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CONTENTS:

SADRŽAJ:

LITERATURE SURVEY ON FISH TISSUES CONTAMINATION BY HEAVY METALS AND ELEMENTS IN THE DANUBE RIVER, FROM 1433-845 RKM

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PREGLED LITERATURE O KONTAMINACIJI TKIVA RIBA TEŠKIM METALIMA I ELEMENTIMA U RECI DUNAV, OD 1433-845 RKM

Apstrakt

Teški metali i elementi mogu prodreti i akumulirati se u akvatičnim organizmima putem lanaca ishrane, te se smatraju kritičnim kontaminantima vodenih ekosistema. S obzirom da su ribe nalaze na vrhu lanca ishrane, mogu akumulirati velike količine teških metala i elemenata u tkivima. Dunav je druga najduža reka u Evropi i prolazi kroz Srbiju dužinom od 587,4 km. Najveći industrijski gradovi nalaze se na obalama Dunava (Beograd, Novi Sad, Pančevo i Smederevo) od kojih ni jedan grad nema sisteme za preradu komunalnih i industrijskih otpadnih voda. U okviru ove studije analizirani su objavljeni radovi o akumulaciji teških metala u različitim tkivima riba na Dunavu od 1433 rkm do 845 rkm toka, kako bi se procenilo koje su vrste, tkiva i elementi najzastupljeniji u analizama. Konačan uzorak obuhvatao je 16 članaka objavljenih od 1996. do 2017. godine. Rezultati pokazuju da je najčešće proučavano tkivo mišić (26,67%), a slede jetra (21,67%) i škrge (18,33%). Tkiva koja su takođe proučavana bile su gonade (6,67%), creva (8,33%) i slezina (3,33%). Najčešće ispitivane vrste su som (*Silurus glanis*) (15,52%), šaran (*Cyprinus carpio*) (12,07%) i smuđ (*Sander lucioperca*) (10,35%). Manje zastupljene u analiziranim radovima su deverika (*Abramis brama*) (8,62%) i mrena (*Barbus barbus*) (6,9%). Najviše analizirani teški metali i elementi bili su As, Pb, Cd, Cu, Zn, Fe, Ni, Mn i Co. Elementi koji su takođe bili zastupljeni u analizama bili su Cr, Hg, Sr, Al, Ba i Se. Na osnovu istraživanja literature, dunavski deo koji nije bio proučavan, predstavlja rečni tok od 1132 do 863 rkm koji velikim delom pripada Nacionalni Park "Đerdap" gde treba usmeriti buduće istraživanje.

Ključne reči: *Dunav, teški metali, elementi, ribe, tkiva*
Keywords: *Danube River; heavy metals; trace elements, fish; tissues*

INTRODUCTION

Heavy metals have high potential to enter and accumulate in food chains and therefore are considered as critical contaminants of aquatic ecosystems (Erdoğrul and Erbilir 2007). Given that fish are situated at the top of the food chain they can accumulate large amount of heavy metals (Yilmaz et al. 2007). Heavy metals are taken up through different organs of the fish because of the affinity between them, and then are concentrated at different levels in different organs of the body (Bervoets *et al.* 2001). Accumulation of heavy metals in muscle tissues was the most studied, given that muscle tissue is the main fish part that is consumed by humans (Begum et al. 2013; Storelli et al. 2006). However, it is important to analyze other tissues since muscles are not always a good indicator of the whole fish body contamination (Has-Schön et al. 2006).

The Danube River is the second longest river in Europe and runs through Serbia at a length of 587.4 km. The biggest industrial capacities are largely located on the Danube river banks - Belgrade, Novi Sad, Pančevo and Smederevo (Petrović 2015). The main problem is that none of them has any kind of system for treating municipal wastewaters (Veljković 2005).

Within this study, published articles regarding heavy metal accumulation in different tissues of fish in the Danube in Serbia were analyzed in order to evaluate which species, tissues and elements were the most represented in the analyses. The main aim was to assess present practices in research of heavy metal pollution in this region, as well as to identify key gaps regarding the particular river sections, types of pollutants, tissues, and trophic and functional groups of fish communities that were inadequately represented in research

Figure 1. Map of the study area on the Danube River (river km): 1) Maletin et al. 1996 2) Poleksić et al. 2010; 3) Jarić et al. 2011; 4) Višnjić-Jeftić et al. 2010; 5)Lenhardt et al. 2012; 6) Sunjog et al. 2012; 7) Zrnčić et al. 2012; 8) Rašković et al. 2014; 9) Subotić et al. 2013; 10) Jovanović et al. 2017; 11) Jovičić et al. 2014; 12) Ivanović et al. 2016; 13) Milošković et al. 2016; 14) Morina et al. 2016; 15) Kostić et al. 2017; 16) Subotić et al. 2013

MATERIAL AND METHODS

We conducted a literature survey on current studies dealing with the heavy metal uptake in the Danube fish species inhabiting different trophic levels. The survey included previous research in the Danube Basin, between 852 river km and 1432 river km. Danube enters Serbia at 1433rkm and up to 1296 rkm represents boarder area between Serbia and Croatia (137km). Boarder area represents 58 % of the Croatia's overall area used for commercial freshwater fishing (Zrnčić et al. 2012). Serbia boards with Romania from 1075 to 845rkm (230km). The localities that are shown on the Figure 1and represents studies included in our literature survey are (rkm): 1. Danube-Tisa-Danube channel and Danube River near Novi Sad (1250); 2. Bačko Novo Selo, Zemun, downstream Đerdap II dam (1319, 1173, 861); 3. Bačka Palanka, Beograd, downstream Đerdap II dam (1299, 1169, 863); 4. Prahovo, downstream Đerdap II dam (863); 5. Zemun (1173); 6. Zemun (1173); 7. Batina, Aljmas, Dalj (1432, 1354, 1381); 8. Zemun (1173); 9., 10., 11. Beograd (1169); 12. Grocka (1132); 13. Novi Sad, Zemun, Radujevac (1257, 1173, 852); 14. Zemun (1173); 15. Beograd (1169); 16. Zemun, Grocka (1173, 1132).

Articles were obtained from personal records of relevant publications collected previously by authors. Final sample comprised 16 articles published during 1996-2017.

RESULTS AND DISCUSSION

The results of the literature survey are presented in the Table 1. The results indicated that the most studied fish tissue was muscle (26.67%), followed by liver (21.67%) and gills (18.33%). Tissues that were also studied with the smaller percentage were gonads (6.67%), intestines (8.33%) and spleen (3.33%). Only a single author reported concentration of heavy metals in less studied tissues such as operculum, swimming bladder, gallbladder, heart, brain, vertebrae (1.67%). As for the analyzed species, species that were most studied included wels catfish (*Silurus glanis*) (15.52%), carp (*Cyprinus carpio*) (12.07%), and pike-pearch (Sander lucioperca) (10.35%). Bream (*Abramis brama*) and barbell (*Barbus barbus*) were also studied, but less frequently (8.62%, 6.90%). Prussian carp *(*Carassius gibelio), sterlet (*Acipenser ruthenus*) and silver carp (Hypophthalmichthys molitrix) were represented with 5,17%, while bleak (Alburnus alburnus), pike (*Esox lucius*), burbot (*Lota lota*) accounted for 3.45%. Other studied species were represented with 1.72%. The most analyzed elements were As, Pb, Cd, Cu, Zn, Fe, Ni, Mn and Co. The elements that were also represented in the analyzes were Cr, Hg, Sr, Al, Ba and Se.

Based on the literature survey, the Danube section that was not studied, included river stretch from 1132 to 863 rkm. Given that Danube flows through Serbia at a length of 587.4 km, unstudied section includes 269 rkm, which represents nearly a half of the total Danube flow through Serbia. From 1039 rkm (Golubac) to 933rkm (Kladovo) extends National Park Đerdap. According to Milenković et al. (2005) the Iron Gate (Đerdap Gorge-117 km long) as a biggest hydropower dam and reservoir system has not been investigated. Iron Gates I and II along with the hydrotechnical regulation works along the Danube tributaries have changed the sediment discharge of the Danube (Panin & Jipa 2002). It has been documented that the Iron Gate reservoirs, are significant sinks for nutrients, as well as pollutants (Panin & Jipa 2002). Based on our study, the territory of the National Park Đerdap represents the least studied part of the Danube.

Muscle was the most frequently studied tissue, which is probably not surprising as it represents the main fish for human consumption (Storelli *et al.* 2006). Liver is the

Table 1. Data regarding studied research, locality, species, elements and tissues (M-muscle, G-gills, L-liver, SP-spleen, GO-gonads, I-intestine, WB-whole body, K-kidney, H-heart, BR-brain, V-vertebrae, SB-swimming bladder, GI-gizzard, GB-gallbladder, OP-operculum)

Authors	Locality (rkm)	Species	Elements	Tissues
Maletin *et al.*, 1996	around 1250	*Alburnus alburnus,Carassius auratus,Cyprinus carpio, Tinca tinca, Anguila anguila, Esox lucius, Micropterus salmoides,Silurus glanis,Stizostedion lucioperca*	Cd, Co, Cu, Fe, Mn, Ni, Pb,Zn	G,M,L,SP,GO
Poleksić *et al.*,2010	1319; 1173; 861	*Acipenser ruthenus*	Cd, As, Pb, Cr, Hg, Cu, Ni, Fe, Mn, Zn	M, G, L, I
Jarić *et al.*, 2011	1299; 1169; 863	*Acipenser ruthenus*	Ag, Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Sr, Zn, Li	M, G, L, I
Višnjić-Jeftić *et al.*, 2010	863	*Alosa immaculata*	Al, As, Cd, Cu, B, Ba, Fe, Mg, Sr, Zn, Li, Co, Cr, Mn, Mo, Ni, Pb	M, G, L
Lenhardt *et al.*,. 2012	1173	*Hypophthalmichthys molitrix,Abramis brama,Blicca bjoerkna, Cyprinus carpio, Silurus glanis*	Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Se, Sr i Zn	M, G, L, GO
Sunjog *et al.*,2012	1173	*Barbus barbus*	Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Sr, Zn	M, G, L, GO
Zrnčić *et al.*, 2012	1432; 1354; 1381	*Chondrostoma nasus, Ctenopharingodon idella, Leuciscus idus, Alburnus alburnus, Rutilus rutilus, Carassius gibelius, Cyprinus carpio, Abramis brama, Aspius aspius, Esox lucius, Sander lucioperca, Silurus glanis, Lota lota, Hypophthalmichthys molitrix, Lota lota*	As, Cd, Hg, Pb	M
Rašković *et al.*, 2014	1173	*Barbus barbus, Acipenser ruthenus*	As, B, Ba, Cd, Co, Cu, Fe, Hg, Li, Mn, Mo, Ni, Pb, Se, Sr i Zn.	M, G, L
Subotić *et al.*, 2013	1168-1170	*Sander lucioperca, Silurus glanis, Lota lota, Cyprinus carpio*	Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Hg, Li, Mn, Mo, Ni, Pb, Se, Sr, i Zn	M, G, L
Subotić *et al.*, 2013	1170	*Sander lucioperca, Silurus glanis, Cyprinus carpio, Neogobius gymnotrachelus, Neogobius melanostomus*	As, Cu, Fe, Hg, Mn i Zn	M,L,WB
Jovičić *et al.*, 2014	1169	*Silurus glanis*	As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se i Zn	M,G,L,SP,K, I, GO, H, BR, V, SB, GI, GB, OP
Ivanović *et al.*,2016	1132	*Hypophthalmichthys molitrix, Cyprinus carpio, Silurus glanis*	As, Cd, Hg, Pb	M,L,I
Milošković *et al.*,2016	1257;1173;852	*Sander lucioperca,Silurus glanis, Abramis brama*	Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb I Zn	M
Morina *et al.*,2016	1173;	*Barbus barbus*	Al, As, B, Ba, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Se, Sr i Zn	M,G, L,I
Kostić *et al.*,2017	1170	*Abramis brama*	Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Sr i Zn	M,G,L
Jovanović *et al.*, 2017	1173; 1132	*Carassius auratus gibelio,Barbus barbus,Abramis brama,Cyprinus carpio, Stizostedion lucioperca, Silurus glanis*	As, Cd, Cu, Fe, Hg, Pb, Zn	M

second most frequently analyzed tissue. It is metabolically active tissue and has higher accumulation potential for metal accumulation than muscle tissue (Storelli *et al.* 2006). The gills are considered to be the main site of the metal uptake from the water, and high metal concentrations in gills can indicate that the main route of contamination is the water (Bervoets and Blust 2003; Storelli *et al.* 2006). The spleen is considered as important metal storage tissue as the kidneys and the liver (Yancheva *et al.* 2014). Other fish organs and tissues have been poorly studied so far.

The most frequently analyzed species was the wels catfish. It is economically important and highly prized fish species and well represented in fishermen's catch (Hegedis *et al.* 2013). Carp was the second most frequently studied fish species, which is understandable given that it is the most popular species in the diet of the population in Serbia (Hegedis *et al.* 2013). Pike-perch is an economically important fish species for commercial and recreational fishing (Hegedis *et al.* 2013). Bream and barbell were also studied. Bream is among higher quality fish while the barbell is a common species in fishermen's catch and an extremely attractive species for recreational fishing (Hegedis *et al.* 2013).

In analyzed studies As, Pb, Cd, Cu, Zn, Fe, Ni, Mn and Co were the most frequently studied elements. These elements represent some of the major pollutants regarding environmental impact and human health (Schenone *et al.* 2014). With the exception of Mn and Ni, maximum allowed concentrations (MAC) in fish meat were established for the above mentioned elements for the utilization in human diet. Nevertheless, other elements should also be included in analyses in order to evaluate their potential impact on fish.

CONCLUSIONS

To conclude, the most frequently studied fish tissue was muscle, while the most frequently studied species was wels catfish. As, Pb, Cd, Cu, Zn, Fe, Ni, Mn and Co were the most frequently analyzed elements. Future studies should include more fish species and include those tissues that have been neglected so far. Also, future research efforts should also cover the section of the Danube River in Serbia that has been neglected so far (1132 rkm-863 rkm).

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