmental pollutants, heavy metals have become a great concern in recent years due to their nonbiodegradability, ability to bioaccumulate in aquatic ecosystems, and the associated ecological risks [3]. Heavy metals such as Hg, Cd, Cr, Cu, Zn, Mn, and Pb are present in the food and water taken in our bodies. Heavy metal contamination is a significant environmental threat and tends to build up in an organism's body to a toxic level [4–6].

Several studies and monitoring programs have focused on heavy metal concentrations affecting fish [7]. Fish can be used as bioindicators for monitoring aquatic pollution because of their relatively large body size, long life cycle, position in higher trophic levels of the aquatic food chain, and their use for human consumption [8, 9]. Many studies in the aquatic ecosystem reported that metals are released and further dissolved in water and might assimilate in the fish body by two main routes: adsorption from water through the gills and food absorbed through the digestive tract [10–12]. Among the aquatic ecosystems, rivers are highly exposed to pollution due to industrial discharge, sewage, and agricultural runoff [13]. In many developing countries, waste treatment facilities are not fully operational because of energy expenditure and lack of maintenance. Their rivers crossing urban and periurban areas become contaminated due to discharging of domestic and industrial wastes into the water bodies, leading to an increase in the extent of metals in river water [14–16]. River Borkena is entirely found within the Awash Basin, Ethiopia, which originates from Kutaber Woreda and crosses Dessie and Kombolcha towns. The river is used for cleaning, recreation, irrigation of vegetables, swimming, drinking by animals, and as a living habitat for various fish species [15, 17–19].

Beyene et al. [17] reported that residents and manufacturing firms of Dessie and Kombolcha towns used the river as a dumping site for waste materials released from domestic, commercial, and discharging effluents from various industries along with polluted water. Dessie et al. [19] also found that the river is highly polluted to the extent of water death. *L. intermedius* is a large, hexaploid, barbine minnow species found in most Ethiopian drainage basins. It takes up a considerable part of the commercial fish landings in the country [20]. Therefore, monitoring the level of heavy metal concentrations in commercially important fish species such as the African big barb (*L. intermedius*) is essential to provide scientific information for managing the Borkena River.

Thus, the present study aimed to determine the extent of selected heavy metals (Cu, Cr, Cd, and Pb) concentrations in the water and health risks through the intake of *L. intermedius* collected from the Borkena River.

2. Materials and Methods

2.1. Sampling Location. The Borkena River is found in Eastern Amhara, Ethiopia, located at latitude of 11.90° N and longitude of 39.40° E. Borkena and Jara are the foremost tributaries of the river and three subbasins: Dessie, Kombolcha, and Chefa. Many industries are located in the center of Kombolcha Town and close to the Borkena River [21]. After crossing some areas, the river joins with the Awash River. The present study was conducted in three districts where the Borkena River passes (Kombolcha, Harbu, and Kemissie) as shown in Figure 1. The four sampling sites were chosen along the river basin, and their geographical locations are given in Table 1. Human settlement, agricultural areas, and industrial activities are considered to select the study sites.

2.2. Water Sample Collection. The samples were collected during the dry season in April 2017. Water samples were taken from Dawudo, Mishion bahir, Harbu, and Chereti in sterilized (soaked in 5% nitric acid solution for a day and washed with deionized water) bottles. Three samples of 0.5 L of water were taken at each sampling site and were filtered through a 0.45 μm membrane filter. The samples were acidified with 10% HNO_3 and cooled in a refrigerator until analysis [22].

2.3. Collection of Fish Samples. A total of 40 fish samples were taken from the Borkena River. The fish samples were captured using Nordic survey monofilament nylon gill nets (6–12 cm stretched mesh size) and immediately transported in an icebox to the laboratory for subsequent dissection and sample preparation and analysis for the heavy metals contents. The fish samples were dissected, and the three organ components were collected.

2.4. Laboratory Analysis. After dissection, the fish's muscle, liver, and kidneys were separated and oven-dried at 105°C until a constant weight was recorded. According to Kucuksezgin et al. [23], microwave digestion methods are essential to speed up the digestion and reduce the possibility of contamination. 0.5 g of the homogenized samples of the muscles and kidneys and 0.1 g of the liver were added to Teflon vessels containing 6.0 mL HNO_3, 2.0 mL $HClO_4$, and 4.0 mL H_2O_2 and digested by placing them in a microwave oven digestive system using the microwave digestion program.

The residue was filtered through a 0.45 μm Whitman filter paper and transferred to a 50 mL volumetric flask. Consequently, the residue was diluted to an equivalent level with deionized water for the muscle and kidney and 25 mL for the liver. The digests were analyzed for Cd, Cr, Cu, and Pb using a flame atomic absorption spectrophotometer with aqueous calibration standards prepared from the standard stock solutions as per the standard protocols of APHA [24]. The heavy metal concentration values in the present study of the fish tissues were presented as wet weight (ww). Samples were analyzed at Wollo University (Biology Laboratory) and Mekelle (Ezana Analytical Laboratory), Ethiopia.

2.5. Human Health Risk Estimation

2.5.1. Estimated Daily Intake (EDI). Daily intake of each heavy metal was evaluated by taking 30 g d^{-1} per person [25] and the average body weight of adult Ethiopian as 60 kg [26] using the following equation.

$$\mathrm{EDI} = \mathrm{Cx}\frac{\mathrm{DR}}{\mathrm{WAB}}, \quad (1)$$

where C is the average dry weight concentration of metals in fish muscle (mg kg^{-1} dry weight), DR is the daily average fish ingestion rate, and WAB is the average body weight (kg).

2.5.2. Hazard Quotient (HQ). HQ was calculated using the following equation:

$$\mathrm{HQ} = \frac{\mathrm{EDI}}{\mathrm{RfD}}, \quad (2)$$

where RfD is the oral reference dose (mg kg^{-1} day^{-1}).

The RfD values were 0.04 $\mu g\ g^{-1}\ day^{-1}$ for (Cu), 0.003 for (Cr), 0.001 for (Cd), and 0.004 for (Pb) [27].

2.5.3. Total Hazard Index (THI). THI was evaluated as the sum of THQ of all metals [28] and calculated as follows:

$$\mathrm{THI} = \sum \mathrm{THQs}. \quad (3)$$

2.5.4. Cancer Risks (CRs). The CR for Cr, Cd, and Pb was examined using the following equation [29].

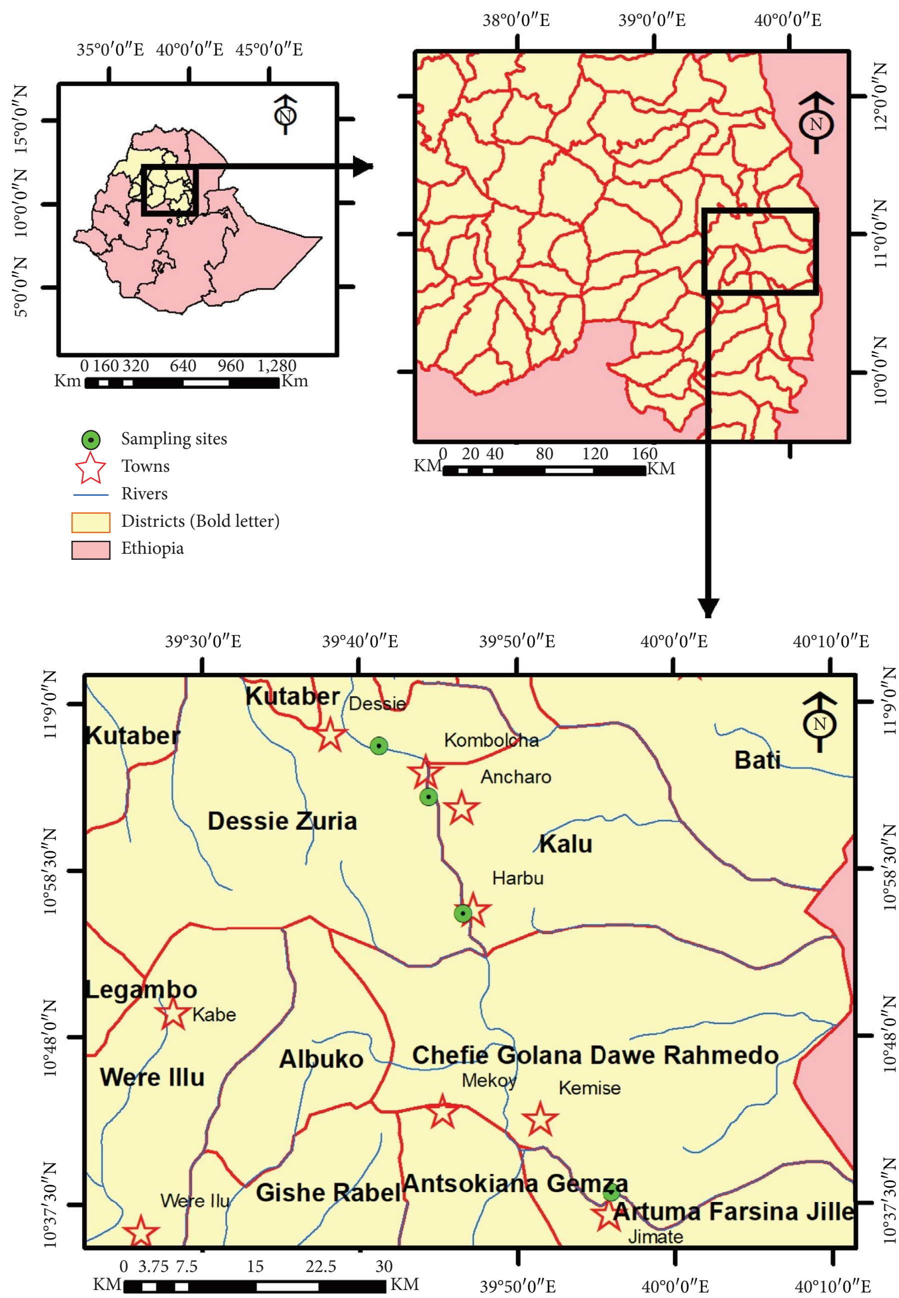

Figure 1: A map of the study area and the specific sampling sites.

Table 1: The geographical location of selected sampling sites in the Borkena River.

Name of sampling sites	Altitude (m.a.s.l.)	Coordinates	
		Latitude	Longitude
Dawudo	1960	11° 6′ 16.27″ N	039° 41′17.04″ E
Mishion bahir	1794	11° 3′ 3.67″ N	039° 44′26.22″ E
Harbu	1483	10° 55′ 44.47″ N	039° 46′35.88″ E
Chereti	1426	10° 38′ 10.00″ N	039° 55′58.18″ E

$$\text{CR} = \text{EDI} * \text{CSF}, \tag{4}$$

where CSF is the cancer slope factor.

The cancer slope factor value was 0.50 $\text{mg kg}^{-1}\,\text{day}^{-1}$ (Cr), 6.30 $\text{mg kg}^{-1}\,\text{day}^{-1}$ (Cd), and 0.0085 $\text{mg kg}^{-1}\,\text{day}^{-1}$ for (Pb) set by [30].

2.5.5. Weakly Intake (EWI). The estimated weekly intake (EWI; mg/kg bw/week) was determined using the following equation developed by USEPA [31]:

$$\text{EWI} = \frac{Cm\text{xCR}}{\text{WAB}}, \tag{5}$$

where CR represents the fish consumption rates (0.19 kg week^{-1}) [32].

2.5.6. The Percentage of Provisional Tolerable Weekly Intake (%PTWI). The %PTWI was evaluated for each heavy metal using the following equation developed by [33].

$$\%PTWI = \frac{EWI}{PTWI} x100. \quad (6)$$

The PTWI (mg/kg bw/week) is a reference dose set by the joint World Health Organization (WHO)/Food and Agricultural Organization (FAO) Expert Committee on Food Additive, and it epitomizes innocuous weekly ingestion of contaminants [29] and recommended by the European Food Safety Authority [34]. The PTWI values for Cu, Cr, Cd, and Pb are 3.5, 0.7, 0.007, and 0.025 mg/kg bw/week, respectively [29, 34].

2.6. Validation of the Method. As shown in Tables 2 and 3, the limit of detection for the selected metals in water samples and fish organs from the selected river sites was confirmed using selected validation parameter [35]. The spiking experiments were also analyzed using standard reference materials [36]. Certified reference materials such as $CuSO_4.5H_2O$, $CdCl_2$, $CrCl_3.6H_2O$, and Pb $(NO_3)_2$ were purchased from Central Drug House (P) Ltd. (India), Samir Tech Chem Pvt. Ltd. (India), and Pharma-Cos Ltd. (England).

2.7. Data Analysis. Statistical analysis and data plotting were performed using SPSS (version 20) and excel for Windows 10. Differences in the mean metal concentrations between the water samples and fish organs were employed with one-way analysis of variance (ANOVA), followed by the Tukey-HSD test at the 95% confidence level. The data generated in the present study were mainly normally distributed, and no transformation was required for statistical analysis. The relationship between heavy metals was examined by Pearson's correlation analysis. Principal component analysis (PCA) (PAST 10 Windows) was employed to determine the source of metals. For all statistical tests, a probability of $p < 0.05$ was considered significant.

3. Results

3.1. Heavy Metal Concentration in Water. The mean concentration of the selected metals in the water samples of the Borkena River is presented in Table 4. The concentration of Cu in the surface water samples collected from Dawudo had a higher mean value of 0.030 ppm, while it was lower at Chereti (0.017 ppm). In contrast, Cr was detected only at Mishion bahir with a mean concentration of 0.033 ppm. The average concentration of Cd for the surface water samples was about 0.020 ppm. However, the Pb concentration for surface water samples was below the detectable limit in all river sites.

High concentrations of Cu appeared in all sites revealing anthropogenic sources due to agrochemicals (pesticides and artificial fertilizers) applied to agricultural fields, effluents from the textile industry, and deposition of wastes from the close towns [15]. Figure 2 illustrates that Cr had a higher concentration at Mishion bahir than at other sites due to its location close to Kombolcha town and prone to elevated anthropogenic pressure and industrial discharges. At Dawudo, except for Cu, the investigated metals were recorded at their lowest level, which may indicate less waste flow into the site. Similarly, a decreasing concentration trend of metals, except Cd, was recorded at Chereti, which may be due to less anthropogenic effect and natural purification process by Chefa Wetland [44].

Table 2: Summary of method limits of detection and spiking experiments for water samples.

S/No.	Metal			
	Cu	Cr	Cd	Pb
Spiked concentration (ppm)	1.00	1.00	1.00	1.00
Detection limit (ppm)	0.01	0.02	0.01	0.01

Table 3: Summary of method limits of detection and spiking experiments for fish organs.

S/No.	Metal			
	Cu	Cr	Cd	Pb
Spiked concentration (ppm)	15	2.00	2.00	2.00
Detection limit (ppm)	0.003	0.006	0.002	0.10

3.2. Correlation Matrix of Heavy Metals in Water and Fish. Pearson's correlation coefficient for the different heavy metals concentrations in the water and muscle of *L. intermedius* is indicated in Table 5. A very strong positive significant correlation was found for the combinations of chromium and cadmium both in water ($r = 0.674^*$, $p < 0.05$) and fish tissue ($r = 0.673^*$, $p < 0.05$). Copper and cadmium ($r = 0.173$) exhibited a positive relationship in the tissue of *L. intermedius*. On the other hand, copper was not associated with chromium and cadmium in the ambient environment (water) implying that Cu has a different source than other metals.

3.3. Principal Component Analysis (PCA). Principal component analysis was employed to identify the possible anthropogenic sources of heavy metals in the water samples. Two principal components were extracted, which contributed 89.18% of the total sample variance. The total variance of PC1 and PC2 was 72.885 and 16.293, respectively. The first principal component (PC1) was strongly influenced by Cr and Cd and the second principal component (PC2) by Cu (Table 6).

3.4. Heavy Metal Concentration in Fish Body. The average concentrations of heavy metals (Cu, Cr, Cd, and Pb) accumulated in the muscle, kidney, and liver of *L. intermedius* were expressed as ppm and presented (Table 7). The bioaccumulation of different metals in the organs of *L. intermedius* confirmed significant variation ($p < 0.05$).

Table 4: Comparison of the mean (±SD) heavy metal concentrations in the Borkena River water with guidelines and other literature (ppm).

Guidelines/locality	Cu	Cr	Cd	Pb	References
WHO	2	0.05	0.01	0.05	WHO [37]
EPA	1.3	0.05	0.01	0.05	EPA [38]
USEPA	2.25	—	0.01	0.11	USEPA [39]
River Niger	0	—	ND	0.05	Izuchukwu Ujah et al. [40]
Liuyang River	2.90	0.73	0.07	1.20	Jia et al. [41]
Swarnamukhi River Basin	0.03	ND	ND	ND	Patel et al. [42]
Kali River	—	0.06	0.06	0.13	Mishra et al. [43]
Dawudo	0.030 ±0 .010	ND	0.0200 ± 0	ND	This study
Mishion bahir	0.027 ±0 .006	0.0333 ± 0.012	0.0200 ± 0	ND	This study
Harbu	0.023 ±0 .006	ND	0.0200 ± 0	ND	This study
Chereti	0.017 ±0 .006	ND	0.023 ±0 .006	ND	This study

ND represents not detected.

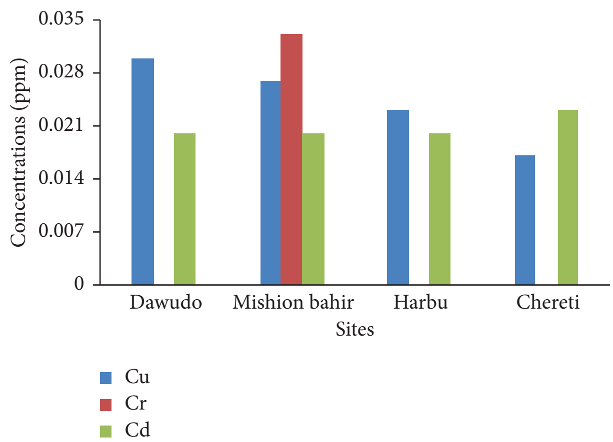

Figure 2: Site-wise heavy metal concentration (ppm) comparisons in the water of the Borkena River.

Table 5: Pearson's correlation matrix of heavy metals in water and fish tissue.

	Copper	Chromium	Cadmium
Water samples			
Copper	1	−0.540	−0.563
Chromium	−0.540	1	0.674*
Cadmium	−0.563	0.674*	1
Fish muscle			
Copper	1		
Chromium	−0.069	1	
Cadmium	0.173	0.673*	1

*Correlation is significant at the 0.05 level (2-tailed).

Table 6: Results of principal component analysis for heavy metals in water collected from the Borkena River.

Heavy metals	Component	
	PC 1	PC 2
Cu	−0.812	0.582
Cr	0.869	0.311
Cd	0.879	0.230
Eigen value	2.187	0.489
% total variance	72.885	16.293
Cumulative %	72.880	89.180

Table 7: The heavy metal concentrations in the fish (*L. intermedius*) organs sampled from the Borkena River.

Organs	Metal concentration			
	Cu	Cr	Cd	Pb
Muscle	2.048 ± 0.383*	1.398 ± 0.506*	0.056 ± 0.040*	ND
Kidney	12.924 ± 3.426*	2.271 ± 1.551*	1.768 ± 1.361*	ND
Liver	13.463 ± 5.283*	16.634 ± 25.801*	0.219 ± 0.189*	ND

ND represents not detected, and *values with in the column are significant at the 0.05 level (Tukey test is applied).

The analysis result for the accumulated heavy metals in the muscle, liver, and kidney tissues of *L. intermedius* showed variation in concentration. The relative abundance of metals was recorded in the order of the liver (Cr > Cu > Cd), kidney (Cu > Cr > Cd), and muscles (Cu > Cr > Cd). It is clear from Table 7 that the concentration of copper in the fish organs ranged from 13.463 ± 5.283 to 2.048 ± 0.383, and the concentration of chromium ranged from 16.634 ± 25.801 to 1.398 ± 0.506. The concentration of Cd was low in all organs compared to Cu and Cr, ranging from 1.768 ± 1.361 to 0.028 ± 0.040. The concentrations of heavy metals in selected organs analyzed were in the order of magnitude as the liver > kidney > muscle.

3.5. Health Risk Estimation. The human health risks obtained from the ingestion of fish were calculated based on daily intake (EDI), hazard quotient (HQ), weekly intake (EWI), percentage provisional tolerable weekly intake (% PTWI), carcinogenic risk (CR), and total hazard index (THI), as summarized in Table 8. The estimated daily and weekly intakes of heavy metals in the edible tissue of the studied fish species were measured in the order of Cu > Cr > Cd > Pb. On the contrary, the percentage of provisional tolerable weekly intake (%PTWI) was recorded in the order of Cd > Cr > Cu > Pb. The pollutants' highest hazard quotient (HQ) for noncarcinogenic health risk was recorded in Cr, followed by Cd, Cu, and Pb. As shown in Table 8, the estimated values of HQ for all heavy metals were less than 1. The calculated total hazard index for the adult population was less than one, with a value of 0.293. The results showed that there is no potential health effect due to

Table 8: Health risk assessment of the different metals in the studied fish species.

Metals	Mean level (ppm)	EDI	HQ	EWI	%PTWI	CR	THI
Cu	2.048	$1.0E-03$	0.0256	$6.5E-03$	0.1853	—	0.293
Cr	1.398	$7.0E-04$	0.2329	$4.4E-03$	0.6322	$3.5E-04^{*}$	
Cd	0.066	$3.0E-05$	0.0330	$2.0E-04$	2.9857	$2.1E-04^{*}$	
Pb	ND	$5.0E-06$	0.0013	$3.1E-09$	0.1267	$4.3E-08$	

*Values indicate CR above the acceptable limit (10^{-6}–10^{-4}) USEPA [45].

the consumption of the targeted fish species. Carcinogenic risk assessment in the muscles tissues of *L. intermedius* was carried out for Cr, Cd, and Pb. It can be seen that the carcinogenic health risk values of Cr, Cd, and Pb were found to be 3.5×10^{-4}, 2.1×10^{-4}, and 4.3×10^{-8}, respectively. This indicates that the fish collected from Borkena River might cause carcinogenic threat to the consumers, by the level of Cr and Cd concentrations.

4. Discussion

4.1. Heavy Metal Concentrations in Water and Fish. Considerable variation in the concentrations of the selected heavy metals was observed among the study sites and fish organs. In this study, Cd concentration was lower than that reported by Sabbir et al. [46], who reported 0.46–4.40 μg/L. Elhag Elhussien and Adwok [47] measured heavy metal concentrations (0.019 mg/L–0.025 mg/L) from White Nile, Gezira Aba, Sudan, which are close to the findings of this study.

Agricultural fertilizers and biocides contain various metals such as Cd, Hg, Pb, Al, As, Cr, Cu, Mn, Ni, and Zn. These metals may enter the aquatic ecosystem via runoff [8]. High concentrations of Cu occurred in all sites due to the agrochemicals (pesticides and artificial fertilizers) resulting from agricultural farms, effluents from textiles, and the deposition of wastes from nearby towns [15]. Dirbaba et al. [3] in the Awash River Basin in Ethiopia and Varol [48] researched on Tigris River in Turkey and reported Cu discharged due to dirty sewage. In this study, all the selected metals had higher concentrations at Mishion bahir, which may be due to the elevated anthropogenic pressure and released untreated effluents from industrial zones [21]. This is in agreement with other studies (Imran et al. [49] reported that Keenjhar Lake is increasingly contaminated because of industrial effluent discharged from the Kotri industrial area along the Kalri-Baghar feeder canal and other anthropogenic activities). Liu et al. [50] described that rivers are highly vulnerable to contamination among the water bodies due to the continuous flow of wastewater without treatment and open dumping and throwing of municipal wastes directly into the river.

Dawudo was less polluted by the selected heavy metals than other sites, implying that it received little pollutants from agricultural, industrial, and sewage drains. Similarly, the concentration decreased at Chereti, which may be due to the recycling and filtration process at Chefa Wetland, indicating that wetlands can regulate the environment by controlling pollutants that enter into different sources and improve the water quality [44]. The average concentration of metals in all stations was below the utmost consumption except for cadmium. Similarly, Sabbir et al. [46] found the highest cadmium concentration, which is close to Khulna Shipyard Station ($2879.8 \pm 10.47\,\mu$g kg^{-L}), Bangladesh. The high cadmium level in the Borkena River water could be attributed to the industrial and agricultural discharge and the spill of petrol from vehicles distributed within the river [51]. The inability to detect Pb in the water samples could be due to their adsorption to suspended solids in the river [8]. Previous studies of heavy metals in different environmental matrices show risks to human health and the ecosystem due to their bioaccumulation, nondegradability, and transfer along the food chain [52, 53].

Fish are sensitive to various kinds of pollutants absorbing metals through their respiratory surfaces and on the body surfaces. Variations in metal concentrations of the fish tissues could be due to the availability of proteins such as metallothioneins to which these metals may bind [54]. This study is in agreement with Izuchukwu Ujah et al. [38], Dsikowitzky et al. [55], and Asare et al. [56], who reported heavy metal accumulation in different organs of the fish tissues. Previous studies confirmed that the highest heavy metal accumulation was found in the liver than in other fish organs possibly, associated with the uptake pathway and the activity of metallothioneins, metal-binding proteins, which play an important role in metal regulation and detoxification of nonessential metals [55, 57–59]. Muscles retained the lowest concentration of the measured metals which is in line with the report of other authors [54, 60–64].

4.2. Sources of Heavy Metals. As Table 5 shows, Pearson's correlation coefficients of Cr and Cd were significantly positively associated with each other. Cu had a low relationship with other metals. The significantly positive interelemental correlation between Cr and Cd denotes the possibility of similar sources that came from industrial effluents and agricultural inputs. The study by Damtew et al. [21] reported that many factories are found in the center of Kombolcha Town and close to the Borkena River.

Another important statistical method used to investigate the possible sources of heavy metals was PCA. In the first factor, Cr and Cd revealed that the two highest loading values coincided with the correlation matrix result. In the second component, only Cu exhibited a high loading value. This might indicate that agriculture might be the major anthropogenic contributor for this metal due to excess application of fertilizers and pesticides [15]. Dirbaba et al. [3] reported that the enrichment of Cu in the surface sediment might be because of anthropogenic sources released from agrochemicals, discharges from textile and sugar factories, and deposition of municipal wastes from the nearby towns, Adama and Wonji.

4.3. Human Health Risk Assessment. Estimating metal concentrations in the fish samples is essential to assess human health risks via the intake of contaminated fish [65]. EDI, HQ, EWI, %PTWI, CR, and THI indices were used to determine the human health risks associated with fish consumption, as depicted in Table 8. The EDI values of the trace metals recorded in this study were below the threshold value set by JECFA [66], implying that the consumption of the examined fish species is safe without risk to human health. However, this value was higher than the results of previous reports on the Tendaho water reservoir [67]. The estimated weekly intake of Cd and Pb in these findings was far less than those reported by Dsikowitzky et al. [55] for *Oreochromis niloticus, Labeobarbus intermedius*, and *Clarias gariepinus* from the Awassa and Koka Rift Valley Lakes, Ethiopia.

According to USEPA [68], the recommended level for HQ is less than 1. The HQ for each metal in the current study was below 1, indicating that the health risk associated with the noncarcinogenic effect is relatively low. The hazard index (HI) cumulative heavy metals values in this study were less than 1 (Table 8), and this implies minimal noncarcinogenic risk to the adult population of consumers with respect to the estimated levels of Cu, Cr, Cd, and Pb. HI values less than one were considered; no health effect is expected to occur [69, 70]. The carcinogenic factors observed for Cr and Cd for fish consumption in the Borkena River were above the acceptable limit of cancer risk [45]. Taking into consideration that Cr and Cd are utmost toxic elements [71], our study suggests that consumers may face carcinogenic health threats from the point of Cr and Cd concentrations.

5. Conclusion

In conclusion, this study which focused on the concentration status of heavy metals was carried out by taking water and fish samples from the Borkena River. The study measured the presence of four heavy metals, including Cu, Cr, Cd, and Pb, in the water sample and some tissues of *L. intermedius*. The study revealed the presence of copper, chromium, and lead in the water sample at a level lower than the standard safe value except for cadmium. The concentration of heavy metals bioaccumulated in the liver was recorded as very high, followed by the kidney, while the muscle recorded the lowest concentration. It is noted that the risk of noncarcinogenic adverse health effects of fish intake is safe for consumers. However, there is a probability of potential risks to developing cancer relating to fish consumption in the future. Controlling waste at the source and implementing remediation strategies, a ban on agrochemicals, pesticides, wastewater treatment, and safe disposal of waste material along the Borkena River are required to reduce heavy metal pollution in the river.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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