Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Fingerprint characteristics and health risks of trace metals in market fish species from a large aquaculture producer in a typical arid province in Northwestern China

Xu-Nuo Wang \textsuperscript{a,d}, Yang-Guang Gu \textsuperscript{a,b,c,*}, Zeng-Huan Wang \textsuperscript{a,d}

\textsuperscript{a} South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Guangzhou 510300, China
\textsuperscript{b} Key Laboratory of Fishery Ecology and Environment, Guangdong Province, Guangzhou 510300, China
\textsuperscript{c} Key Laboratory of Open-Sea Fishery Development, Ministry of Agriculture and Rural Affairs, Guangzhou 510300, China
\textsuperscript{d} Key Laboratory of Aquatic Product Processing, Ministry of Agriculture and Rural Affairs, No. 213, Huadu Avenue East, Guangzhou 510800, China

A B S T R A C T

Concentrations of nine metals were measured in eight common cultured fish species obtained from forty-three aquatic product markets across three cities in Xinjiang province, to establish fingerprint characteristics and assess potential human health risks due to the consumption of fish. Metal levels (μg/kg, wet weight) in fish muscles were: 1204.88–5113.19 Al, 2.09–12.44 V, 6.10–31.86 Cr, 2368.80–8949.52 Fe, 2.01–10.26 Co, 4082.72–12785.68 Zn, 174.89–763.83 Cu, 0.33–2.24 Cd, and 5.74–9.90 Pb. Fingerprint analysis revealed that the studied fish species from the three cities exhibited a similar pattern of distribution. From the viewpoint of human health, the assessment of non-carcinogenic risk indicated no significant adverse health effects due to consumption of the assessed fish species.

© 2020 Elsevier B.V. All rights reserved.

1. Introduction

Food safety is increasingly elicited attention with China’s rapid economic growth (Lam et al., 2013; Lu et al., 2015). It is believed that the aquatic products are more safety than terrestrial animal products, particularly coronavirus pandemic outbreak in Wuhan of China. Identification the geographical origins of foods is very important for food safety. Fingerprint characteristics of trace metals are patterns of elemental composition, which are used to identify the geographical origins of agricultural products and fishes (Vasconcelos et al., 2007; Wang et al., 2020). A series of studies revealed that agricultural products and fishes could be identified by fingerprint-characteristic technique (Liu et al., 2019; Vasconcelos et al., 2007; Wang et al., 2020). However, identifying the fish geographical origins based on muscles are unknown.

Trace metals are natural constituents of the earth’s crust and ubiquitous throughout the environment (Pan and Wang, 2012; Wedepohl, 1995). Trace metals present in the environment, originate primarily from natural processes but can also result from the accumulation of metals released from anthropogenic activities (Hu and Cheng, 2013). The major anthropogenic inputs of trace metals to the environment are via fossil fuel, industrial plants, waste disposal, mining and smelting, urban runoff, combustion of biomass, agricultural and horticultural materials (Bandowe et al., 2014; Hu and Cheng, 2013). Emitted trace metals enter aquatic systems primarily through domestic wastewater effluents, coal-burning power plants, non-ferrous metals smelters, sewage sludge and atmospheric deposition (Nriagu and Pacyna, 1988).

* Corresponding author at: South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Guangzhou 510300, China.
E-mail address: hydrobio@163.com (Y.-G. Gu).
Table 1
Characteristics of fish samples of the study.

| Fish species               | Body length (cm) | Body weight (g) |
|---------------------------|------------------|-----------------|
| Cyprinus carpio           | 45–56            | 1023–1378       |
| Aristichthys nobilis      | 45–67            | 1533–1887       |
| Hypophthalmichthys molitrix| 45–62           | 1522–1630       |
| Ctenopharyngodon idellus   | 41–53            | 898–1285        |
| Oreochromis spp            | 18–23            | 546–581         |
| Carassius auratus         | 15–18            | 317–360         |
| Ophiocephalus argus        | 38–43            | 776–988         |
| Scophthalmus maximus       | 30–38            | 813–856         |

Trace metals are generally classified as potentially toxic or nutritionally essential. Some trace metals such as Fe, Cu, Zn, Cr, Co, Mn, Mo and Se have key biological functions and are essential at low concentrations. However, some metals including Cd, Pb and As have no biological functions and are toxic even at low concentrations (Amaral et al., 2008; Bandowe et al., 2014; Zoroddu et al., 2019). Furthermore, even at low exposure levels, toxic metals can negatively affect human health when ingested over extended periods and even essential metals may have toxic effects when intake exceeds threshold concentrations. Fish are important food source for humans, as they are abundant in protein, vitamins, essential minerals and unsaturated fatty acids (Gu et al., 2018a; Mwakalapa et al., 2019). Based on their rich nutrients as well as delicious tastes, per capita fish consumption is increasing dramatically in China since 1980s (Fu et al., 2019; Gui et al., 2018) and per capita fish consumption has increased dramatically in China since the 1980s (Gu et al., 2018b, 2015b; Wang and Tan, 2019). Fish commonly accumulate trace metals from the aquatic environment and their diet (Gu et al., 2018b, 2015b; Wang and Tan, 2019). Consequently, trace metal pollution is concentrated in fish tissues, threatening fish health and posing a risk to humans and other animals consuming fish (Gu et al., 2015a; Türkmen et al., 2009; Zhang and Wang, 2012).

Northwestern China, comprising Shanxi, Qinhai, Gansu, Xinjiang and Ningxia provinces, is a typically arid region. The farmland soils and cities in this region are contaminated with trace metals, resulting in trace metals being released into the aquatic ecosystem (Gu and Gao, 2017; Niu et al., 2013). Xinjiang is located in northwestern China and the hinterland of Eurasia, covering an area of 1.66 million km² and accounting for one sixth of Chinese territory (GXJ, 2019). Xinjiang is surrounded by high mountains such as the Altay, Tarbagatai, Pamir and Karakoram, and Kunlun Mountains (GXJ, 2019). Northwestern China is classified as an arid region, with an average annual rainfall of only 154.4 mm (GXJ, 2019). Xinjiang, however, is substantially nurtured by mountain snowmelt and runoff, forming over 570 rivers, while also containing 139 lakes and 479 reservoirs (GXJ, 2019). These abundant water resources have resulted in Xinjiang containing the largest aquaculture producer in Northwestern China (Gui et al., 2018). However, there are no currently available studies on the fingerprint characteristic features and health risks of heavy metals in aquatic products from Northwestern China. To fill this gap, this study (1) analyzed the concentrations of trace metals in commonly available market fish species, (2) characterized fingerprint information for the metal content of fish, (3) and estimated the potential human health risks associated with the ingestion of these fish species.

2. Material and methods

2.1. Sample collection and analytical methods

Xinjiang's aquaculture occupies an important role in western China and aquaculture in Xinjiang produced 157,273 tons of farmed fish in 2017 (Du, 2012; Gui et al., 2018; Yu, 2017). The studied fish species Ctenopharyngodon idellus, Cyprinus carpio, Hypophthalmichthys molitrix, Carassius auratus, and Aristichthys nobilis are ranked in the top fifth of fish production (Yu, 2017).

In August 2018, a total of eight fish species were procured alive from fourteen aquatic product markets, across the cities Yining, Aksu and Urumchi in Xinjiang province, including C. carpio, A. nobilis, H. molitrix, C. idellus, Oreochromis spp, C. auratus, Ophiocephalus argus and Scophthalmus maximus (Fig. 1), with the ranges in physical characteristics of samples summarized in Table 1. The fish were slaughtered instantly and forty-three individual fish samples representing eight fish species were collected and transferred to the laboratory and rinsed with distilled water three times. The fish were then dissected to remove dorsal muscles (>200 g) which were immediately frozen and stored in polyethylene bags at −20 °C prior to metal analysis. The detailed procedures for metal extraction used in this study have been previously described (Gu et al., 2018a).

2.2. Quality assurance/quality control

All samples were analyzed in triplicate. Analytical blank were applied to perform background correction of results. Two China National Standard Reference Materials GBW10050 (GSB-28) shrimp and GBW10024 (GSB-15) scallop were analyzed to check the recovery of the analytical method, which fell within a satisfactory range (97% to 109%). Metal concentrations in samples were measured using inductively coupled plasma mass spectrometry (ICP-MS, 7700S, Agilent, USA).
2.3. Health risk assessment model

The non-carcinogenic human health risk due to the ingestion of fish muscles was appraised by the target hazard quotient (THQ). Higher THQ values mean a higher probability of experiencing long-term non-carcinogenic risks (Gu and Gao, 2017). If the THQ is below 1, there are no adverse health effects and if the THQ exceeds 1, then adverse health effects are present (Mwakalapa et al., 2019). The THQ is established using Eq. (1) as follows:

$$THQ = \frac{EF \times ED \times FIR \times C}{RfD \times BW \times AT} \times 10^{-3}$$  \hspace{1cm} (1)

where, EF is the exposure frequency to metals (365 days/year); ED is the exposure duration (76.34 years in China) equivalent to life expectancy (CNBS, 2019); FIR is the ingestion rate of aquatic products (9.04 g/day) in Xinjiang province in 2017 (CNBS, 2019); C is the metal concentration in fish muscles (mg/kg wet weight); RfD is the oral reference dose (mg/kg/day); the RfD values (mg/kg/day) are based on 1.0 for Al, 5.0E−03 for V, 7.0E−0.1 for Fe, 3.0E−04 for Co, 3.0E−01 for Zn, 4.0E−02 for Cu, 1.0E−03 for Cd, 2.0E−2 for Pb (USEPA, 2018), and 3E-03 for Cr (Zhang and Wang, 2012); BW is the average body weight for an adult individual (China adult: 58.1 kg); AT is the averaged exposure time for non-carcinogens 27,864 days (assuming exposure for 76.34 years and 365 days/year) (Gu et al., 2018a).

Furthermore, exposure to two or more metals may lead to additive and/or interactive effects. In order to estimate the risk of exposure to multiple metals, the total THQ is the sum of individual metal THQ values, based on the method of Gu et al. (2017):

$$Total\,THQ = THQ(metal\,1) + THQ(metal\,2) + \ldots + THQ(metal\,n)$$  \hspace{1cm} (2)
3. Results and discussion

3.1. Heavy metal concentration

The concentrations of 9 trace metals in fish samples are shown in Table 2. The overall mean trace metal concentrations decreased in the ranked order of Zn > Fe > Al > Cu > Cr > Pb > V > Co > Cd. The highest concentrations of V, Cr, Cu and Cd in fish species were all found in samples from Yining city, while the maximum Al, Fe, Co and Zn concentrations in fish species were detected in samples from Aksu city. The highest Pb concentrations in fish species was found in samples from Urumchi city. The trace metal concentrations in all fish samples from all three cities were lower than the permissible limits for human consumption in Chinese and FAO guidelines (Table 2).

The Al and Zn concentrations in fish samples were comparatively very low (1204.88–5113.19 µg/kg for Al and 4082.72–12785.68 µg/kg for Zn) across all three cities in Xinjiang. The highest Al and Zn concentrations were both found in C. carpio from Aksu city, at 5113.19 µg/kg and 12785.68 µg/kg, respectively. The V concentrations detected in fish species varied from 2.09 to 12.44 µg/kg across the three cities. The maximum V concentration of 12.44 µg/kg was detected in A. nobilis.
Fig. 2. Fingerprint characteristics of various fish species in three cities in Xinjiang province and fingerprint characteristics of soil background values in Xijiang prefecture. The relevant trace metal background data values in Xijiang are based on the reported natural background values of soil elements in China (CEMS, 1990).

from Yining city. Across the three cities the Cr and Cd concentrations ranged from 6.10 to 31.86 µg/kg and from 0.33 to 2.24 µg/kg, respectively. The highest Cr and Cd concentrations of 31.86 µg/kg and 2.24 µg/kg, respectively, were both detected in O. argus from Yining city.

Among all three cities, the Fe and Co concentrations detected in fish muscle tissues ranged from 2368.80–8949.52 µg/kg and 2.01–10.26 µg/kg, respectively. The maximum Fe and Co concentrations of 8949.52 µg/kg and 10.26 µg/kg were both found in H. molitrix collected from Aksu city. The Cu and Pb concentrations detected in fish muscle tissues across all three cities, varied from 174.89 to 763.83 µg/kg and from 5.74 to 9.90 µg/kg, respectively. The highest Cu level of 763.83 µg/kg was observed in C. carpio from Yining city. The maximum Pb concentration of 9.90 µg/kg, was found in H. molitrix.

As shown Table 3, compared with previous reported literatures in China, the concentrations of trace metals in the present study were lower than those in fishes from Pearl River Delta (Cheng et al., 2013), Chendu (Xu et al., 2019), Nanjing (Fu et al., 2013), Changshu (Fu et al., 2013), and Taihu Lake (Fu et al., 2013), and comparable to this from Lhasa (Jiang et al., 2014).

3.2. Fingerprint analysis

The results of fingerprint analysis in fish species from the three cities in Xinjiang province are illustrated in Fig. 2. The studied fish species from all three cities presented a similar pattern of distribution based on multi-metal fingerprint analysis of fish muscle tissues, indicating that these fish species had a similar mechanism of bioaccumulation for these metals. The top-three wave crests in fish muscle tissues were observed in Al, Fe and Zn locations and the top-two wave peaks in Xinjiang soil background values were found in Al and Fe. The Zn wave peak in fish muscle tissues were attributed to fish biomagnification (Cheng et al., 2013). Similar fingerprint features were also found for both fish muscles and soil background values, implying that these species can reflect their living environments and may be cultivated in the Xinjiang Uygur Autonomous Region. Therefore, the results of fingerprint analysis revealed that multi-metal composition in fish muscles could identify the fish geographical origins.
3.3. Health risk assessment

The appraised fish consumption THQ values and TTHQ values for inhabitants of the three cities of Xinjiang province are illustrated in Fig. 3. The TTHQ values were $9.51 \times 10^{-3} \pm 3.37 \times 10^{-3}$ for Yining, $1.23 \times 10^{-2} \pm 4.24 \times 10^{-3}$ for Aksu and $8.75 \times 10^{-3} \pm 2.25 \times 10^{-3}$ for Urumchi. In Yining city, the average THQ values were $3.31 \times 10^{-4} \pm 2.34 \times 10^{-4}$ for Al, $1.51 \times 10^{-4} \pm 1.86 \times 10^{-4}$ for V, $8.96 \times 10^{-3} \pm 1.90 \times 10^{-3}$ for Pb. In Aksu city, the average THQ values were $4.73 \times 10^{-4} \pm 3.45 \times 10^{-4}$ for Al, $2.09 \times 10^{-4} \pm 1.71 \times 10^{-4}$ for V, $6.10 \times 10^{-4} \pm 1.16 \times 10^{-4}$ for Cr, $1.55 \times 10^{-3} \pm 5.64 \times 10^{-4}$ for Fe, $3.62 \times 10^{-3} \pm 1.95 \times 10^{-3}$ for Co, $4.45 \times 10^{-3} \pm 2.53 \times 10^{-3}$ for Zn, $1.26 \times 10^{-3} \pm 3.03 \times 10^{-4}$ for Cu, $1.07 \times 10^{-3} \pm 2.25 \times 10^{-3}$ for Cd. In Urumchi city, the average THQ values were $3.46 \times 10^{-4} \pm 1.69 \times 10^{-4}$ for Al, $1.84 \times 10^{-4} \pm 8.55 \times 10^{-5}$ for V, $5.28 \times 10^{-4} \pm 2.09 \times 10^{-4}$ for Cr, $1.07 \times 10^{-3} \pm 4.62 \times 10^{-4}$ for Fe, $2.55 \times 10^{-3} \pm 1.28 \times 10^{-3}$ for Co, $2.88 \times 10^{-3} \pm 7.91 \times 10^{-4}$ for Zn, $1.10 \times 10^{-3} \pm 2.93 \times 10^{-4}$ for Cu, $9.21 \times 10^{-5} \pm 3.66 \times 10^{-5}$ for Cd, and $6.24 \times 10^{-6} \pm 1.76 \times 10^{-6}$ for Pb. Accordingly, both the values of THQ and TTHQ in the three cities were significantly lower than 1, indicating that metal concentrations observed in the fish muscle tissues posed no significant risk to health for consumers.

4. Conclusions

Aquatic product quality safety has become a major health concern worldwide. In the present study, an investigation into the concentrations of trace metals in fish species was performed, using commercially available fish samples from three cities in Xinjiang. The overall mean trace metal concentrations were ranked in the order: Zn > Fe > Al > Cu > Cr > Pb > V > Co > Cd. Trace metal concentrations in all of the fish species were less than the permissible limits for human consumption according to the Chinese mandatory standards (GB 2762–2012) and FAO guidelines. Fingerprint analysis showed that all fish species had a similar pattern of bioaccumulation of these metals and had comparable living environments. In terms of THQ and TTHQ methods, the health risk evaluation in the present study indicated that the human health risks associated with trace metal exposure via consumption of these fish species were all negligible.
Xu-Nuo Wang: Investigation, Data curation, Writing - original draft. Yang-Guang Gu: Supervision, Conceptualization, Visualization, Writing - review & editing. Zeng-Huan Wang: Methodology, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This study was funded by the National Key R&D Program of China (2019YFD0901105), the Key Laboratory of Fishery Ecology and Environment of Guangdong Province, China (FEEL-2017-14) and the Guangdong Natural Science Foundation, China (2018A030313037).

References

Amaral, A.F.S., Arruda, M., Cabral, S., Rodrigues, A.S., 2008. Essential and non-essential trace metals in scalp hair of men chronically exposed to volcanogenic metals in the Azores, Portugal. Environ. Int. 34 (8), 1104–1108.
Bandowe, B.A.M., Bigalke, M., Boamah, L., Nyarko, E., Saalia, F.K., Wilcke, W., 2014. Polycyclic aromatic compounds (PAHs and oxygenated PAHs) and trace metals in fish species from Ghana (West Africa): Bioaccumulation and health risk assessment. Environ. Int. 65, 135–146.
CEMS (China Environmental Monitoring Station), 1990. Natural Background Values of Soil Elements in China. China Environmental Science Press.
Cheng, Z., Man, Y.B., Nie, X.P., Wong, M.H., 2013. Trophic relationships and health risk assessments of trace metals in the aquaculture pond ecosystem of Pearl River Delta, China. Chemosphere 90 (7), 2142–2148.
CNBS (China National Bureau of Statistics), 2019. China Statistical Yearbook 2018. http://www.stats.gov.cn/tjsj/ndsj/2018/indexch.html.
Du, J.S., 2012. Water resource and aquaculture in Xinjiang province. Sci. Fish Farm. (11), 3 (in Chinese).
FAO (Food and Agriculture Organization of the United Nations), 1983. In: Cornelia, E. Nauen (Ed.), Compilation of Legal Limits for Hazardous Substances in Fish and Fishery Products. Food and Agriculture Organization of the United Nations, AO Fisheries Circular No. 464, pp. 5–100.
Fu, J., Hu, X., Tao, X.C., Yu, H.X., Zhang, X.W., 2013. Risk and toxicity assessments of heavy metals in sediments and fishes from the Yangtze River and Taihu Lake, China. Chemosphere 93 (9), 1887–1895.
Fu, L., Lu, X.B., Niu, K., Liu, J., Chen, J., 2019. Bioaccumulation and human health implications of essential and toxic metals in freshwater products of Northeast China. Sci. Total Environ. 673, 768–776.
Gu, Y.G., Gao, F.D., 2017. Spatial distribution and health risk assessment of heavy metals in provincial capital cities, China. Environ. Chem. 36 (1), 62–71 (in Chinese).
Gu, Y.G., Huang, H.H., Liu, Y., Gong, X.Y., Liao, X.L., 2018b. Non-metric multidimensional scaling and human risks of heavy metal concentrations in wild marine organisms from the Maowei Sea, the Beibu Gulf, South China Sea. Environ. Toxicol. Pharmacol. 59, 119–124.
Gu, Y.G., Lin, Q., Huang, H.H., Wang, L.G., Ning, J.J., Du, F.Y., 2017. Heavy metals in fish tissues/stomach contents in four marine wild commercially valuable fish species from the western continental shelf of South China Sea. Mar. Pollut. Bull. 114 (2), 1125–1129.
Gu, Y.G., Lin, Q., Wang, X.H., Du, F.Y., Yu, Z.L., Huang, H.H., 2015a. Heavy metal concentrations in wild fishes captured from the South China Sea and associated health risks. Mar. Pollut. Bull. 96 (1–2), 508–512.
Gu, Y.G., Lin, Q., Yu, Z.L., Wang, X.N., Ke, C.L., Ning, J.J., 2015b. Speciation and risk of heavy metals in sediments and human health implications of heavy metals in edible nebtok in Beibu Gulf, China: A case study of Qinzhou Bay. Mar. Pollut. Bull. 101 (2), 852–859.
Gu, Y.-G., Ning, J.-J., Ke, C.-L., Huang, H.-H., 2018a. Bioaccessibility and human health implications of heavy metals in different trophic level marine organisms: A case study of the South China Sea. Ecotoxicol. Environ. Saf. 163, 551–557.
Guisado, S., Li, J.S., Sena, S.D.S., 2018. Aquaculture in China - Success Stories and Modern Trends. Wiley Blackwell, pp. 1–71.
GXJ (The Government of Xinjiang Uygur Autonomous Region of China), 2019. About Xinjiang. http://www.xinjiang.gov.cn/ljxj/index.html.
Hu, Y.A., Cheng, H.F., 2013. Application of Stochastic models in identification and apportionment of heavy metal pollution sources in the surface soils of a large-scale region. Environ. Sci. Technol. 47 (8), 3752–3760.
Jiang, D.S., Hu, Z.Z., Liu, F., Zhang, R.F., Duo, B., Fu, J.J., Cui, Y.B., Li, M., 2014. Heavy metals levels in fish from aquaculture farms and risk assessment in Lhasa, Tibetan Autonomous Region of China. Ecotoxicology 23, 577–583.
Ke, C.L., Gu, Y.G., Liu, Q., Li, L.D., Huang, H.H., Cai, N., Sun, Z.W., 2017. Polycyclic aromatic hydrocarbons (PAHs) in wild marine organisms from South China Sea: Occurrence, sources, and human health implications. Mar. Pollut. Bull. 117 (1–2), 507–511.
Lam, H.M., Remais, J., Fung, M.C., Xu, L., Sun, S.S.M., 2013. Food supply and food safety issues in China. Lancet 381 (9882), 2044–2053.
Liu, H.Y., Zhao, Q.Y., Guo, X.Q., Tang, C.H., Yu, X.N., Zhan, T.F., Qin, Y.C., Zhang, J.M., 2019. Application of isotopic and elemental fingerprints in identifying the geographical origin of goat milk in China. Food Chem. 277, 448–454.
Lu, Y.L., Jenkins, A., Ferrier, R.C., Bailey, M., Gordon, I.J., Song, S., Huang, J., Jia, S., Zhang, F., Liu, X., Feng, Z.Z., Zhang, Z.B., 2015. Addressing China's grand challenge of achieving food security while ensuring environmental sustainability. Sci. Adv. 1 (1), e1400039.
MPHC (Ministry of Public Health of China), 2012. Chinese National Standard of Maximum Levels of Contaminants in Food specified (GB 2762–2012). Mwakalapa, E.B., Simukoko, C.K., Mmochi, A.J., Mdegela, R.H., Berg, V., Bjørgen Müller, M.H., Lyche, J.L., Polder, A., 2019. Heavy metals in farmed and wild mullet (Mugil cephalus) and wild mullet (Mugil cephalus) along the coasts of Tanzania and associated health risk for humans and fish. Chemosphere 224, 176–186.
Niu, L.L., Yang, F.X., Xu, C., Yang, H.Y., Liu, W.P., 2013. Status of metal accumulation in farmland soils across China: From distribution to risk assessment. Environ. Pollut. 176, 55–62.
Nriagu, J.O., Pacyna, J.M., 1988. Quantitative assessment of worldwide contamination of air, water and soils by trace metals. Nature 333 (6169), 134–139.
Pan, K., Wang, W.X., 2012. Trace metal contamination in estuarine and coastal environments in China. Sci. Total Environ. 421–422, 3–16.
Türkmen, M., Türkmen, A., Tepe, Y., Töre, Y., Ateş, A., 2009. Determination of metals in fish species from Aegean and Mediterranean seas. Food Chem. 113 (1), 233–237.
USEPA. 2018. Regional screening levels (RSLS) - summary table. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables.
Vasconcelos, R., Reis-Santos, P., Tanner, S., Fonseca, V., Latkoczy, C., Günther, D., Costa, M., Cabral, H., 2007. Discriminating estuarine nurseries for five fish species through otolith elemental fingerprints. Mar. Ecol. Prog. Ser. 350, 117–126.

Wang, W.X., Tan, Q.G., 2019. Applications of dynamic models in predicting the bioaccumulation, transport and toxicity of trace metals in aquatic organisms. Environ. Pollut. 252, 1561–1573.

Wang, F., Zhao, H.Y., Yu, C.D., Tang, J., Wu, W., Yang, Q.L., 2020. Determination of the geographical origin of maize (Zea mays L.) using mineral element fingerprints. J. Sci. Food Agric. 100 (3), 1294–1300.

Wedepohl, H.K., 1995. The composition of the continental crust. Geochim. Cosmochim. Acta 59 (7), 1217–1232.

Xu, X.X., Huo, Q.L., Dong, Y.Y., Zhang, S.R., Zhanbiao, Y., Xian, J.R., Yang, Y.X., Cheng, Z., 2019. Bioaccumulation and health risk assessment of trace metals in fish from freshwater polyculture ponds in Chengdu, China. Environ. Sci. Pollut. Res. 26 (32), 33466–33477.

Yu, J.Y., 2017. Report on 2017 Fishery Work Conference of Xinjiang Province. http://www.shuichan.cc/news_view-317456.html.

Zhang, W., Wang, W.X., 2012. Large-scale spatial and interspecies differences in trace elements and stable isotopes in marine wild fish from Chinese waters. J. Hard Mater. 215–216, 65–74.

Zoroddu, M.A., Aaseth, J., Crisponi, G., Medici, S., Peana, M., Nurchi, V.M., 2019. The essential metals for humans: a brief overview. J. Inorg. Biochem. 195, 120–129.