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MONITORING THE ECOLOGICAL STATE AND ANTHROPOGENIC LOADING OF THE LUDA YANA RIVER THROUGH THE USE OF INDICATOR MACROZOOBENTHOS

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Abstract

The study aims to monitor the ecological state and anthropogenic load of the Luda Yana River, part of the Maritsa River catchment. For this purpose, five biotopes of the Luda Yana River and its tributary Strelchanska Luda Yana (Strelcha, Popintsi, Svoboda, Rosen and Pazardzhik) were visited in 2025. A total of 711 specimens of 23 taxa of macroinvertebrate organisms belonging to Oligochaeta, Mollusca, Crustacea, Plecoptera, Ephemeroptera, Trichoptera, Odonata, Heteroptera, Coleoptera, Diptera, Chironomidae and Hydracarina were collected from all biotopes. Basic metrics and indices concerning the abundance and number of the collected indicator macrozoobenthos were calculated. The ecological state of the Luda Yana River is presented and discussed. The ecological state has been reported to range from moderate (Popintsi biotope) to very bad (Strelcha, Svoboda and Rosen biotopes). The content of Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Hg, and Pb in samples of macrozoobenthos, waters and sediments from two biotopes (Svoboda and Pazardzhik) was determined. The highest content of Fe, Al and Mn was found. The bioconcentration factor was considered. National and international legislative norms were used to compare the results of the chemical analyses.

Key words*: bioindication, Bulgaria, ecological indices, heavy metals and metalloids, river ecosystem.*

INTRODUCTION

The Luda Yana River rises in the Sashtinska Sredna Gora under the name Panagyurska Luda Yana and flows through the Panagyurska Valley. After the village of Buta it flows under the name Luda Yana, enters the Pazardzhik-Plovdiv Plain, and flows into the Maritsa River. Tributaries of the river are the Banska Luda Yana River, the Strelchanska Luda Yana River and others. The waters in the lower reaches of the Luda Yana River are used for irrigation (Kiradzhiev, 2013; Gartsiyanova et al., 2021; 2023). The Luda Yana River flows through the Panagyurishte Ore Region, which extends between the central Srednogorie and Stara Planina Mountains and includes several ore deposits, including Assarel, Medet, Elshitsa, Tsar Asen, and Radka (Popov et al., 2003). Pollution of the Luda Yana River is a result of industry, wastewater discharge from urban sewage systems, and agriculture (livestock farms) (Gartsiyanova et al., 2021; 2023). Mining (from exploration through exploitation to deposit closure) impacts the environment, leading to land degradation, air, surface water, and soil pollution, loss of biodiversity, and more (Jhariya et al., 2016). Mineral extraction is associated with the release of large amounts of waste material. Tailings dams, which store a variety of mining waste, are among the most environmentally damaging pollutants (Agboola et al., 2020). Water resources are among the most affected by mining (Jhariya et al., 2016). The importance of rivers as water resources lies in their provision of water for household, industrial, and agricultural needs, as well as various activities (including fishing), which is why their protection from pollution is extremely important (Shanbehzadeh et al., 2014). Heavy metals are characterised by significant toxicity, persistence, bioaccumulation and biomagnification (Garai et al., 2021). About 99.9% of heavy metals

accumulate in sediments, while about 0.1% are dissolved in water (Pradit et al., 2013; Hacısalihoğlu & Karaer, 2016). Aquatic organisms are exposed to the effects of dissolved heavy metals in water on the one hand and those in sediments on the other (Garai et al., 2021). Macroinvertebrates are characterised by low mobility and long lifespan, which is why they can reflect changes in the aquatic environment. Pollution of the aquatic environment leads to changes in the composition and structure of aquatic organism communities (Varadinova et al., 2022). Few authors have investigated the water quality of the Luda Yana River based on the biological quality element (BQE) macrozoobenthos (Vidinova et al., 2008; Georgieva et al., 2014; Zaharieva et al., 2024). Rabadjieva et al. (2009) investigated heavy metal concentrations in waters from the Luda Yana River. No studies were found that affected the circulation of heavy metals in waters, sediments and macrozoobenthos of the studied river ecosystem.

The present study aims to monitor the ecological state and anthropogenic load of the Luda Yana River using the abundance and numbers of indicator macroinvertebrate fauna, and the concentrations of heavy metals and metalloids in macrozoobenthos, water, and sediments.

MATERIALS AND METHODS

In the spring of 2025, five sites (designated as biotopes) were visited along the Luda Yana River and its tributary, the Strelchanska Luda Yana River (Figure 1).



Figure 1. Map of the studied biotopes

The Strelcha biotope falls within a section of the Strelchanska Luda Yana River named “The Strelchanska Luda Yana River from its sources to the town of Strelcha” of Type R03 Mountain Rivers in Ecoregion 7 Eastern Balkans. The Popintsi biotope is located within a section of the Luda Yana River named “The Panagyurska Luda Yana from Panagyurishte to the confluence of the Strelchanska Luda Yana” of Type R05 Semi-mountainous Rivers in Ecoregion 7. The Svoboda, Rosen and Pazardzhik biotopes fall within a section of the Luda Yana River named “The Luda Yana River from its confluence of the Strelchanska Luda Yana to its mouth” of Type R05. Strelcha biotope (42°29'52.7"N 24°19'31.5"E; 515 m above sea level) is located along the Strelchanska Luda Yana River to the town of Strelcha. The bottom substrate of the river section in this biotope consists of silt, sand, and stones. Popintsi biotope (42°25'28.6"N 24°16'00.7"E; 373 m above sea level) is located along the Luda Yana River, northwest of the centre of the village of Popintsi. Svoboda biotope (42°23'59.1"N 24°17'31.2"E; 370 m above sea level) is located along the Luda Yana

River, in proximity to the Radka mine. Rosen biotope (42°18'45.7"N 24°21'56.1"E; 293 m above sea level) is located along the Luda Yana River, south of the centre of the village of Rosen. Pazardzhik biotope (mouth) (42°09'38.8"N 24°22'52.0"E; 228 m above sea level) is located along the Luda Yana River, in proximity to the wastewater treatment plant (WWTP) of the town of Pazardzhik, shortly before the river flows into the Maritsa River. The bottom substrate in the four biotopes is sand and stones.

Sampling of macroinvertebrates was carried out according to standard methods (Cheshmedjiev et al., 2011; BDS EN ISO 10870:2012; Regulation No. H-4, 2012; Belkinova et al., 2013; BDS EN 16150:2026). The taxonomic affiliation of the collected macrozoobenthos was determined in laboratory conditions using a Stereo Zoom Microscope KERN OZL 464T24. According to Regulation No. H-4 (2012) and Belkinova et al. (2013), the following were calculated:

- total number of macroinvertebrate taxa;
- number of taxa from orders Ephemeroptera, Plecoptera and Trichoptera (EPT);
- Oligochaeta & Diptera in percentage;
- Filter feeders in percentage;
- EPT taxa in percentage;
- German trophic index Rithron Feeding Type Index;
- saprobiological index – Pantle & Buck (SPUB);
- biotic index (BI).

Basic ecological indices have been determined (Table 1).

Table 1. Main ecological indices

INDEX	*FORMULA*	*INTERPRETATION*
Shannon Index (H')*	$H' = -\sum_{i=1}^{S}(p_i \ln p_i)$ where $p_i=n_i/N$; n_i is the number of specimens of each i species; N is the number of specimens of all species.	Index values ≤1.99 show very low diversity; 2.00-2.49 – low diversity; 2.50-2.99 – moderate diversity; 3.00-3.49 – high diversity; ≥3.50 – very high diversity.
Simpson's Index (D)*	$D = \frac{\sum_i n_i(n_i-1)}{N(N-1)}$	Index values range from 0 to 1. A value close to 0 indicates infinite diversity. A value close to 1 indicates no diversity.
Simpson's index of diversity (1-D)**	$1 - \frac{\sum_i n_i(n_i-1)}{N(N-1)}$	Index values range from 0 to 1. A value closer to 1 indicates greater diversity and vice versa.
Berger Parker Dominance Index (d)***	$d = \frac{n_{max}}{N}$ where n_{max} is the number of specimens of the most common species.	Index values range from 0 to 1. Higher values indicate lower diversity.
Pielou's evenness index (J')****	$J' = \frac{H'}{H_{max}} = \frac{H'}{ln\, S}$ where S is the number of species; H' is the Shannon Index.	The index has a maximum value of 1, which indicates an even distribution of specimens and higher diversity.

Legend: * - according to Kim et al., (2017); Baliton et al., (2020); ** - according to Okpiliya, (2012); Arzamani et al., (2018); *** - according to Okpiliya, (2012); **** - according to Patrício, (2009); Arzamani et al., (2018); ***** - according to McDonald, (2010); Roy & Bhattacharya (2024)

Water and sediment sampling were carried out in accordance with BDS EN ISO 5667-6:2016 and BDS ISO 5667-12:2017, respectively. The samples of surface water, sediments and biological element macrozoobenthos were collected from two biotopes – the Svoboda biotope, in a region with mining activity, and the Pazardzhik biotope, before the confluence of the Luda Yana River into the Maritsa River (before the mouth). All samples were analysed for 12 heavy metals and metalloids (Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Hg and Pb) using an Inductively Coupled Plasma Mass Spectrometer (ICP-MS DRC-e, Perkin Elmer) according to BDS EN ISO 21424:2020. The chemical analysis was carried out in an accredited laboratory. The heavy metals content in the samples of water, sediments and

biological elements is compared with the norms of national and international legislation (Dutch target values, 2000; Regulation No. 31, 2004; Regulation No. 3, 2008; Regulation No. 18, 2009; Regulation on environmental quality standards, 2010; Regulation No. H-4, 2012; Commission Regulation (EU) 2023/915). The Bioconcentration factor (BCF) was presented as the ratio of the pollutant concentration in the tissues or organs of aquatic organisms (macrozoobenthos) to the pollutant concentration in the aquatic environment (waters and sediments) (Sabljic & Protic, 1982; Yarsan & Yipel, 2013).

RESULTS AND DISCUSSIONS

Ecological state based on the BQE macrozoobenthos

In the present study, a total of 22 taxa (including Hydracarina) and 711 macroinvertebrate specimens were found in the five biotopes of the Luda Yana River and its tributary (Table 2).

Table 2. Taxonomic composition and number of macrozoobenthos from the Luda Yana River and Strelchanska Luda Yana River (Nt – number of taxa; Nsp – number of specimens)

Taxonomic composition	*Strelcha*		*Popintsi*		*Svoboda*		*Rosen*		*Pazardzhik*	
	Nt	Nsp	Nt	Nsp	Nt	Nsp	Nt	Nsp	Nt	Nsp
Oligochaeta	1	93	2	2	-	-	1	1	-	-
Mollusca	1	1	1	6	1	1	-	-	-	-
Crustacea	-	-	-	-	-	-	-	-	1	35
Plecoptera	-	-	1	1	-	-	1	1	-	-
Ephemeroptera	-	-	3	94	3	39	2	12	2	9
Trichoptera	-	-	3	8	1	2	1	1	1	32
Odonata	-	-	1	19	2	4	1	2	2	18
Heteroptera	-	-	-	-	-	-	1	1	-	-
Coleoptera	-	-	-	-	1	2	1	1	-	-
Diptera	2	6	3	5	-	-	2	2	2	3
Chironomidae	1	184	2	22	2	101	1	1	1	2
Hydracarina	-	-	-	-	-	-	-	-	-	presence

In the present study, the highest number of taxa was found in the orders Ephemeroptera (4 taxa: *Baetis* sp., nymph; *Cloeon* sp., nymph; *Caenis horaria* (Linnaeus, 1758), nymph; *Serratella ignita* (Poda, 1761), nymph), Trichoptera (3 taxa: *Hydropsyche ornatula* McLachlan 1878, larvae; *Anabolia nervosa* (Curtis, 1834), larvae; *Limnephilus rhombicus* (Linnaeus, 1758), larva) and Diptera (3 taxa: *Simulium* sp., larvae; *Tabanus* sp., larvae; Diptera, pupae). Taxa from the orders Ephemeroptera and Trichoptera are more sensitive to anthropogenic load.

The greatest taxonomic diversity was found in the Popintsi biotope (15 taxa). In the Popintsi, the dominant taxon is *Baetis* sp. nymph (74 specimens; Ephemeroptera); in the Svoboda biotope – Chironomidae (85 specimens); in the Rosen biotope – *C. horaria*, nymph (10 specimens; Ephemeroptera); in the Pazardzhik biotope – *Gammarus pulex* (Linnaeus, 1758) (35 specimens; Crustacea: Malacostraca). From the Strelchanska Luda Yana River, in the Strelcha biotope, *Chironomus plumosus* (Linnaeus, 1758), larvae (184 specimens; Chironomidae) dominate. The highest number of EPT taxa was found in Popintsi, with 7 taxa. The ecological state of the Luda Yana River, as measured by the total number of macroinvertebrate taxa and the number of EPT taxa, varies from good in the Popintsi biotope to moderate downstream in the Svoboda, Rosen, and Pazardzhik biotopes. The ecological state of the Strelchanska Luda Yana River in the Strelcha biotope was found to be poor in terms of the total number of macroinvertebrate taxa and very poor in terms of the number of EPT taxa (Table 3). The share of Oligochaeta & Diptera is highest in the Strelcha biotope from the Strelchanska Luda Yana River – 97.89% of the total abundance, followed by the Svoboda biotope from the Luda Yana River – 67.79%. The share of Filter feeders is highest in the Strelcha – 1.76% of the total abundance. Representatives of the Filter feeders ecological group were not found in the Svoboda and Rosen. The percentage of EPT taxa was highest in the Popintsi biotope, followed by the Rosen

biotope (Figure 2). Higher EPT taxa in percentage indicate less pollution.

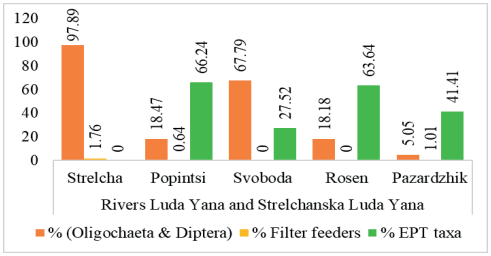


Figure 2. Basic macrozoobenthos abundance metrics

The distribution of indicator macrozoobenthos in the Luda Yana River and its tributaries, grouped by feeding type, was examined. Based on this distribution, the Rithron Feeding Type Index was calculated. In the Strelcha, Svoboda and Rosen biotopes, deposit feeders predominate ($DF_{Strelcha}$=97.54%; $DF_{Svoboda}$=30.20%; DF_{Rosen}=50.00%), while in the Popintsi and Pazardzhik biotopes, scrapers ($SC_{Popintsi}$=52.87%; $SC_{Pazardzhik}$=41.41%) (Figure 3).

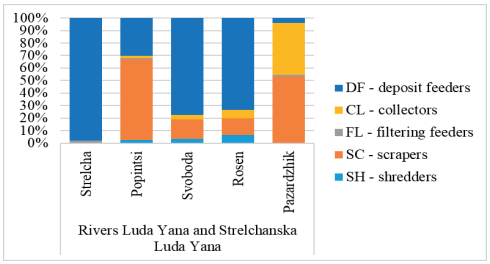


Figure 3. Distribution of macrozoobenthos by trophic groups (in percentages of the total number)

The calculated Rithron Feeding Type Index shows a good ecological state in the Popintsi and Pazardzhik biotopes and a very bad one in the other three biotopes. In addition, Rithron Feeding Type Index values <0.5 indicate an imbalance in the ecosystem, including organic pollution (Table 3).

In the Strelcha biotope, the indicator macrozoobenthos comprises four saprobic groups: xeno-oligosaprobic, β-mesosaprobic, polysaprobic, and poly-α-mesosaprobic (each with one taxon). In the Popintsi, the indicator macrozoobenthos, indicating oligo-β-mesosaprobic conditions (with four taxa), dominates. In the Rosen and Pazardzhik, the indicator macrozoobenthos for β-α-mesosaprobic conditions (with 3 taxa each) was established. In the Svoboda, an equal number of taxa of macroinvertebrates (indicating oligo-β-mesosaprobic conditions) and β-α-mesosaprobic conditions (with 2 taxa each) were established. Based on the saprobic importance, the indicator weight and the abundance of the macrozoobenthos indicator taxa, the saprobic index was calculated and a bad ecological state of the waters of the Strelchanska Luda Yana River in the Strelcha and a change in the ecological state of the waters of the Luda Yana River from good in the Svoboda and Popintsi to very good in the Rosen and Pazardzhik were found (Table 3).

The indicator macrozoobenthos from both rivers belongs to A, B, C, D, and E groups, respectively, sensitive, less sensitive, relatively tolerant, tolerant, and most tolerant organisms. In all investigated biotopes from the Luda Yana River, group C taxa dominate, except the Strelcha biotope from the Strelchanska Luda Yana River, where groups C, D and E are represented by an equal number of taxa (1 taxon). In the Strelcha biotope, the largest numbers of tolerant macrozoobenthos specimens were found (Figure 4). The calculated biotic index (BI) indicates a moderate ecological state in the Popintsi biotope, a bad ecological state in the Svoboda and Pazardzhik biotopes, and a very bad ecological state in the Strelcha and Rosen biotopes (Table 3).

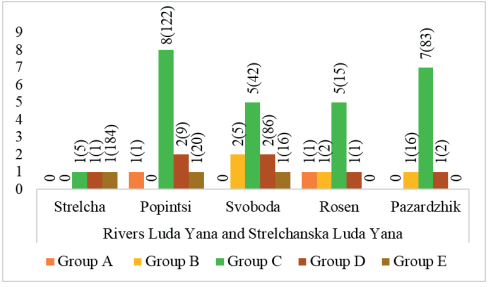


Figure 4. Distribution of established macrozoobenthos by sensitivity groups (number of taxa/number of specimens)

Table 3. Ecological state of the studied river ecosystem
(red – very bad; orange – bad; yellow – moderate; green – good; blue – very good)

Metrics *Biotopes*	*Total number of taxa*	*Number of EPT taxa*	*Rithron Feeding Type Index*	*SPUB*	*BI (nEQR)*
	Luda Yana River and tributary				
Strelcha	5	0	0.004	3.73	1(0.3)
Popintsi	16	7	0.67	2.09	3(0.6)
Svoboda	10	4	0.19	2.10	2(0.4)
Rosen	11	4	0.20	1.50	2(0.2)
Pazardzhik	10	3	0.53	1.81	2(0.4)

Shannon Index (H') values range from 0.76 to 1.92, which indicates very low diversity in all studied biotopes, with the lowest values found in the Strelcha biotope (Strelchanska Luda Yana River) and Svoboda biotope (Luda Yana River). In the Strelcha biotope, the Simpson's Index (D) value is the highest (D=0.53), and the Simpson's index of diversity (1-D) value is the lowest (1-D=0.47), indicating lower diversity in this biotope, followed by the Svoboda biotope. Berger Parker Dominance Index (d) is highest in Strelcha biotope (d=0.65), followed by Svoboda biotope (d=0.57), which again shows lower diversity in these two biotopes. Pielou's evenness index (J') has the lowest values in the Strelcha and Svoboda biotopes (J'=0.47 and J'=0.59, respectively), which indicates a lower evenness in the distribution of taxa (Table 4).

Table 4. Ecological indices of the macrozoobenthos communities from the Luda Yana River and tributary

Indices	*Strelcha*	*Popintsi*	*Svoboda*	*Rosen*	*Pazardzhik*
Total number of taxa	5	16	10	11	9 (and presence of Hydracarina)
Total number of specimens	284	157	149	22	99
Shannon Index (H')	0.76	1.81	1.36	1.92	1.59
Simpson's Index (D)	0.53	0.26	0.38	0.20	0.25
Simpson's index of diversity (1-D)	0.47	0.74	0.63	0.80	0.75
Berger Parker Dominance Index (d)	0.65	0.47	0.57	0.45	0.35
Pielou's evenness index (J')	0.47	0.65	0.59	0.80	0.72

Based on the calculated metrics and indices for the indicator macrozoobenthos in the Luda Yana River and the Strelchanska Luda Yana River, a moderate ecological state was established in the Popintsi biotope, a bad state in the Pazardzhik biotope, and a very bad state in the Strelcha, Svoboda, and Rosen biotopes.

Vidinova et al. (2008) assessed water quality in the Luda Yana River after Rosen village using physicochemical parameters and macroinvertebrates. According to the calculated indices, the authors report that the Luda Yana River, after Rosen, belongs to the III category of waters. In the present study, a very bad ecological state was found for the Rosen biotope. Zaharieva et al. (2024) conducted hydrobiological monitoring of the Luda Yana River near the village of Popintsi based on BQE macrozoobenthos. The authors report a moderate ecological state in this section of the river, findings confirmed by the present study.

Content of heavy metals and metalloids

In the macrozoobenthos samples from the Luda Yana River, Svoboda biotope, the content of heavy metals and metalloids decreases in the order: Fe > Al > Mn > Cu > Zn > Cr > Pb > Co > Ni > As > Cd > Hg; in the water samples – in the order: Al > Fe > Mn > Cu > Zn > Ni > Cr > Co > Pb > Cd > As; in the sediment samples – in the order: Fe > Al > Mn > Zn > Cu > Pb > Co > Cr > Ni > As > Cd. In the macrozoobenthos samples from the Luda Yana River, Pazardzhik biotope, the content of heavy metals and metalloids decreases in the order: Al > Fe > Mn > Cu > Zn > Co > Cr > Pb > Ni > As > Cd > Hg; in the water samples – in the order: Fe > Mn > Cr > Zn > As > Cu > Al > Ni > Hg > Co > Cd > Pb; in the sediment samples – in the order: Fe > Al > Mn > Cu > Zn > Pb > Cr > Co > Ni > As > Cd. In general, in both studied sections (Svoboda and Pazardzhik) of the Luda Yana River, the highest

concentrations of Fe, Al, and Mn, and the lowest concentrations of Cd and As, were found. A higher content of Al, Cr, Fe, Cu, Zn, As and Pb was reported in macrozoobenthos samples from the Svoboda biotope compared to the Pazardzhik biotope. The content of all investigated heavy metals and metalloids is higher in the samples of waters from the Svoboda biotope compared to the Pazardzhik biotope. At the same time, the content of the investigated heavy metals and metalloids was higher in the sediment samples from the Pazardzhik biotope compared to the Svoboda biotope, except for Zn and Cd (Figures 5 and 6).

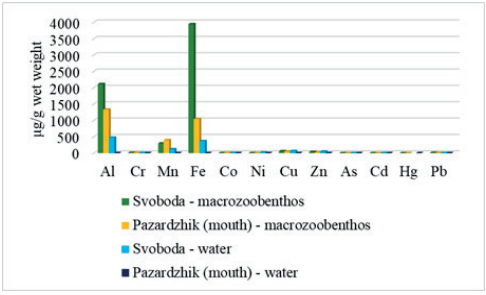


Figure 5. Content of heavy metals and metalloids in macrozoobenthos (µg/g wet weight) and water (µg/g wet weight) from the Luda Yana River

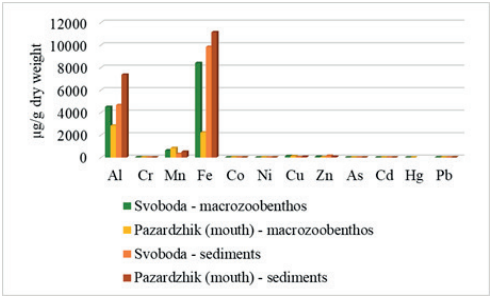


Figure 6. Content of heavy metals and metalloids in macrozoobenthos (µg/g dry weight) and sediments (µg/g dry weight) from the Luda Yana River

Bioconcentration factors (BCF) in the macrozoobenthos compared to Svoboda biotope waters have the highest values for Pb (BCF_{Pb}=38.04) and Fe (BCF_{Fe}=10.87), and the lowest for Ni (BCF_{Ni}=0.15).

The macrozoobenthos accumulated 253.6 times more Pb and 72.47 times more Fe from the waters compared to Ni. The values of the bioconcentration factor in the macrozoobenthos compared to sediments from the Svoboda biotope are the highest for Cu (BCF_{Cu}=3.97) and Cr (BCF_{Cr}=2.94), and the lowest for Zn (BCF_{Zn}=0.51). The macrozoobenthos accumulated 7.78 times more Cu and 5.77 times more Cr from the sediments than Zn. The values of the bioconcentration factor (BCF) in the macrozoobenthos compared to waters from the Pazardzhik biotope have the highest values for Al (BCF_{Al}=1329805.20) and Pb (BCF_{Pb}=132536.54), and the lowest for Hg (BCF_{Hg}=75.00). The macrozoobenthos accumulated 17730.74 times more Al and 1767.15 times more Pb from the waters compared to Hg. Bioconcentration factors in the macrozoobenthos compared to sediments from the Pazardzhik biotope are highest for Cd (BCF_{Cd}=2.67) and lowest for Fe (BCF_{Fe}=0.20). The macrozoobenthos accumulated 13.35 times more Cd from the sediments than Fe. According to the reported BCF values, the macrozoobenthos from the Pazardzhik can be determined as highly bioaccumulative (BCF>5000; Khan et al., 2022) of the elements Al, Pb, Co, Mn, Cu, Zn and Ni (Table 5). The obtained extremely high BCF values for Al (over 1.3 million) and for Pb (over 130 thousand) are due to a potential short-term dilution of the dissolved metals in the water samples at the river mouth during the sampling period (spring season) in contrast to the stable, long-term accumulation within the macrozoobenthos tissues.

Monitoring the content of heavy metals and metalloids in biota, waters and sediments from the Svoboda biotope is justified by the nearby suspected source of anthropogenic load - the Radka mine and the existing risk of pollution of the river ecosystem in this area. While the choice of the Pazardzhik biotope is related to the need to monitor the ecological state of the river ecosystem and the load with heavy metals and metalloids downstream, before the confluence of the Luda Yana River into the Maritsa River.

In the present study, excesses of six heavy metals and metalloids were found in macrozoobenthos samples, in accordance with the norms specified in Regulation No. 31 (2004), Dineva (2023), and Commission Regulation (EU) 2023/915. In the macrozoobenthos samples from the Svoboda, higher excesses of Al, Cr, Cu and Pb were

found compared to the macrozoobenthos from the Pazardzhik. Higher excesses of Ni and Cd were found in the macrozoobenthos samples from the Pazardzhik. In both biotopes from the Luda Yana River, no excesses of Zn, As and Hg were detected in the macrozoobenthos samples (Figure 7).

Table 5. Bioconcentration factor values

	Svoboda		*Pazardzhik*	
	Macrozoobenthos/ Waters	**Macrozoobenthos/ Sediments**	**Macrozoobenthos/ Waters**	**Macrozoobenthos/ Sediments**
BCF_{Al}	4.51	0.97	1329805.20	0.38
BCF_{Cr}	2.88	2.94	1246.27	1.08
BCF_{Mn}	2.57	2.06	41189.59	1.63
BCF_{Fe}	10.87	0.85	4693.88	0.20
BCF_{Co}	1.95	0.80	46674.66	1.31
BCF_{Ni}	0.15	0.95	5999.14	0.51
BCF_{Cu}	0.97	3.97	41122.54	1.68
BCF_{Zn}	0.82	0.51	8744.04	0.65
BCF_{As}	-	0.79	424.98	0.53
BCF_{Cd}	3.56	1.56	4608.00	2.67
BCF_{Hg}	-	-	75.00	-
BCF_{Pb}	38.04	2.02	132536.54	0.57

The results of the chemical analyses of surface water samples from the Luda Yana River, Svoboda biotope, show an excess of Al, 18.76 times above the maximum permissible concentrations (MPC) specified in Regulation No. H-4 (2012), and an excess of Cd – 0.18 times above the MPC specified in the Regulation on environmental quality standards (2010). In the surface water samples from the Pazardzhik, no excesses of the examined heavy metals and metalloids were found according to the norms specified in Regulation No. H-4 (2012), Regulation No. 18 (2009) and Regulation on environmental quality standards (2010). In sediment samples from the Luda Yana River, Svoboda, an excess was reported only for Zn, 1.05 times above the Dutch target values (2000). In the sediments from the Luda Yana River, Pazardzhik, exceedances were found for Co (1.25 times), Cu (1.79 times) and Pb (1.51 times) compared to the Dutch target values (2000). In both biotopes, the content of the examined heavy metals and metalloids did not exceed the norms specified in Regulation No. 3 (2008).

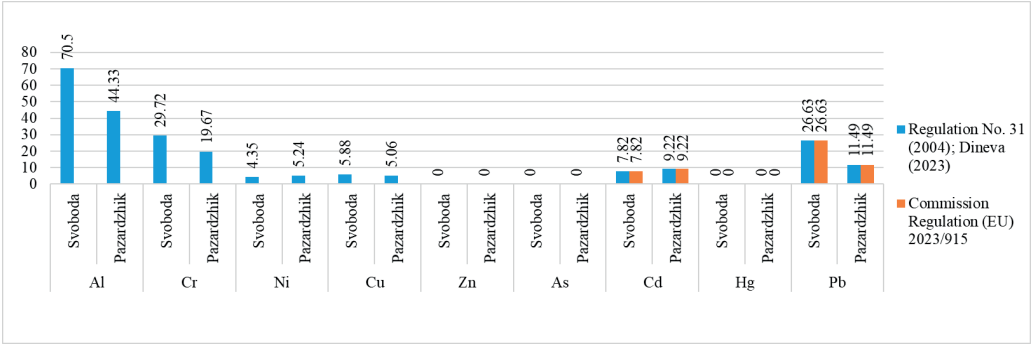


Figure 7. Excesses (in times) of the investigated heavy metals and metalloids in macrozoobenthos samples from the Luda Yana River

Gartsiyanova et al. (2020) investigated spatio-temporal changes in water quality of the Luda Yana River (at Rosen and before the mouth) and the Strelchanska Luda Yana River (after Strelcha) for the period 1981-2018 using complex indices to assess water quality status. The authors report that during the study period, the waters of the Luda Yana River did not meet

the requirements for good chemical status under Regulation No. H-4 (2012). The worst and critical values of the Water Quality Index were established for the Luda Yana River near Rosen. Gartsiyanova et al. (2021) investigated the state of the water in the Luda Yana River (at Rosen and at the mouth) using various indices. The authors define the waters as slightly polluted according to the Bavarian Surface Quality Index (CJ) and as polluted and highly polluted according to the Water Pollution Index (WPI) at Rosen; as well as absent to lightly polluted by CJ and moderately to heavily polluted by WPI at the mouth. The authors explain the bad quality of the water with increased levels of Fe, Mn, and Cu, as well as with high values of the indicators BOD5, ammonium, and nitrate nitrogen. In the present study, a very bad ecological state was found for the Rosen, and a bad state for the Pazardzhik biotope (mouth). In the waters of the Luda Yana River at Pazardzhik, the highest Fe and Mn content was also found, which, however, does not exceed the norms of national and international legislation. Gartsiyanova et al. (2022) investigated the water quality of the Strelchanska Luda Yana River (after Strelcha); on the Luda Yana River (near Popintsi and near Chernogorovo) through the use of physicochemical parameters and heavy metals (Cu, Fe, Mn, Pb, As, Zn, Cd and Ni). The authors indicate that the Luda Yana River in the section near Popintsi is the most polluted, and the one near Chernogorovo is in the best quality, and report persistent and significant pollution with heavy metals (Fe, Mn, Cd and Cu). In the current study of the Luda Yana River, the best ecological state (moderate) was recorded in the Popintsi compared to the other investigated biotopes. Gartsiyanova et al. (2023) analysed the water quality by physicochemical parameters in the catchment basin of the Luda Yana River for the period 2018-2021. The authors defined the waters of the Luda Yana River as highly polluted due to long-term anthropogenic impacts and reported elevated levels of some heavy metals. The authors identify the most favourable conditions for the Luda Yana River from mouth to source.

CONCLUSIONS

The ecological state of the waters of the Luda Yana and Strelchanska Luda Yana Rivers was assessed based on the taxonomic diversity and abundance of the indicator macrozoobenthos. The values of the calculated metrics and indices show a moderate ecological state of the Luda Yana River upstream (Popintsi biotope – BI(nEQR)=3(0.6)), very bad for the Strelchanska Luda Yana River at the Strelcha biotope (Number of EPT taxa – 0; Rithron Feeding Type Index=0.004; BI(nEQR)=1(0.3)), for the Luda Yana River at the Svoboda (Rithron Feeding Type Index=0.19) and Rosen (Rithron Feeding Type Index=0.20; BI(nEQR)=2(0.2)), as well as bad ecological state of the Luda Yana River before its confluence with the Maritsa River (Pazardzhik biotope – BI(nEQR)=2(0.4)). In addition, the chemical analyses performed on samples from the Svoboda and Pazardzhik biotopes revealed high contents of Fe, Al and Mn. More than half of the investigated heavy metals and metalloids have higher concentrations in the macrozoobenthos from Svoboda than in those from Pazardzhik (mouth). The content of all investigated heavy metals and metalloids was higher in the waters from Svoboda and higher in the sediments from Pazardzhik (mouth), except for Zn and Cd. According to the reviewed legislative documents, the highest exceedances were found for Al (70.5 and 44.33 times), Cr (29.72 and 19.67 times), Pb (26.63 and 11.49 times) and Cd (7.82 and 9.22 times) in the macrozoobenthos samples (from Svoboda and Pazardzhik, respectively), and for Al (18.76 times) in the water samples from Svoboda. Based on the monitoring carried out, permanent and more in-depth studies of the ecological state of the waters of the Luda Yana River and its tributaries, as well as the content of heavy metals and metalloids in river ecosystems, especially in areas with potential sources of anthropogenic load, are recommended in order to protect biodiversity, habitats and ensure a favorable environment for the life of hydrobionts.

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