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CIRCULATION OF CADMIUM (CD) IN THE SYSTEM *ALBURNUS ALBURNUS* (LINNAEUS, 1758), WATER AND SEDIMENTS FROM THE DANUBE RIVER, NORTHWESTERN BULGARIA

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Abstract

In 2020, 30 specimens of bleak (Alburnus alburnus Linnaeus, 1758), 3 samples of water and 3 samples of sediments were collected from the Danube River (Kudelin) in the northwestern part of the Republic of Bulgaria. Samples of water and sediments, of tissues/ organs (liver, skin and muscles) of bleak were investigated for the presence of cadmium (Cd). The concentrations of Cd in the studied tissues/ organs of Alburnus alburnus decreased as follows: liver (C_{Cd} = 1.38 ± 0.55 mg.kg^{-1} wet weight) > skin (C_{Cd} = 0.50 ± 0.18 mg.kg^{-1} wet weight) > muscles (C_{Cd} = 0.09 ± 0.05 mg.kg^{-1} wet weight). The reported concentrations of Cd in water samples are C_{Cd} = 0.008 ± 0.006 mg.l^{-1}, and in sediments samples C_{Cd} = 1.55 ± 2.35 mg.kg^{-1} dry weight.

Key words*: Alburnus alburnus, cadmium, Danube River, Kudelin, northwestern Bulgaria.*

INTRODUCTION

With a length of 2,857 km, the Danube River ranks second in length in Europe (Baltălungă & Dumitrescu, 2008). The river has hundreds of tributaries - approximately 300 (Gasparotti et al., 2013).

Larger tributaries of the Danube River are the Morava River with a length of nearly 270 km (the Czech Republic/Slovakia/ Austria), the Tisza River with a length of 977 km (Ukraine/Slovakia/Romania/Hungary/ Serbia), the Sava River approximately 944 km (Slovenia/Croatia/Bosnia and Herzegovina/ Serbia), Timok River with a length of 202 km (Serbia/ Bulgaria), Iskar River - 368 km (Bulgaria), Olt River with a length of 615 km (Romania), Prut River - 967 km (Romania/ Moldova), etc. (Parvanov et al., 2008; Postolachi et al., 2012; Sakan et al., 2013; Serbula et al., 2016; Kilianova et al., 2017; Iordache et al., 2019; Bakiu, 2020).

The Danube River receives water from its numerous tributaries and is highly vulnerable to contamination (Frincu et al., 2020).

Heavy metals are among the most hazardous pollutants in the aquatic environment due to their toxicity and accumulation in aquatic organisms and the surrounding environment (Janjić et al., 2015). In fish, cadmium accumulates chiefly in the kidneys and liver (Kumar & Singh, 2010). There are few studies on heavy metals content in tissues/ organs of bleak from the Bulgarian section of the Danube River (Chunchukova & Kuzmanova, 2017; Chunchukova et al., 2017; Shukerova et al., 2017; Chunchukova, 2018; Chunchukova et al., 2020; Zaharieva & Kirin, 2020).

The study aims to provide information on the circulation of cadmium (Cd) in the system bleak (*Alburnus alburnus* Linnaeus, 1758), water and sediments from the Bulgarian section of the Danube River, near the village of Kudelin, northwestern Bulgaria.

MATERIALS AND METHODS

Samples of water and sediments, and fish, during 2020 were collected from the Danube River, close to Kudelin. Kudelin (44°11′30″N, 22°40′5″E) is a village in northwestern Bulgaria. It is located in Vidin district and is situated near the Timok River and Danube River, which form part of the border of Bulgaria with the Republic of Serbia and Republic of Romania (Figure 1).

Figure 1. Danube River, Kudelin, northwestern Bulgaria (www.icpdr.org)

The scientific fishing was carried out using fishing gear mentioned in a permit issued by the Executive Agency of Fisheries and Aquaculture (EAFA). The species of all caught fish was defined by Karapetkova & Zhivkov (2006). TL, MH and BW namely the total length (cm), the maximum body height (cm) and the body weight (g) of the studied specimens of *A. alburnus*, were noted (Table 1).

Table 1. Length (TL), height (MH) and weight (BW) of the studied specimens of *A. alburnus* from the Danube River, Kudelin

***Alburnus alburnus* N = 30**	**TL**	**MH**	**BW**
Min – Max	9.1-12.5	1.7-2.9	4-12
Mean ± SD	10.61 ± 0.86	2.26 ± 0.27	6.40 ± 1.69

Three samples of water, three samples of sediments, as well as tissues and organs samples (liver, skin and muscles) of bleak, were sent for chemical analysis on ICP "OPTIMA 7000" Perkin-Elmer in an accredited laboratory at the Institute of Biodiversity and Ecosystems Research at the Bulgarian Academy of Sciences, Sofia, Bulgaria. In the study was fixed the bioconcentration factor (BCF). The linear correlation coefficient of Spearman (r_s) was also calculated.

RESULTS AND DISCUSSIONS

In 2020, 30 specimens of *Alburnus alburnus* (L., 1758) from the Danube River's freshwater ecosystem, Kudelin, were studied. *Alburnus alburnus* is a freshwater fish that inhabits the upper layers of the water. The species is subject to sport fishing (Karapetkova & Zhivkov, 2006).

Liver, skin and muscles samples of *A. alburnus* were analyzed for cadmium presence (Cd). The chemical analysis data are given in $mg.kg^{-1}$ wet weight; $mg.kg^{-1}$ dry weight. Water samples and sediments samples from the same section of the river were also collected and tested for Cd content. The chemical analysis data of water samples are in $mg.l^{-1}$ and of sediments samples in $mg.kg^{-1}$ dry weight (Table 2).

Table 2. Cadmium (Cd) concentrations in tissues/ organs of *A. alburnus*, water and sediments from the Danube River, Kudelin

Tissues/organs of *A. alburnus*, water, sediments		**Min - Max**	**Mean ± SD**
liver	$mg.kg^{-1}$ wet weight	0.78-1.86	1.38 ± 0.55
	$mg.kg^{-1}$ dry weight	2.27-6.79	4.25 ± 2.31
skin	$mg.kg^{-1}$ wet weight	0.38-0.70	0.50 ± 0.18
	$mg.kg^{-1}$ dry weight	0.48-0.84	0.61 ± 0.21
muscles	$mg.kg^{-1}$ wet weight	0.05-0.15	0.09 ± 0.05
	$mg.kg^{-1}$ dry weight	0.13-0.37	0.23 ± 0.12
water	$mg.l^{-1}$	0.001-0.011	0.008 ± 0.006
sediments	$mg.kg^{-1}$ dry weight	0.15-4.27	1.55 ± 2.35

Of the examined tissues/ organs of *A. alburnus*, the highest concentrations of Cd were reported in the liver samples (C_{Cd} = 1.38 ± 0.55 mg.kg^{-1} wet weight), followed by those in skin samples (C_{Cd} = 0.50 ± 0.18 mg.kg^{-1} wet weight) and muscles samples (C_{Cd} = 0.09 ± 0.05 mg.kg^{-1} wet weight). The study showed that the examined element concentrations in samples of bleak decreased in the order: liver > skin > muscles. During the study, concentrations of Cd in the water samples (C_{Cd} = 0.008 ± 0.006 mg.l^{-1}) and in the sediments samples (C_{Cd} = 1.55 ± 2.35 mg.kg^{-1} dry weight) from the Danube River, Kudelin were also indicated (Table 2).

The cadmium (Cd) concentrations in the liver, skin and muscles of bleak were studied in 2019 by Zaharieva & Kirin (2020) from the same section of the Danube River. The authors found that concentrations of cadmium in bleak samples decreased in the order: liver (C_{Cd} = 0.80 ± 0.56 mg.kg^{-1} wet weight) > skin (C_{Cd} = 0.21 ± 0.15 mg.kg^{-1} wet weight) > muscles (C_{Cd} = 0.08 ± 0.07 mg.kg^{-1} wet weight), which was confirmed in the present study. In 2020, higher Cd concentrations were reported in the liver, skin and muscles samples of *A. alburnus* compared to those found in 2019, by 1.73 times, 2.38 times and 1.13 times, respectively.

The study presented cadmium (Cd) excess in tissues/ organs samples of *A. alburnus* in relation to the norms specified in national and international documents. The Cd concentrations in liver, skin and muscles of *A. alburnus* exceeded the standard for Cd (0.05 mg/kg) in Ordinance No. 31 of 2004 on the maximum levels of contaminants in foodstuffs, by 27.6, 10 and 1.8 times, respectively. The reported Cd concentrations in the liver and skin of *A. alburnus* exceeded the norm (0.2 mg/kg) given by the Food and Agriculture Organization (FAO) by 6.9 and 2.5 times, respectively (Figure 2).

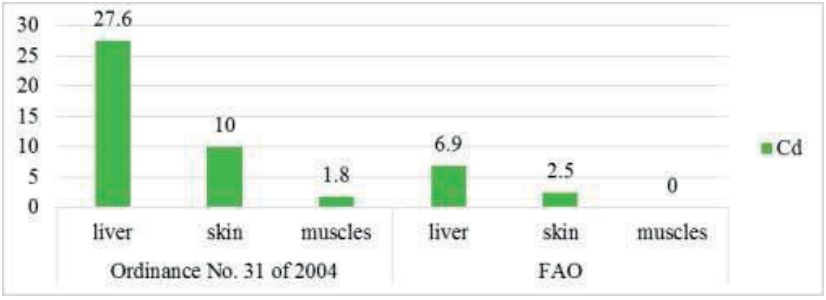

Figure 2. Excess of Cd in tissues/ organs (mg.kg^{-1} wet weight) of *A. alburnus* from the Danube River, Kudelin

The concentrations of cadmium (Cd) in water samples were considered with the norms in documents from the national legislation (Ordinance on environmental quality standards for priority substances and certain other pollutants of 2010; Ordinance No. 18 of 2009 on the quality of water for irrigation of crops). Excess of Cd in water was found only with the norm (0.0009 mg/l) in the Ordinance on environmental quality standards of 2010, namely by 8.89 times (Figure 3).

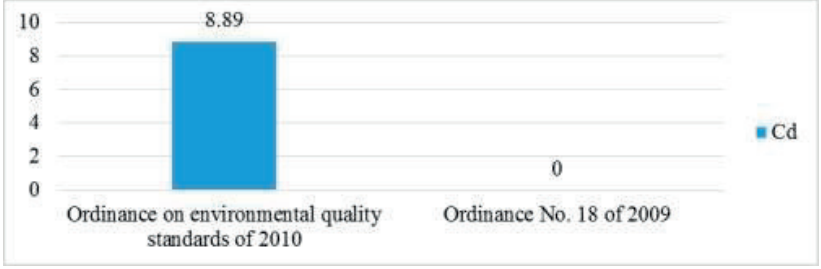

Figure 3. Excess of Cd in water (mg/l) from the Danube River, Kudelin

The study compared the cadmium concentrations (Cd) in sediment samples with the norms specified in national and international documents. The Cd concentrations in sediments did not exceed the norm (2 mg/kg at pH 6.0-7.4) in Ordinance No. 3 of 2008 on the norms for the permissible content of harmful substances in soils. Still, they exceeded the Dutch Target Values (0.8 mg/kg) by 1.94 times (Figure 4).

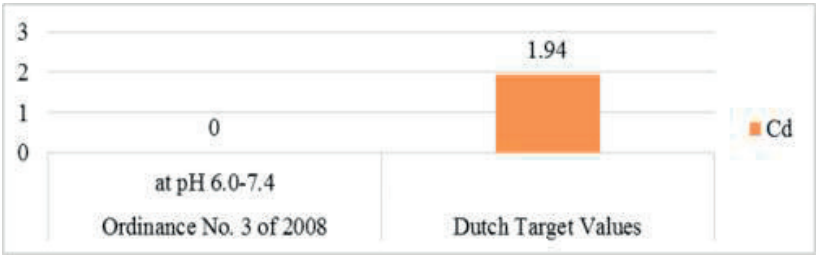

Figure 4. Excess of Cd in sediments (mg/kg) from the Danube River, Kudelin

The bioconcentration factor of water ((BCF = [$C_{host\ tissues}$]/[C_{water}])) and the bioconcentration factor of sediments ((BCF = [$C_{host\ tissues}$]/[$C_{sediments}$])) were calculated. In both cases, the liver samples had the highest Cd accumulation, and the muscles samples had the lowest (Table 3).

Table 3. Bioconcentration factor BCF and BCF

***Alburnus alburnus* /Water**	**BCF_{Cd}**
C_{liver}/C_{water}	172.50
C_{skin}/C_{water}	62.50
C_{muscle}/C_{water}	11.25
***Alburnus alburnus*/Sediments**	**BCF_{Cd}**
$C_{liver}/C_{sediments}$	2.74
$C_{skin}/C_{sediments}$	0.39
$C_{muscle}/C_{sediments}$	0.15

The linear correlation coefficient of Spearman (r_s-1.0) shows very high correlations between the Cd content in water and sediments and those in the studied liver, skin and muscles samples of *A. alburnus*.

Chunchukova & Kuzmanova (2017) found a significant negative correlation ($p<0.05$) between concentrations of arsenic in *Pomphorhynchus laevis* (acanthocephalan on *A. alburnus*) and those in sediments from the Danube River (Vetren). Chunchukova et al. (2017) fixed Spearman's rank correlation coefficient (r_s). They found a highly significant correlation ($p<0.01$) between the concentrations of lead (Pb) in *Pomphorhynchus tereticollis* (acanthocephalan on *A. alburnus*) and those in the Danube River's sediments (the Vetren area). Chunchukova (2018) reported a significant correlation ($p<0.05$) between the nickel (Ni) content in *P. laevis* and those in skin samples of bleak from the Danube River (Vetren). Zaharieva & Kirin (2020) found a very high correlation between the content of copper, cadmium and arsenic in tissues/ organs of *A. alburnus* and those in Danube River's water and sediments (the Kudelin biotope) – r_s=0.86-0.99 relative to water content; $p<0.05$ and r_s=0.96-0.99; $p<0.05$.

CONCLUSIONS

In 2020, 30 specimens of *A. alburnus* (L., 1758), three water samples, and three samples of sediments were collected from the Danube River (Kudelin). All collected samples were tested for the presence of cadmium (Cd). With regard to the examined tissues/ organs of bleak, cadmium concentrations were the highest in the liver samples (C_{Cd} = 1.38 ± 0.55mg.kg^{-1} wet weight), followed by those in

the skin samples (C_{Cd} = 0.50 ± 0.18 mg.kg^{-1} wet weight) and the muscles samples (C_{Cd} = 0.09 ± 0.05 mg.kg^{-1} wet weight). The bioconcentration factor values prove the highest Cd accumulation occurred in the liver and the lowest in muscles for both the water and the sediments. A very significant correlation was found between the Cd content in both water and sediments, and those in the bleak studied biological samples.

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