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Original Scientific Paper

Health risk assessment of metal intake from fish species caught from the Danube River in Serbia

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A R T I C L E   I N F O

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A B S T R A C T

The aim of the present study was to assess the potential health risks associated with the consumption of metals accumulated in fish meat of common carp, Wels catfish, and silver carp caught from 2010 to 2021 from the Danube River in Serbia. Therefore, estimation of daily intake rate (EDI), percentage of provisional tolerable weekly intake (% PTWI), target hazard quotient (THQ), hazard index (HI), and target cancer risk (TR) were calculated. Results of health risk assessments showed that the highest values of EDI were found for Hg in common carp, for As, Hg, and Pb in silver carp, while in Wels catfish the highest EDI was detected for Pb and Hg. In all three fish species, the highest % PTWI values were determined for Hg, while % PTWI for As, Cd, and Pb were lower than 5%. HIs higher than 1 were detected in common carp and Wels catfish during 2013 and in Wels catfish during 2010, indicating a potential for adverse non-carcinogenic health effects. In silver carp, HIs were lower than 1. The TR for As from 2010 to 2021 was regarded as acceptable, except in common carp during 2013, when it was defined as an unacceptable carcinogenic risk (higher than 10^{-4}). The TR for Cr ranged from 10^{-6} to 10^{-4} in all three fish species, so was regarded as acceptable, while the TR for Pb was indicated as negligible (lower than 10^{-6}).

1. Introduction

In previous decades, emerging attention has been paid to environmental pollution with metals that have detrimental effects both to fish and human health (*Cordeli et al.*, 2023). The increase of metal level in aquatic environments has been due to different anthropogenic activities, like mining, accidental chemical waste discharge, agriculture drainage, industrial and sewage discharge (*Milošković and Simić*, 2023). Metals are non-biodegradable, persist in the environment for long periods, and accumulate in different tissues of the body, impairing health (*Cordeli et al.*, 2023). Heavy metals like arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg) do not have any physiological role and are very toxic at low levels (*Vardhan et al.*, 2019). Fish accumulate metals by absorption through gills, guts, and skin, and the level of tissue deposition depends on the content in water and sediment, fish species, time of

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exposure, and type of feeding behaviour (*Milošković and Simić*, 2023). Since fish are very sensitive to aquatic pollution (*Colin et al*., 2016), they are appropriate as bioindicators of environmental metal pollution (*Milošković and Simić*, 2023). Moreover, consuming fish contaminated with metals poses a risk to human health and can have detrimental effects on the nervous system, gastrointestinal tract, kidneys, and also can lead to anaemia, hypertension, and increased risk of cancer (*Cordeli et al*., 2023). Recently, various methods have been developed to assess health risks in order to assess the adverse effects of consuming fish contaminated with metals on human health (*USEPA*, 2000; *JECFA*, 2011; *Li et al*., 2013; *Jovic and Stankovic*, 2014; *Ahmed et al*., 2015; *Griboff et al*., 2017; *Malavolti et al*., 2020).

In Serbia, only 16% of wastewater is treated (*NALED*, 2019) and the Danube River, as the second longest river in Europe, is exposed to numerous pollutants (*Cordeli et al*., 2023). Furthermore, reviews by *Cordeli et al*. (2023) and *Milošković and Simić* (2023) presented detected levels of metals in the meat of different fish species caught from the Danube River in the past 15 years. Since in the performed studies, the health risks associated with fresh-water fish consumption were not established, the aim of the present study was to determine the potential risk associated with the consumption of metals accumulated in fish meat of common carp, Wels catfish, and silver carp caught from 2010 to 2021 from the Danube River in Serbia.

2. Materials and methods

2.1. Material

Data regarding concentrations of arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), lead (Pb), and zinc (Zn) in fish muscles published in the past 15 years were included for health risk assessment. The studies performed on three fish species (common carp, Wels catfish, and silver carp) caught from the Danube River were considered. For determination of health risks after consumption of common carp, the data used were presented by *Lenhardt et al*. (2012), *Subotić et al*. (2013a), *Subotić et al*. (2013b), *Ivanović et al*. (2016), *Milanov et al.* (2016), *Jovanović et al.* (2017), and *Aleksić et al.* (2025). For Wels catfish, studies used were performed by *Lenhardt et al.* (2012), *Ivanović et al.* (2016), *Milanov et al.* (2016), *Jovičić et al.* (2016), *Milošković et al.* (2016), *Jovanović et al.* (2017), and Aleksić et al. (2025). Data regarding silver carp were from studies by *Lenhardt et al.* (2012), *Ivanović et al.* (2016), *Milanov et al.* (2016), and *Aleksić et al.* (2025).

2.2. Methods

Assessment of health risks (estimation of daily intake rate – EDI, percentage of provisional tolerable weekly intake – % PTWI, target hazard quotient – THQ, hazard index – HI, and target cancer risk – TR) was performed according to the equations presented by Aleksić et al. (2025). Before calculation, concentrations of metals originally presented in dry weight were transformed to wet weight (wet weight refers to the weight of the sample including its water content) according to *Subotić et al.* (2021).

3. Results and discussion

3.1. Estimation of daily intake rate (EDI) and percentage of provisional tolerable weekly intake (% PTWI)

Figures 1 and 2 illustrate the estimated daily intake (EDI) (µg/kg of body weight (BW) per day) and percentage of provisional tolerable weekly intake (% PTWI) for common carp, Wels catfish, and silver carp caught from the Danube River in Serbia in the past 15 years. EDI levels were the highest for Fe and Zn in common carp (2.65 and 8.49 µg/kg BW per day, respectively), followed by Wels catfish (2.28 and 2.11 µg/kg BW per day, respectively), and silver carp (5.77 and 2.90 µg/kg BW per day, respectively). Regarding toxic elements, in common carp, the highest EDI levels were found for Hg (0.13 µg/kg BW per day; *Jovanović et al*., 2017), As (0.05 µg/kg BW per day; *Aleksić et al*., 2025), and Hg (0.04 µg/kg BW per day; *Ivanović et al*., 2016), in silver carp the highest EDI was for Pb (0.04 µg/kg BW per day; *Ivanović et al*., 2016), while in Wels catfish, the highest EDIs detected were for Pb (0.43 µg/kg BW per day; *Lenhardt et al.,* 2012) and Hg (0.17 µg/kg BW per day; *Milošković et al*., 2016).

The highest % PTWI were found for Hg in common carp (22.34%) (Jovanović et al., 2017), Wels catfish (29.73%) (*Milošković et al*., 2016), and silver carp (7.67%) *(Ivanović et al*., 2016). Furthermore, % PTWI for As, Cd, and Pb in fish meat of common carp, Wels catfish, and silver carp were lower than 5%.

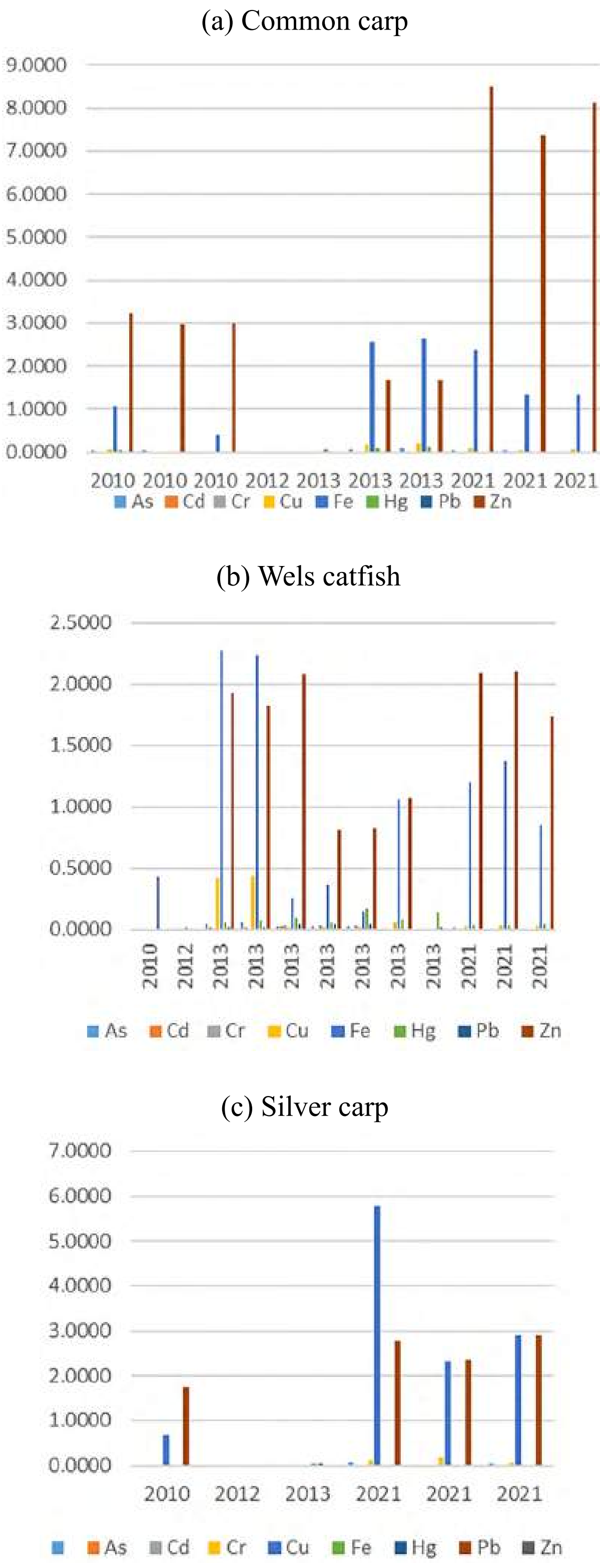

Figure 1. Estimation of daily intake rate (EDI; µg/kg BW/day) in fish meat of common carp, Wels catfish, and silver carp caught from the Danube River in Serbia for the period 2010-2021

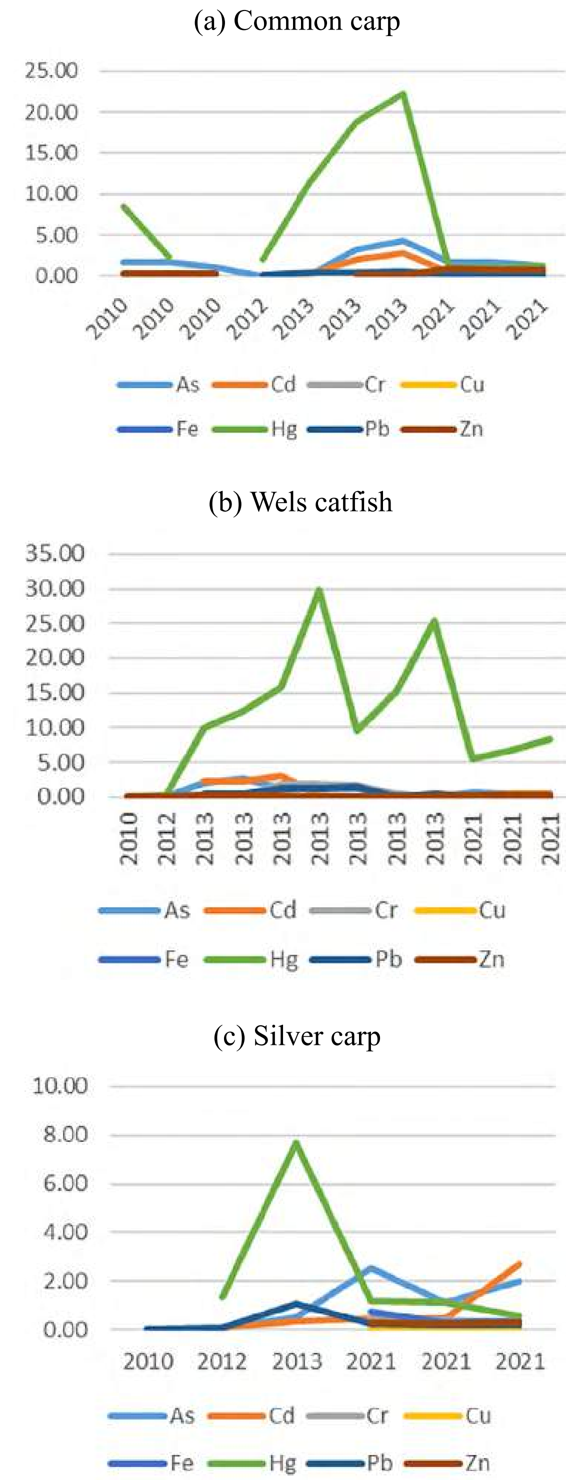

Figure 2. Percentage of tolerable weekly intake (% PTWI) of metals in fish meat of common carp, Wels catfish, and silver carp caught from the Danube River in Serbia for the period 2010-2021

3.2. Target hazard quotient (THQ) and hazard index (HI)

In Figure 3, we present results of calculated target hazard quotient (THQ) and hazard index (HI) for the meat of common carp, Wels catfish, and silver carp caught from the Danube River in Serbia in the past 15 years. The highest HIs were found in common carp caught in 2013 from Grocka (2.18; *Jovanović et al*., 2017) and Zemun (1.75; *Jovanović et al*., 2017). In those studies, the THQ of Hg largely contributed to HI. In Wels catfish, the highest HI was found during 2010 (5.27; *Lenhardt et al*., 2012) due to the high contribution of lead to the THQ. Moreover, in Wels catfish caught in Zemun and Grocka during 2013 (*Jovanović et al*., 2017), Novi Sad, Zemun, and Radujevac during 2011-2013 (*Milošković et al*., 2016), and in Vinča during 2013 (*Ivanović et al*., 2016), HIs was higher than 1. The consumption of those fish posed a significant health hazard to consumers (*USEPA*, 2010), mainly due to high contribution of Hg to the THQ. In silver carp, observed HIs were lower than 1, although in 2013 (*Ivanović et al*., 2016), HI was slightly below 1 (0.99), indicating potential adverse non-carcinogenic health effects (*USEPA*, 2010). The latest research (*Aleksić et al*. 2025) performed in 2021 showed that HIs of common carp, Wels catfish, and silver carp caught from the Danube River have decreased in the past decade.

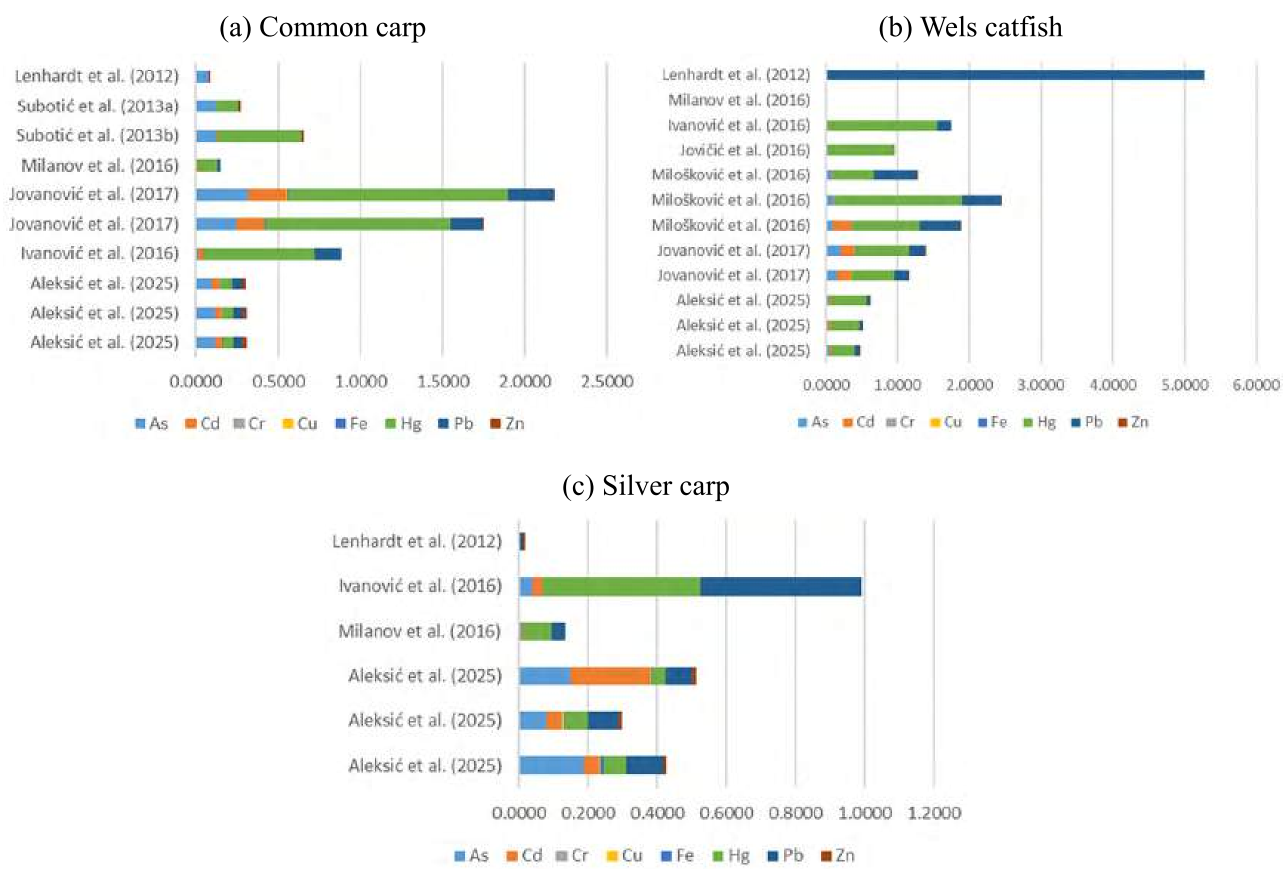

Figure 3. Target hazard quotient (THQ) and hazard index (HI) in fish meat of common carp, Wels catfish, and silver carp caught from the Danube River in Serbia for the period 2010-2021

3.3. Target cancer risk (TR)

Table 1 shows the target cancer risk (TR) calculated for fish meat of common carp, Wels catfish, and silver carp caught from the Danube River in Serbia for the period 2010-2021. The TR for As ranged in common carp from 1.11E-06 (*Milanov et al*., 2016) to 1.43E-04 (*Jovanović et al*., 2017), in Wels catfish from 1.29E-06 (*Ivanović et al*., 2016) to 9.04E-05 (*Jovanović et al*., 2017), and in silver carp from 3.09E-06 (*Milanov et al*., 2016) to 8.43E-05 (*Aleksić et al*., 2025). The TR for As in previous studies was regarded as acceptable, except in common carp (*Jovanović et al*., 2017) when was higher than 10^{-4} and recognised as unacceptable carcinogenic risk. The TR for Cr ranged from 10^{-6} to 10^{-4} in all three fish species,

Table 1. Target cancer risk (TR) in fish meat of common carp, Wels catfish, and silver carp caught from the Danube River in Serbia for the period 2010-2021

As	Cr	Pb	Region	Year of sampling	Reference
			Common carp		
5.41E-05	3.14E-06	3.45E-08	Novi Sad	2021	Aleksić et al. (2025)
5.43E-05	3.29E-06	4.01E-08	Zemun	2021	Aleksić et al. (2025)
4.32E-05	3.71E-06	4.01E-08	Grocka	2021	Aleksić et al. (2025)
4.29E-06		1.17E-07	Vinča	2013	Ivanović et al. (2016)
1.11E-04		1.43E-07	Zemun	2013	Jovanović et al. (2017)
1.43E-04		2.04E-07	Grocka	2013	Jovanović et al. (2017)
1.11E-06		1.70E-08	Belgrade	2012	Milanov et al. (2016)
5.66E-05	2.86E-07		Belgrade	2010	Subotić et al. (2013b)
5.66E-05			Belgrade	2010	Subotić et al. (2013a)
3.39E-05			Belgrade	2010	Lenhardt et al. (2012)
			Wels catfish		
2.43E-05	2.26E-06	3.81E-08	Novi Sad	2021	Aleksić et al. (2025)
1.56E-05	2.76E-06	2.60E-08	Zemun	2021	Aleksić et al. (2025)
1.68E-05	2.61E-06	2.26E-08	Grocka	2021	Aleksić et al. (2025)
6.90E-05		1.41E-07	Zemun	2013	Jovanović et al. (2017)
9.04E-05		1.68E-07	Grocka	2013	Jovanović et al. (2017)
4.29E-05	2.07E-05	4.13E-07	Novi Sad	2011-2013	Milošković et al. (2016)
4.71E-05	2.00E-05	3.89E-07	Zemun	2011-2013	Milošković et al. (2016)
3.86E-05	1.86E-05	4.37E-07	Radujevac	2011-2013	Milošković et al. (2016)
1.12E-05	3.94E-06	2.91E-09	Belgrade	2013	Jovičić et al. (2016)
1.29E-06		1.46E-07	Vinča	2013	Ivanović et al. (2016)
		3.84E-06	Belgrade	2010	Lenhardt et al. (2012)
			Silver carp		
8.43E-05	5.11E-06	7.65E-08	Novi Sad	2021	Aleksić et al. (2025)
3.65E-05	4.36E-06	6.56E-08	Zemun	2021	Aleksić et al. (2025)
6.68E-05	3.60E-06	5.76E-08	Grocka	2021	Aleksić et al. (2025)
3.09E-06		2.72E-08	Belgrade	2012	Milanov et al. (2016)
1.71E-05		3.40E-07	Vinča	2013	Ivanović et al. (2016)
		7.29E-09	Belgrade	2010	Lenhardt et al. (2012)

and so is regarded as acceptable. Furthermore, the TR for Pb in all observed studies was lower than 10^{-6} and indicated as negligible, except in the study by *Lenhardt et al*. (2012) (3.84E-06).

4. Conclusion

Results of health risk assessment of fish meat of common carp, Wels catfish, and silver carp caught from the Danube River in Serbia for the period 2010-2021 showed that regarding toxic elements, the highest values of EDI were found for Hg in common carp, for As, Hg, and Pb in silver carp, while in Wels catfish, the highest EDI was detected for Pb and Hg. Moreover, the highest % PTWI were determined for Hg in all three fish species reaching 29.73%, while % PTWI for As, Cd, and Pb were below 5%. HIs higher than 1 were detected in common carp and Wels catfish during 2013 due to high contribution of Hg to the THQ, indicating a potential for adverse non-carcinogenic health effects. In Wels catfish, the highest HI was found during 2010, due to high contribution of Pb to the THQ. However, in silver carp, observed HIs were lower than 1. The TR for As in previous studies was regarded as acceptable, except in common carp during 2013, when was higher than 10^{-4} and recognised as an unacceptable carcinogenic risk. The TR for Cr ranged from 10^{-6} to 10^{-4} in all three fish species, and so is regarded as acceptable. Furthermore, the TR for Pb in all observed studies was lower than 10^{-6} and indicated as negligible, except during 2010 when it was indicated as acceptable.

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