Letter to Editor

Analysis of Heavy Metals of Muscle and Intestine Tissue in Fish – in Banan Section of Chongqing from Three Gorges Reservoir, China

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Received: June 27, 2006
Accepted: July 6, 2007

Abstract

The present study was carried out to investigate contamination of heavy metals in 19 fish species from the Banan section of Chongqing in the Three Gorges, Yangtze River. The results showed that the mean concentrations of heavy metals were higher in intestine than muscle, except zinc in upper strata. In the fish inhabiting the upper strata, there were significant differences between mean concentrations of As, Cr, Cu and Hg in muscle and intestine ($P < 0.05$). There were also significant differences between mean concentrations of Cr and Cu in muscle and intestine in the fish inhabiting middle strata. However, significant differences between mean concentrations of As, Cd, Hg, Pb and Zn were measured in fish inhabiting bottom strata in both intestine and muscle tissues ($P < 0.05$). For the fish inhabiting different strata, the concentrations of As, Cd, Cr, Cu, Hg and Pb in muscle and intestine of the fish from bottom strata (BS) were higher than those in both upper strata (US) and middle strata (MS); whereas a higher concentration of Zn was measured in muscle and intestine from fish inhabiting upper strata. Mean metal concentrations were found to be higher in age II than those in age I in *Coreius heterodon* (2- and 1-year odl fish respectively). The overall results indicated that fish muscle in the Banan section were slightly contaminated by heavy metals, but did not exceed Chinese food standards.

Keywords: The Banan Section; Three Gorges Reservoir; heavy metal; muscle; intestine; pollution-fish

Introduction

The Yangtze River is the longest and the most important navigable river in China. The Three Gorges Dam was constructed in the upper stream of the river and formed a reservoir with the biggest sluice capacity in the world. It will bring great economic benefits, whereas it will also probably result in some harm to the aquatic ecosystem. Water quality in the area has worsened with the rapid industrialization and urban development stimulated by the Three Gorges Project [1]. The condition of hydrology has been changed with construction of the dam. Velocity of water flow becomes slow to downstream and the capacity of water purification will be weakened. Great concern has arisen regarding environmental pollution in this region in recent years [1, 2].

Banan is a district near the Yangtze River of Chongqing city, which is the largest city in the Three Gorge area. It produces about 1.2 billion tons/year of wastewater, including 900 million tons of industrial and 300 million tons of domestic wastewater. Industry plants, such as pa-

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per, steel, silk, plating and chemical factories are located along the river, and effluents often cover the swirling waters with white foam. Urban garbage is piled up along the riverbanks and washed away during flood season or trapped in the Three Gorge reservoir [3].

During the past several decades, the increasing usage of heavy metals in industry has led to serious environmental pollution through effluents and emanations [4]. Under certain environmental conditions, heavy metals may be accumulated to a toxic concentration [5], and cause ecological damage [6]. Heavy metals were of particular concern due to their toxicity and ability to be bioaccumulated in aquatic ecosystems [7], as well as persistence in the natural environment. Among the different metals analyzed, lead (Pb), cadmium (Cd), mercury (Hg), chromium (Cr) and arsenic (As) are classified as chemical hazards and maximum residual levels have been prescribed for humans [8, 9, 10]. Essential metals, such as copper (Cu) and zinc (Zn), have normal physiological regulatory functions [11], but may also bioaccumulate and reach toxic levels [12]. Heavy metals pollution in aquatic environment has become a serious problem [13] and also an important factor in the decline of water sediments and fish quality.

Fish are one of the most important and the largest groups of vertebrates in the aquatic system. Trace metals can be accumulated via both food chain and water in fish [14]. Patrick and Loutit [15] reported biomagnification of Cr, Cu, manganese (Mn), iron (Fe), Pb and Zn from bacteria to tubificid worms in fish through the food chain.

Fish have been considered good indicators for heavy metal contamination in aquatic systems because they occupy different trophic levels with different sizes and ages [16]. Meanwhile, fish are widely consumed in many parts of the world by humans, and polluted fish may endanger human health.

In the present study, we selected fish in Banan section of Chongqing city and tried to apply some basis for environmental variance and quality of fish and aims:

1) to determine the levels of heavy metals (As, Cd, Cr, Cu, Hg, Pb and Zn) in the muscle and intestine tissue in order to assess fish quality.
2) to assess the health risk for humans.

Experimental Procedures

Sample Collection

Fish samples were collected in Banan section (Fig.1), located in upper reaches of the Three Gorge of China. Fish were bought in from fisherman in autumn 1997. Nineteen species (Table 1) were selected from all the locations for this study. Three species were from upper and middle strata, respectively, thirteen from bottom strata. At least three to five samples from each fish species were obtained. After capture, fish were immediately frozen at -20°C. All samples were cut into pieces and labeled, and then all sampling procedures were carried out according

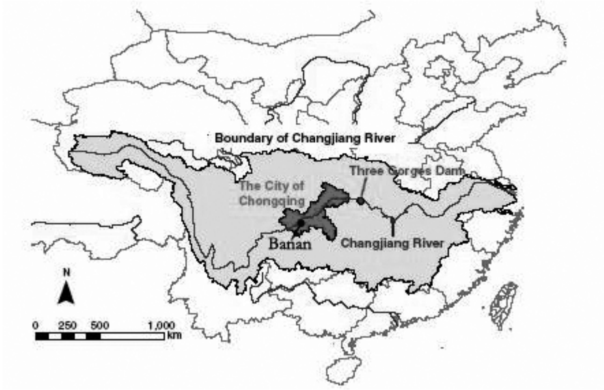

Fig.1. Location of sampling sites for fish samples in Banan section.

to internationally recognized guidelines[17]. The ages were determined by reading the annual ring structure of scales and otoliths. Scale samples for age determination of were taken from beneath the anterior portion of the dorsal fin, above the lateral line of the left side of the fish. Age was determined by counting summer and winter growth zones, which appear on calcified structures of fish body. Otoliths were also taken from the inner ear. Determination was performed under stereo microscope (Carl Zeiss).

Sample Preparation

Fish samples for heavy metals were put onto a dissection tray and thawed at room temperature. They were dissected using stainless steel scalpels and Teflon forceps using a laminar flow bench. A part of the muscle (dorsal muscle without skin) and the intestine (1 g) were removed and transferred in polypropylene vials. Subsequently, samples were put into an oven to dry at 90°C and reached constant weights in the oven. Before acid digestion, a porcelain mortar was employed to grind and homogenize the dry tissue samples. Aliquots of approximately 1 g dried intestine and muscle were digested in Teflon beakers for 12 h at room temperature, and then for 4h at 100°C with 5 ml ultrapure nitric acid (65%, Merck).

Sample Analysis

Heavy metals analysis: Cd, Cr and Pb were measured by graphite furnace atomic absorption spectrophotometry (Perkin-Elmer, 4100 ZL). Cu and Zn concentrations in the extracts were determined by flame atomic absorption spectrophotometry Perkin–Elmer 2100. As and Hg concentrations were determined with a Perkin–Elmer MHS-FIAS coupled to a Perkin–Elmer 4100 ZL spectrophotometer. Results are expressed as microgrammes per gram. The analytical procedure was checked using reference material (MESS-1, the National Center of Canada and CRM 277, the Community Bureau of Reference, Brussels, Belgium,

Table 1. The biological background information of fish

Species name (abbreviation)	Length (cm)	Weight (g)	Age	Main Foods	inhabit stratum
Hypophthalmichthys molitrix(HM)	20.5-36.7	*266-632*	II	Phytoplankton	US
Pseudobagrus fulvidraco(PF)	12.3-14.5	*35.2-40.1*	II	Plankton, inverte-brate	US
Hemiculter nigromarginis(HN)	9.5-12.6	*11.3-28.6*	II	organic-detritus, macrophyte, insect	US
Ctenopharyngodon idellus(CI)	30.5-45.1	*390-1360*	II	macrophyte	MS
Xenocypris argentead(XA)	13.5-16.2	*43.2-79.3*	II	Plankton, macro-phyte, organic-de-tritus	MS
Silurus soldatovi meridionalis(SS)	47-65	*615-2750*	II	fish	MS
Varicorhinus simus(VS)	13.2-18.6	*81-124*	II	periphytic algae	BS
Cyprinus carpio(CC)	21.5-28.7	*255-316*	II	macrophyte, algae, invertebrate	BS
Carassius auratus(CA)	12.5-15.7	*113-142*	II	invertebrate,	BS
Coreius heterodon(CH)	24.5-27.8	*295-349*	I & II	mollusk, insect, organic-detritus	BS
Coreius guichenoti(CG)	23.8-31.2	*295-386*	II	mollusk, insect, macrophyte, egg of fish	BS
Leiocassis longirostris(LL)	35.8-42.6	*754-1150*	I	fish, shellfish, mol-lusk, insect	BS
Leiocassis crassilabris(LC)	21.5-32.1	*282-433*	II	fish, shellfish, mol-lusk, insect, shrimp	BS
Leptobotia elongata(LE)	17.5-22.6	*85-138*	II	fish, shrimp, insect, zooplankton	BS
Rhinogobio typus(RT)	15.3-18.7	*58.1-71.3*	II	invertebrate, algae, organic-detritus	BS
Saurogobio dabryi(SD)	8.5-13.8	*35-66*	II	insect, zooplankton	BS
Hemimyzon abbreviata(HA)	9.3-11.6	*86-105*	III	invertebrate, or-ganic-detritus	BS
Rhinogobio cylimdricus(RC)	18.2-22.5	*135-169*	II	Insect, shrimp, fish, zooplankton	BS
Hemiculter leucisclus(HL)	7.9-11.2	*15-29*	II	insect, organic-detri-tus, macrophyte,	BS

* *US:* fish collected from upper strata; *MS:* fish collected from middle strata; *BS:* fish collected from bottom strata.

and details were in [18] and [19]. For each matrix, analyses of three blank samples were performed along with the samples. Quality control was assured by the analysis of reagent blank and procedural blanks.

Data Statistics

Statistics were performed using SPSS 11.5 software. ANOVA with post hoc test analyses based on Turkey was used to compare differences between samples. A P-value of 0.05 or less was considered statistically significant. For One-way ANOVA compared the metals concentration in intestine and muscle; for inhabit strata, different metals concentration in intestine and muscles were investigated by Turkey's multiple comparisons of means.

Results

Concentrations of Heavy Metals in Fish Muscle and Intestine

The mean concentrations of Arsenic were found to be 0.113 and 0.142μg/g in muscle and intestine (Table 3). Arsenic concentrations ranged from 0- 0.27μg/g in muscle and 0.05-0.43μg/g in intestine (Fig.2). Hemimyzon abbreviata had the highest As concentrations in muscle and intestine

Table 2. The concentrations of heavy metals (μg/g) compared in same strata between muscle and intestine

Sample	Inhabit strata	As	Cd	Cr	Cu	Hg	Pb	Zn
Muscle	Upper	0.03±0.02^{a}	0.004±0.003^{a}	0.07±0.03^{a}	0.21±0.09^{a}	0.01±0.01^{a}	0.05±0.04^{a}	10.4±5.3^{a}
Intestine	Upper	0.07±0.03^{b}	0.006±0.003^{a}	0.12±0.06^{b}	0.64±0.33^{b}	0.04±0.03^{b}	0.06±0.05^{a}	9.51±1.54^{a}
Muscle	Middle	0.11±0.04^{a}	0.004±0.001^{a}	0.17±0.09^{a}	0.26±0.15^{a}	0.02±0.01^{a}	0.04±0.03^{a}	5.15±3.93^{a}
Intestine	Middle	0.14±0.04^{a}	0.006±0.003^{a}	0.23±0.13^{b,}	0.39±0.18^{b}	0.03±0.01^{a}	0.06±0.03^{a,}	6.38±4.07^{a}
Muscle	Bottom	0.2±0.084^{a}	0.021±0.010^{a}	0.28±0.15^{a}	0.84±0.41^{a}	0.05±0.02^{a}	0.33±0.13^{a}	2.17±0.9^{a}
Intestine	Bottom	0.3±0.142^{b}	0.035±0.015^{b}	0.37±0.18^{a}	1.31±0.55^{a}	0.08±0.032^{b}	0.52±0.21^{b}	3.72±1.72^{b}
Criterion*		0.5	0.1	0.5	10	0.3	1	50

Data are presented as means ± S.E. of three Inhabit strata, muscle and intestine of the two paired tissue: ^{a}P>0.05, ^{b}P< 0.05, significantly different from other tissue. Criterion were from Chinese national criterion collection GB 2736-94: Healthy standard for fresh water fish. Criterion* are from Commission of the Chinese Criterion

Table 3. The mean concentrations of heavy metals (μg/g) in fish.

Sample	As	Cd	Cr	Cu	Hg	Pb	Zn
Muscle	0.113	0.0097	0.173	0.437	0.027	0.14	5.907
Intestine	0.142	0.0127	0.209	0.608	0.038	0.177	6.222

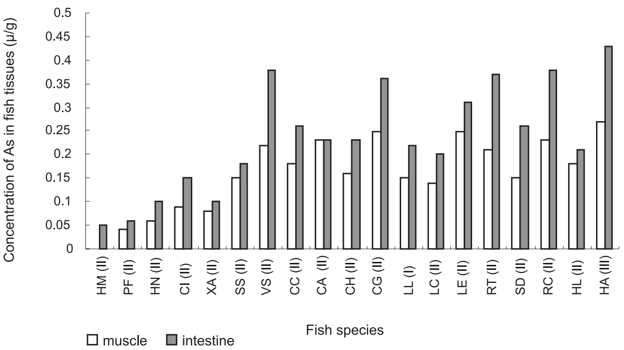

Fig. 2. Distribution of As in fish species.

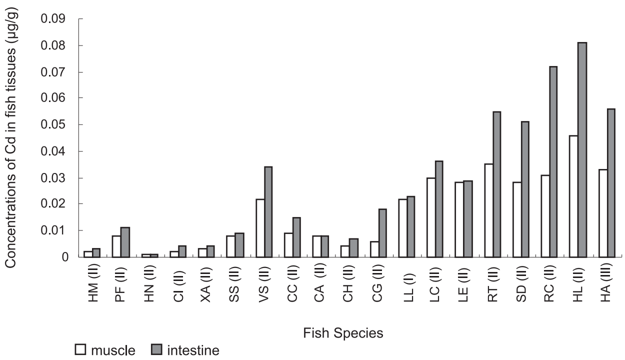

Fig. 3. Distribution of Cd in fish species.

(0.27 and 0.43μg/g, respectively). The lowest As concentrations were found in Hypophthalmichthys molitrix(not detective in muscle and 0.05μg/g in intestine).

The mean levels of cadmium in muscle and intestine were 0.0097μg/g and 0.0127μg/g, respectively (Table 3). The concentrations ranged from 0.001 to 0.046μg/g in muscle and 0.001 to 0.081μg/g in intestine (Fig. 3). The concentrations of cadmium were maximum value found to be 0.046 and 0.081μg/g in Hemibarbus labeo muscle and intestine. Least cadmium concentrations were found 0.001μg/g in Hemiculter nigromarginis muscle and intestine.

Chromium results obtained for different tissues are summarized in Table 3. The concentrations of chromium in the two tissues were different with a mean near 0.173μg/g in muscle and 0.209μg/g in intestine. Chromium was detected in all the samples and the concentrations were found to be 0.03–0.41μg/g in muscles, 0.05–0.45μg/g in intestines, respectively (Fig. 4).The highest concentration (0.41μg/g) was detected in Leptobotia elongata and the lowest was in Hypophthalmichthys molitrix (0.03μg/g) in muscle. Leptobotia elongata and Coreius guichenoti had the highest Cr values (0.45μg/g),while the lowest value (0.05μg/g) was found in Hypophthalmichthys molitrix in intestines.

The concentrations of copper in muscle tissue of fish were much lower than levels in intestine. The mean copper values were 0.437μg/g in muscle and 0.608μg/g in intestine (Table 3). Copper concentrations ranged from 0.1to 1.25μg/g in muscle and 0.17 to 2.33μg/g (Fig. 5). The lowest muscle copper concentrations were found to be 0.1μg/g in Ctenopharyngodon idellus and Hypophthalmichthys molitrix,while the highest was found to

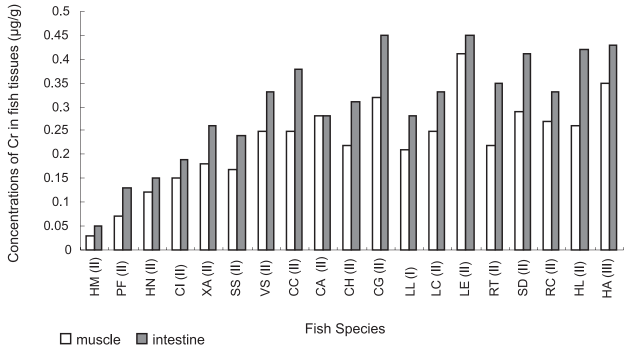

Fig. 4. Distribution of Cr in fish species.

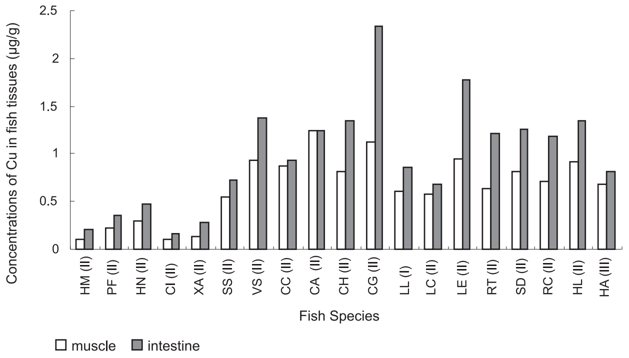

Fig. 5. Distribution of Cu in fish species.

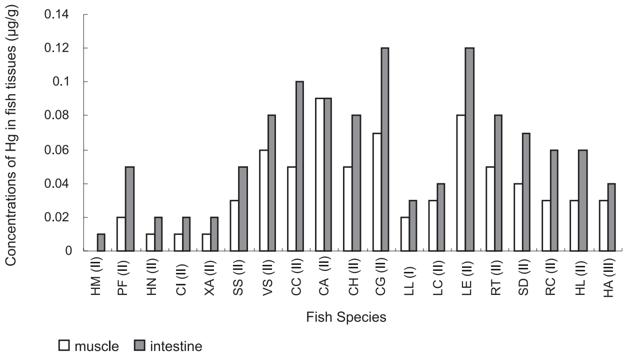

Fig. 6. Distribution of Hg in fish species.

be 1.25μg/g in Carassius auratus. The lowest intestinal Cu concentrations were measured in Ctenopharyngodon idellus(0.17μg/g). The highest Cu concentration (2.33μg/g) was detected in Coreius guichenoti in intestine.

Mercury results obtained for different tissues are summarized in Table 3.The concentrations of mercury, for the two tissues, were different, with a mean near 0.027μg/g in muscle and 0.038μg/g in intestine. Mercury concentrations were found to be not detectable – 0.09μg/g in muscles and 0.01-0.12μg/g in intestines (Fig. 6). Hypophthalmichthys molitrix had lowest concentration (not detectable) and Carassius auratus had highest concentration (0.09μg/g) in muscle. Coreius guichenoti and Leptobotia elongata had highest Hg concentrations (0.12μg/g) in intestines. The lowest intestinal Hg value was found to be 0.01μg/g in Hypophthalmichthys molitrix.

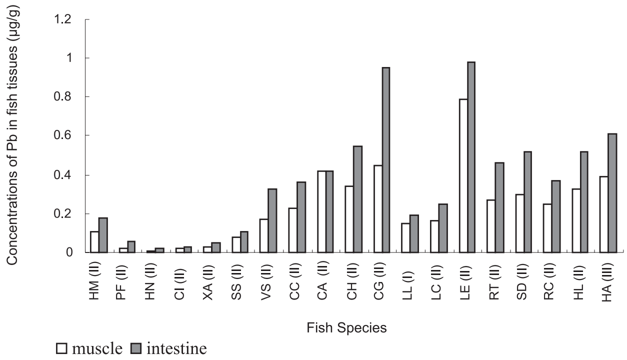

Fig. 7. Distribution of Pb in fish species.

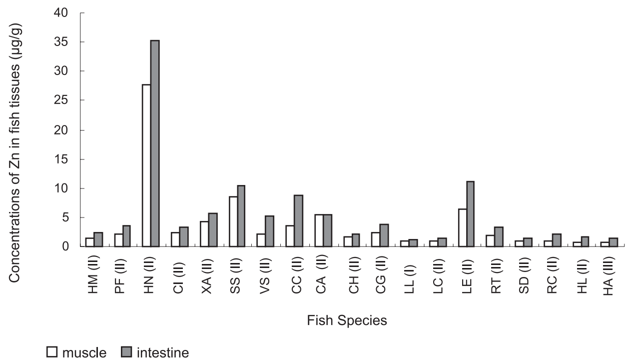

Fig. 8. Distribution of Zn in fish species.

On average, the content of lead in muscle was lower than that in intestine; however, the mean values were 0.14μg/g in muscle and 0.177μg/g in intestine (Table 3). The values reached were 0.01-0.79μg/g in muscles and 0.02-0.98μg/g in intestines (Fig.7). The highest concentrations of lead were found to be 0.79μg/g and 0.98μg/g in Leptobotia elongata muscle and intestine (Fig. 6). The lowest lead concentrations were measured to be 0.01μg/g in muscle and 0.02μg/g in intestine in Hemiculter nigromarginis.

The mean zinc concentrations were 5.907μg/g in muscle and 6.222μg/g in intestine (Table 3). Zinc values in fish species varied from 0.78-27.6μg/g in muscle and 1.25-35.3μg/g in intestine. The maximum zinc level was observed in *Hemiculter nigromarginis* muscle and intestine (27.6μg/g and 35.3μg/g, respectively), while the minimum zinc level in *Hemibarbus labeo* muscle and *Leiocassis longirostris* intestine (0.78μg/g and 1.25μg/g, respectively) (Fig. 8).

Concentrations of Heavy Metals in Fish in Strata

The mean concentrations of heavy metals (As, Cd, Cr, Cu, Hg, Pb and Zn) in muscle and intestine of fish were shown in Table 2. The concentrations of heavy metals in intestine were higher than those in muscle except zinc in upper strata. The concentrations of seven

Table 4. The concentrations of heavy metals (μg/g) compared in different strata in muscle and intestine.

Sample	Inhabit strata	As	Cd	Cr	Cu	Hg	Pb	Zn
Muscle	Upper	0.03±0.02[a]	0.004±0.003[a]	0.07±0.03[a]	0.21±0.09[a]	0.01±0.01[a]	0.05±0.04[a]	10.4±5.3[c]
Intestine	Upper	0.07±0.03[a]	0.006±0.003[a]	0.12±0.06[a]	0.64±0.33[a]	0.04±0.03[a]	0.06±0.05[a]	9.51±1.54[c]
Muscle	Middle	0.11±0.04[b]	0.004±0.001[a]	0.17±0.09[b]	0.26±0.15[a]	0.02±0.01[b]	0.04±0.03[a]	5.15±3.93[b]
Intestine	Middle	0.14±0.04[b]	0.006±0.003[a]	0.23±0.13[b,]	0.39±0.18[b]	0.03±0.01[a]	0.06±0.03[a,]	6.38±4.07[b]
Muscle	Bottom	0.2±0.084[c]	0.021±0.010[c]	0.28±0.15[c]	0.84±0.41[c]	0.05±0.02[c]	0.33±0.13[c]	2.17±0.9[a]
Intestine	Bottom	0.3±0.142[c]	0.035±0.015[c]	0.37±0.18[c]	1.31±0.55[c]	0.08±0.032[b]	0.52±0.21[c]	3.72±1.72[a]

Data are presented as means ± S.E.M. of three Inhabit strata, muscle and intestine of the two paired tissue: [a]P>0.05, [b]P< 0.05, [c]P < 0.01, significantly different from other tissue.

heavy metals in intestine were higher than in muscle, in the fish inhabitated in upper strata. The values of As, Cr, Cu and Hg in intestine were significantly higher than those in muscle ($P<0.05$). There were no significant differences between intestine and muscle in the fish inhabitated in middle strata, except Cr and Cu ($P<0.05$). In the fish inhabitated in bottom strata, As,Cd, Hg, Pb and Zn in intestine had significant difference than those in muscle ($P<0.05$);There were no significant difference of Cr and Cu between the intestine and muscle in the fish.

Table 4 demonstrates that the concentrations of heavy metal in muscle and intestine were diversity in difference strata. The mean concentrations of As, Cd, Cr, Cu, Hg and Pb in muscle in bottom strata were significantly different from those in upper strata ($P<0.01$). The mean concentration of Zn in muscle in upper strata was significantly higher ($P<0.01$) than those in bottom strata. There were significant higher values ($P<0.01$) of As, Cd, Cr, Cu and Pb in intestine in bottom strata than those in upper strata. The value of Zn in intestine in bottom strata had higher concentrations ($P<0.05$) than those in upper strata, while the Zn concentration were significantly higher ($P<0.01$) in upper strata than those in bottom strata.

As showed in Table 4, the mean concentrations of As, Cr and Hg in muscle in middle strata were significantly different from those of upper strata ($P <0.05$);The mean concentrations of Zn in muscle in middle strata were lower than those in upper strata. In the middle strata, the mean concentrations of As,Cr and Hg in muscle were significantly higher ($P <0.05$) than those in upper strata, while the Zn concentration in middle strata were lower than those in upper strata.The mean concentrations of As, Cr and Cu in middle strata were significantly different from those of upper strata ($P <0.05$), while the mean concentrations of Hg and Zn were lower than those in upper strata.

In general, different tissues showed different capacities for accumulating heavy metals. The higher metal concentrations were found in the intestine. However, the muscle tended to accumulate less metal. Heavy metal levels considerably varied among individuals of the same species. The lower age of same species accumulated more heavy metal (Figs. 9 and 10). Higher concentrations of seven heavy metals were found in age II than in age I in *Coreius heterodon*.

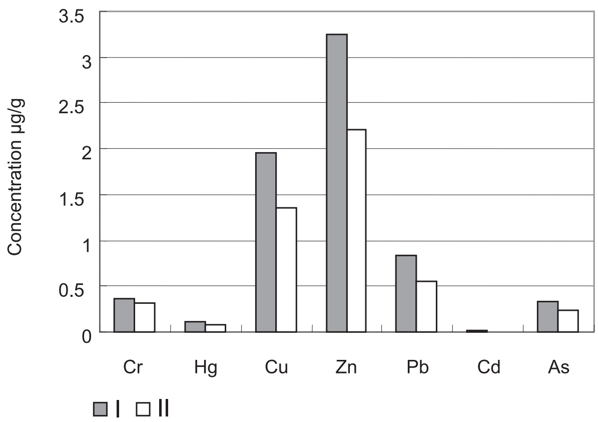

Fig.9. Heavy metals in intestine in ages I and II in *Coreius heterodon.*

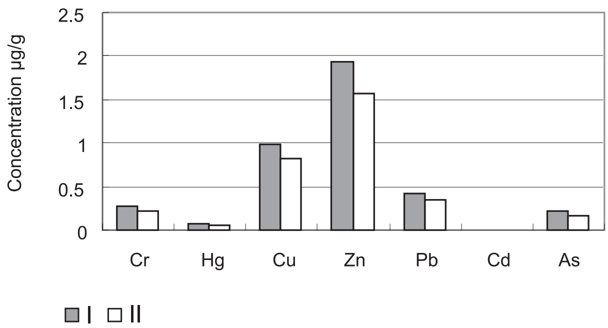

Fig.10. Heavy metals in Heavy metals in muscle in II and I ages in Coreius heterodon.

Discussion of Results

The arsenic values are lower than the concentration from an earlier report [20]. Chen et al. [21] showed that long-term exposure to ingested inorganic As in groundwater could induce blackfoot disease. Chronic exposure to inorganic arsenic may give rise to several health effects, including to the gastrointestinal tract, respiratory tract, skin, liver, cardiovascular system, hematopoietic system and the nervous system [22].

Cadmium concentrations are lower than those reported earlier by Mendil et al. [23] in fish from Turkish Lakes. These values were found to be lower than the acceptable limit proposed by the EU [24] and TFC [25]. The European Community proposed threshold values of metal concentrations in fish muscle of only 0.05μg/g of Cd [26]. Cadmium can be accumulated with metallothioneins and uptake of 3–330mg/day is toxic and 1.5–9 mg/day is lethal to humans [27]. Cadmium injures kidneys and cause symptoms of chronic toxicity, including impairment of kidney function, poor reproductive capacity, hypertension, tumours and hepatic dysfunction [28].

The Cr levels in the samples were much less than those reported by Eisenberg and Topping [29]. Chromium contents were well within the limits prescribed by the FDA. The values were also within the limits of 12– 13μg/ g[30]. The World Health Organization (WHO) has proposed that chromium (VI) is a human carcinogen. Several studies have shown that chromium (VI) compounds can increase in risk of lung cancer [31]. Animal studies have also shown an increase in risk of cancer [32].

Copper concentrations are lower than the values from earlier reports [33]. The copper contents in the samples were much less than the FAO-permitted level of 30μg/g [8] and Chinese food standards (10μg/g) [34]. Excessive intake of copper may lead to liver cirrhosis, dermatitis and neurological disorders [35].

The Hg values were well below the EC recommended value of 0.5–1.0μg/g [24]. Mercury concentrations of 5 ppm (wet weight) in fish muscle can be associated with emaciation, decreasion in coordination, losing appetite, and mortality in fish [36]. Mercury is a known human toxicant and the primary source of mercury contamination in people is through eating fish. Mercury pollution in aquatic ecosystems has received great attention since the discovery of mercury as the cause of Minamata disease in Japan in the 1950s. Mercury poisoning in the adult brain is characterized by damage of discrete visual cortex areas and neuronal loss in the cerebellum granule layer [37]. On the other hand, mercury poisoning during nervous system development may cause catastrophic consequences for infants who exhibit widespread neural impairment [38].

In general, lead values obtained are lower than those reported previously [33]. The fact that toxic metals are present at high concentrations in fish is of particular importance in relation to the FAO/WHO [39] standards for Pb. The maximum permissible doses for an adult are 3 mg Pb per week, but the recommended doses are only one-fifth of those quantities [39]. Chinese food standards [34] are 1μg/g. Turkish acceptable limits and EU limits are 0.4μg/g. The range of international standards for Pb in fish is 0.5–10μg/g [24, 25]. Lead causes renal failure and liver damage in humans [40].

The zinc values were similar to the values of Mendil et al. [23] and higher than those reported in the literature [41]. Marcovecchio [42] recorded mean values of zinc in muscle of 48.8μg/g (wet weight) in *Mugil liza*, and Yilmaz [43] found 51.13μg/g (wet weight) in muscle in *Mugil cephalus*. The measured values was one-fifth as low (2.17-10.4μg/g in muscle and 3.72-9.51 μg/g in intestine, indicating lower metal-contamination in the environment. There are no guidelines on acceptable levels of Zn in muscle of fish by FAO/WHO [39]. Comparing our average values with Chinese food standards (50μg/g)[34], Canadian food standards (100μg/g), Hungarian standards (150μg/g) and a range of international standards (40–100μg/g) [44], our results showed that the values are lower than these guidelines. Therefore, we can conclude that these metals have posed no threat for consumption of these fish. Toxicity due to excessive intake of zinc has been reported to cause electrolyte imbalance, nausea, anaemia and lethargy [45].

The Joint FAO/WHO [57] has set a limit for heavy metal intake based on bodyweight. For an average adult (60 kg body weight), the provisional tolerable daily intake for lead, copper and zinc are 214μg, 3 and 60 mg for muscle, respectively[46]. These values are similar to the literature value of Ahmet et al. [47] and higher than other literature values [41].

Heavy metals, such as lead (Pb), mercury (Hg) and cadmium (Cd) are dangerous for human health because of their accumulation properties [48]. Compared to Chinese food standards, muscle Cr from bottom fish exceed more than 50% of the Chinese food standards, and might impact human health.

For muscle tissue we found a significant increase in heavy metal concentrations with increasing fish age. Higher concentrations of metals were found in younger fish and this generally reflects the short residence time of these metals within the fish, combined with the higher rate of metabolism compared to older organisms [49].

The predominant pathways for heavy metal uptake, target organs, and organism sensitivity are highly variable, and are dependent on factors such as metal concentration, age, size, physiological status, habitat preferences, feeding behavior, and growth rates of fish [50]. Principal component analyses, using the concentrations of metals as independent variables, were unable to demonstrate differences between the sites in terms of the suite of metals accumulated by the fish or their distribution in the fish. Despite their habitat, age and dietary differences, fish were accumulating metals in essentially the same manner [20].

Metals bioaccumulation through aquatic food webs to fish, humans and other piscivorous animals are of environmental and human health concern [51]. Although there are no high levels of heavy metals in fish, a potential danger may occur in the future, depending on agricultural and industrial development in this region. The concentrations are below the limit values for fish proposed by FAO [8].

The concentrations of heavy metals in intestine were higher than in muscle. According to Deb [52], metals may be in high concentrations in the gills, intestine and digestive glands. These organs have relatively high potential for metal accumulation. High levels of heavy metals were found in intestine of fish. Although fish intestines are seldom consumed, it usually accumulated more heavy metals in this study and might represent good biomonitors of metals present in the surrounding environment.

Some metals are natural constituents of the environment. Copper and zinc, for example, are essential elements for living organisms, but it also shows toxicity if the content surpass HS. Other metals, such as Hg and Cd, in contrast, have no biological role. At higher concentrations, heavy metals can become toxic for living organisms. Therefore, at the top of the tropic chain, human beings are especially sensitive to these contaminants due to bioaccumulation. This possibility provides a further reason for compiling the available information in the heavy metal field. Studies from the field and laboratory experiments showed that accumulation of heavy metals in a tissue is mainly dependent upon water concentrations of metals and exposure period [53]. Two heavy metals, including mercury and lead, had exceeded permissible criterions in the river sections flowing past Chongqing [54]. As a result, the heavy metals in fish in the Three Gorges may have worsened with the construction of the Three Gorges Dam.

Fish live in the water and absorb metals biocentrated by humans. More than 10,000 local people suffered from Minamata disease because they ate fish polluted by methyl mercury [38]. With the construction of the Three Gorges Dam, the content of some heavy metals might be changed in fish. Xu [55] estimated that activation of mercury will be strengthened and accelerate enrichment of fish to mercury after the construction of the dam. Mercury in fish will be added to 0.35 to 1.5 times. Increase of residual pollutant in fish endangers safety of ecosystem and human health. The bioaccumulation of heavy metals in fish should be researched due to the change of ecosystem in the Three Gorges Reservoir, and ecological safety of pollutants should be further investigated.

Conclusion

This study was carried out to provide information on heavy metal concentrations of muscle and intestine tissue in fish from the Banan section of Chongqing from the Three Gorges Reservoir, China. All results were well below the limits for fish proposed by Chinese food standards for fish. According to our results, the examined fish were within the limits for human consumption. High levels of heavy metals were found in intestines while the lower levels in muscle of species except Zn in upper strata. For the fish inhabitated in different strata, the concentrations of As, Cd, Cr, Cu, Hg and Pb accumulated in muscle and intestine the fish of bottom strata were higher than those in the upper strata and middle strata. Mean metal concentrations were found to be higher in age II than those in age I in *Coreius heterodon*. Although levels of heavy metals are not high, a potential danger may emerge in the future depending on the industrial wastewaters and domestic activities in this region.

Acknowledgements

This research was supported in part by grants from the Chinese National Distinguished Youth Science Foundation (39925007), China 863 High-Tech Program (2002AA601021), and the Chinese Academy of Science Knowledge Innovation Project (KSCX22SW2102). We are grateful for the constructive criticisms offered to the draft by two anonymous referees. Cheng S.P. Liang W. and He H. improved the language of the manuscript and we also thank the members of the Purification and Rehabilitation Ecology Group.

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