








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

Marija Starčević^{1*} , Branislav Stojanović², Radivoje Anđelković³, Nataša Glamočlija⁴ ,
Milica Laudanović⁴ , Radmila Mitrović⁵  and Milan Ž. Baltić⁴ 

¹ Ministry of Defence of Republic of Serbia, Military Health Department, Veterinary Service Centre, Raška 2, Belgrade 11000, Serbia

² Ministry of Defence of Republic of Serbia, Military Health Department, Veterinary Department, Crnotravska 17, Belgrade 11000, Serbia

³ Ministry of Defence of Republic of Serbia, Rectorate, University of Defense, Veljka Lukića Kurjaka 1, Belgrade 11000, Serbia

⁴ University of Belgrade, Faculty of Veterinary Medicine, Bulevar Oslobođenja 18, Belgrade 11000;

⁵ Institute of Meat Hygiene and Technology, Kačanskog 9, 11000 Belgrade, Serbia

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ABSTRACT

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

*Corresponding author: Marija Starčević, marijadok@gmail.com

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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) ($\mu\text{g/kg}$ 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 $\mu\text{g/kg}$ BW per day, respectively), followed by Wels catfish (2.28 and 2.11 $\mu\text{g/kg}$ BW per day, respectively), and silver carp (5.77 and 2.90 $\mu\text{g/kg}$ BW per day, respectively). Regarding toxic elements, in common carp, the highest EDI levels were found for Hg (0.13 $\mu\text{g/kg}$ BW per day; Jovanović et al., 2017), As (0.05 $\mu\text{g/kg}$ BW per day; Aleksić et al., 2025), and Hg (0.04 $\mu\text{g/kg}$ BW per day; Ivanović et al., 2016), in silver carp the highest EDI was for Pb (0.04 $\mu\text{g/kg}$ BW per day; Ivanović et al., 2016), while in Wels catfish, the highest EDIs detected were for Pb (0.43 $\mu\text{g/kg}$ BW per day; Lenhardt et al., 2012) and Hg (0.17 $\mu\text{g/kg}$ 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%.

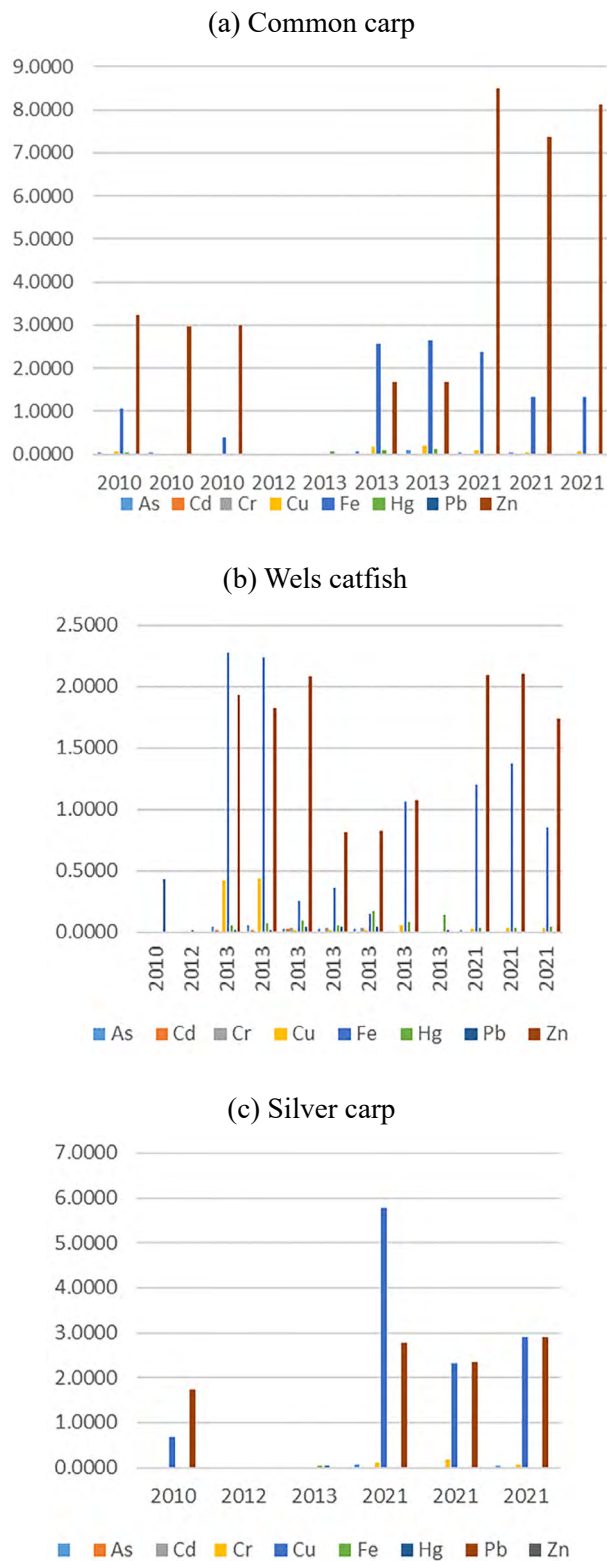


Figure 1. Estimation of daily intake rate (EDI; $\mu\text{g}/\text{kg BW}/\text{day}$) in fish meat of common carp, Wels catfish, and silver carp caught from the Danube River in Serbia for the period 2010-2021

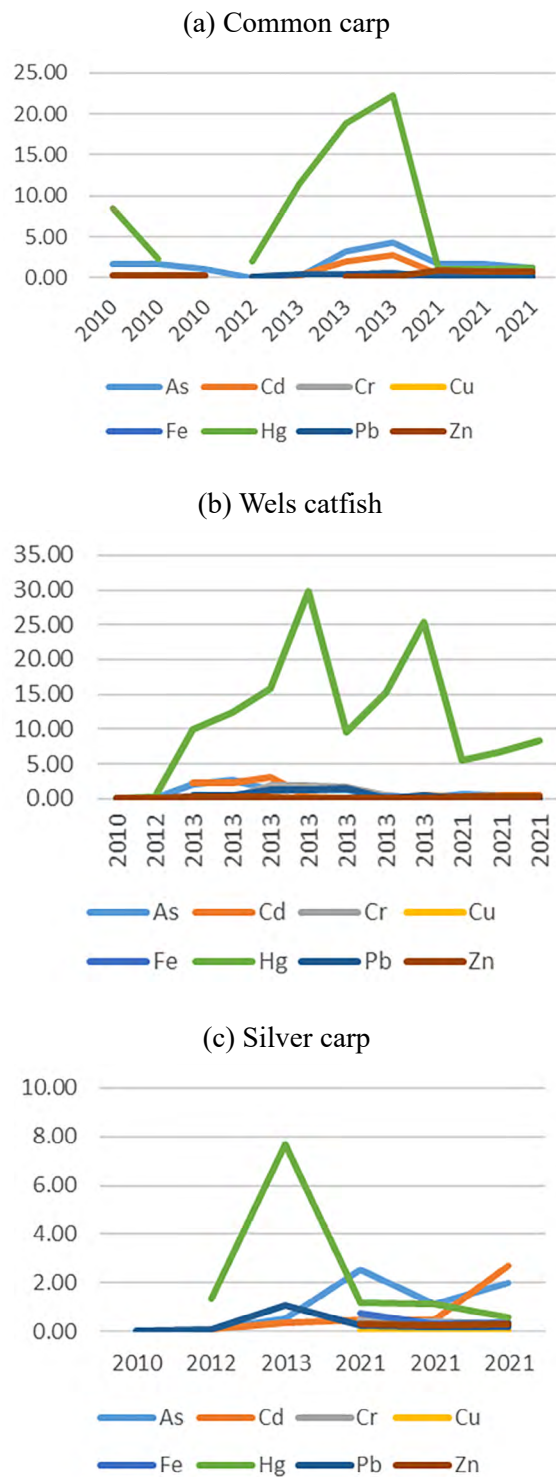


Figure 2. Percentage of tolerable weekly intake (% PTWI) of metals in fish meat of common carp, Wels catfish, and silver carp caught from the Danube River in Serbia for the period 2010-2021

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.

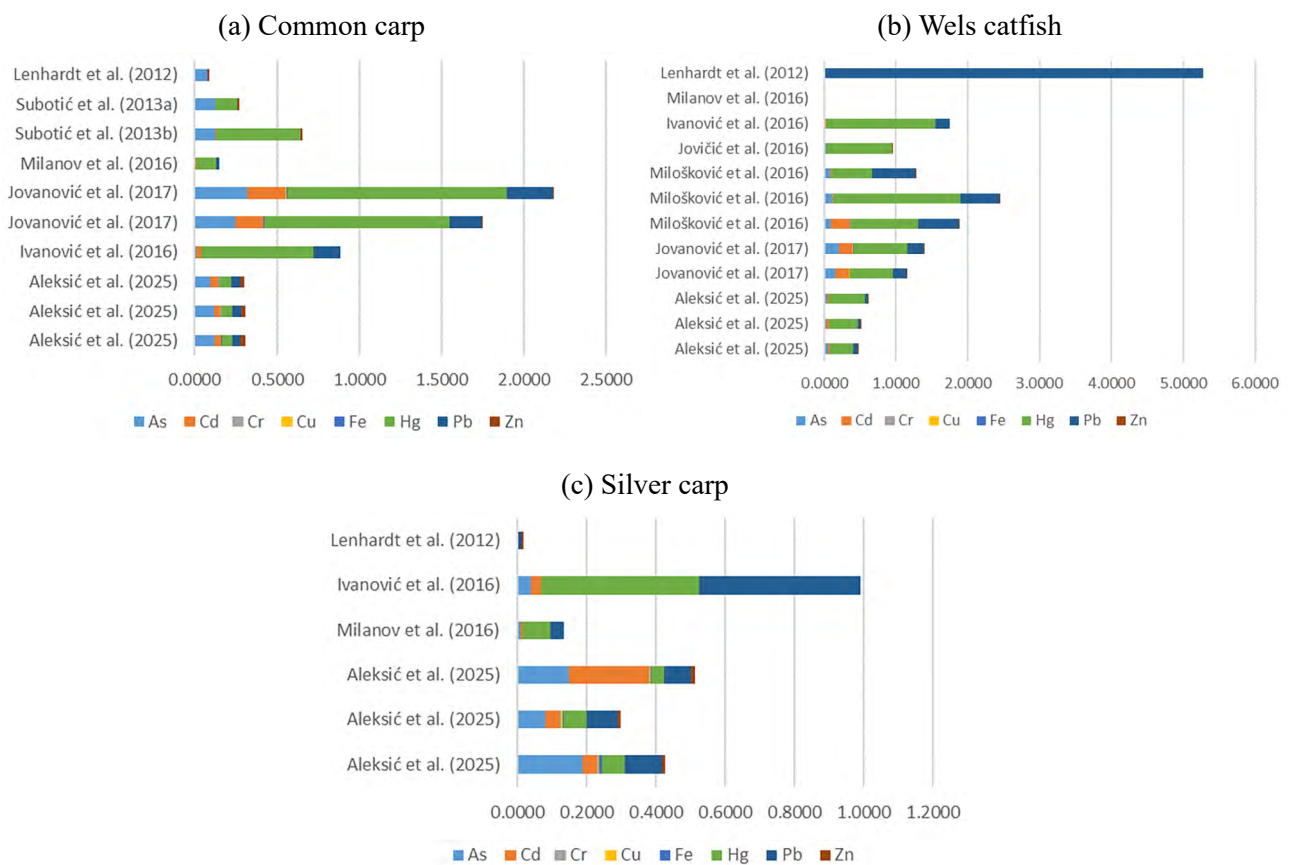


Figure 3. Target hazard quotient (THQ) and hazard index (HI) in fish meat of common carp, Wels catfish, and silver carp caught from the Danube River in Serbia for the period 2010-2021

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 ele-

ments, 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 unaccepta-

ble 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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References

- Ahmed, M. K., Baki, M. A., Islam, M. S., Kundu, G. K., Habibullah-Al-Mamun, M., Sarkar, S. K., & Hossain, M. M. (2015). Human health risk assessment of heavy metals in tropical fish and shellfish collected from the river Buriganga, Bangladesh. *Environmental Science and Pollution Research*, 22(20), 15880–15890. <https://doi.org/10.1007/s11356-015-4813-z>
- Aleksić, J., Glamočlija, N., Laudanović, M., Ivanović, S., Milijašević, M., Baltić, B., & Starčević, M. (2025). The content and associated health risk assessment of toxic elements, micro-, and macrominerals in common carp, Wels catfish, and silver carp from the Danube River in Serbia. *Environmental Geochemistry and Health*, 47, 60. <https://doi.org/10.1007/s10653-025-02370-7>
- Colin, N., Maceda-Veiga, A., Flor-Arnau, N., Mora, J., Fortuño, P., Vieira, C., & de Sostoa, A. (2016). Ecological impact and recovery of a Mediterranean river after receiving the effluent from a textile dyeing industry. *Ecotoxicology and Environmental Safety*, 132, 295–303. <https://doi.org/10.1016/j.ecoenv.2016.06.017>
- Cordeli, A. N., Oprea, L., Cretu, M., Dediu, L., Coadă, M. T., & Mînzala, D. N. (2023). Bioaccumulation of metals in some fish species from the Romanian Danube River: A review. *Fishes*, 8, 387. <https://doi.org/10.3390/fishes8080387>
- Griboff, J., Wunderlin, D. A., & Monferran, M. V. (2017). Metals, As and Se determination by inductively coupled plasma-mass spectrometry (ICP-MS) in edible fish collected from three eutrophic reservoirs. Their consumption represents a risk for human health? *Microchemical Journal*, 130, 236–244. <https://doi.org/10.1016/j.microc.2016.09.013>
- Ivanović, J., Janjić, J., Baltić, M., Milanov, R., Bošković, M., Marković, R. V., & Glamočlija, N. (2016). Metal concentrations in water, sediment and three fish species from the Danube River, Serbia: a cause for environmental concern. *Environmental Science and Pollution Research*, 23(17), 17105–17112. <https://doi.org/10.1007/s11356-016-6875-y>
- JECFA, (2011). Evaluations of the Joint FAO/WHO Expert Committee on Food Additives. World Health Organization. <https://apps.who.int/food-additives-contaminants-jecfa-database/>
- Jovanović, D. A., Marković, R. V., Teodorović, V. B., Šefer, D. S., Krstić, M. P., Radulović, S. B., Ivanović Ćirić, J. S., Janjić, J. M., & Baltić, M. Ž. (2017). Determination of heavy metals in muscle tissue of six fish species with different feeding habits from the Danube River, Belgrade-public health and environmental risk assessment. *Environmental Science and Pollution Research*, 24(12), 11383–11391. <https://doi.org/10.1007/s11356-017-8783-1>
- Jovic, M. & Stankovic, S. (2014). Human exposure to trace metals and possible public health risks via consumption of mussels *Mytilus galloprovincialis* from the Adriatic coastal area. *Food and Chemical Toxicology*, 70, 241–251. <https://doi.org/10.1016/j.fct.2014.05.012>
- Jović, K., Janković, S., Visnjić-Jeftić, Z., Skorić, S., Djikanović, V., Lenhardt, M., Hegediš, A., Krpocetković, J., & Jarić, I. (2016). Mapping differential elemental accumulation in fish tissues: Importance of fish tissue sampling standardization. *Archives of Biological Sciences*, 68, 303–309. <https://doi.org/10.2298/ABS150629019J>
- Lenhardt, M., Jarić, I., Višnjić-Jeftić, Z., Skorić, S., Gačić, Z., Pucar, M., & Hegediš, A. (2012). Concentrations of 17 elements in muscle, gills, liver and gonads of five economically important fish species from the Danube River. *Knowledge and Management of Aquatic Ecosystems*, 407, 2. <https://doi.org/10.1051/kmae/2012028>
- Li, J., Huang, Z. Y., Hu, Y., & Yang, H. (2013). Potential risk assessment of heavy metals by consuming shellfish collected from Xiamen, China. *Environmental Science and Pollution Research*, 20(5), 2937–2947. <https://doi.org/10.1007/s11356-012-1207-3>
- Malavolti, M., Fairweather-Tait, S., Malagoli, C., Vescovi, L., Vinceti, M., & Filippini, T. (2020). Lead exposure in an Italian population: food content, dietary intake and risk assessment. *Food Research International*, 137, e109370. <https://doi.org/10.1016/j.foodres.2020.109370>
- Milanov, R., Krstić, M., Marković, R., Jovanović, D., Baltić, B., Ivanović, J., Jovetić, M., & Baltić, M. (2016). Analysis of heavy metals concentration in tissues of three different fish species included in human diet from Danube River. *Acta Veterinaria Belgrade*, 66(1), 89–102. <https://doi.org/10.1515/acve-2016-0007>
- Milošković, A., & Simić, V. (2023). Bioaccumulation of potentially toxic elements in fish species of Serbia: a review. *Environmental Science and Pollution Research*,

30(12), 32255–32277. <https://doi.org/10.1007/s11356-023-25581-w>.

Milošković, A., Dojčinović, B., Kovačević, S., Radojković, N., Radenković, M., Milošević, D., & Simić, V. (2016). Spatial monitoring of heavy metals in the inland waters of Serbia: A multispecies approach based on commercial fish. *Environmental Science and Pollution Research*, 23, 9918–9933. <https://doi.org/10.1007/s11356-016-6207-2>.

National Alliance for Local Economic Development – NALED, (2019). Serbia processes only 16% of wastewater. <https://naled.rs/en/vestisrbija-preradjuje-tek-16-otpad-nih-voda-233>. Accessed 23 March 2024.

Subotić, S., Spasić, S., Višnjić-Jeftić, Ž., Hegediš, A., Krpo-Četković, J., Mićković, B., Skorić, S., & Lenhardt, M. (2013b). Heavy metal and trace element bioaccumulation in target tissues of four edible fish species from the Danube River (Serbia). *Ecotoxicology and Environmental Safety*, 98, 196–202. <https://doi.org/10.1016/j.ecoenv.2013.08.020>.

Subotić, S., Višnjić-Jeftić, Ž., Spasić, S., Hegediš, A., Krpo-Četković, J., & Lenhardt, M. (2013a). Distribution and accumulation of elements (As, Cu, Fe, Hg, Mn, and Zn) in

tissues of fish species from different trophic levels in the Danube River at the confluence with the Sava River (Serbia). *Environmental Science and Pollution Research*, 20, 5309–5317. <https://doi.org/10.1007/s11356-013-1522-3>.

Subotić, S., Višnjić-Jeftić, Ž., Bojović, S., Đikanović, V., Krpo-Četković, J., & Lenhardt, M. (2021). Seasonal variations of macro-, micro-, and toxic elements in tissues of vimba bream (*Vimba vimba*) from the Danube River near Belgrade, Serbia. *Environmental Science and Pollution Research*, 28, 63087–63101. <https://doi.org/10.1007/s11356-021-15073-0>.

USEPA, (2000). Risk Based Concentration Table; United States Environmental Protection Agency, Philadelphia, PA, USA.

USEPA, (2010). Risk-Based Concentration Table. United States Environmental Protection Agency, Philadelphia, PA, USA.

Vardhan, K. H., Kumar, P. S., & Panda, R. C. (2019). A review on heavy metal pollution, toxicity and remedial measures: Current trends and future perspectives. *Journal of Molecular Liquids*, 290, 111197. <https://doi.org/10.1016/j.molliq.2019.111197>.

Authors info

Marija Starčević, <https://orcid.org/0000-0002-0857-5218>

Branislav Stojanović, /

Radivoje Anđelković, /

Nataša Glamočlija, <https://orcid.org/0000-0003-4799-9416>

Milica Laudanović, <https://orcid.org/0009-0008-6381-2803>

Radmila Mitrović, <https://orcid.org/0000-0003-2912-2784>

Milan Ž. Baltić, <https://orcid.org/0000-0003-4469-3411>