DOI: 10.61458/jepm.2024.214
UDC: 504.5:556.53

CC BY NC ND

Journal of
Engineering & Processing Management

ORIGINAL SCIENTIFIC PAPER

Evaluation of Surface Water Quality in the Drina River Basin

Jelena Vuković[1] | Slavko Smiljanić[1]

[1]Faculty of Technology Zvornik, University of East Sarajevo, Karakaj 34a, Zvornik, Republic of Srpska, Bosnia and Herzegovina

Correspondence
Jelena Vuković
Email: jelena.vukovic@tfzv.ues.rs.ba

Abstract

To evaluate the surface water quality of the Drina River basin, samples were collected from the main river and its tributaries at selected monitoring sites. A total of 17 samples were collected from various locations during the years 2023 and 2024. Various physicochemical parameters and concentrations of heavy metals were analyzed. Overall, most tested samples indicated generally good water quality in terms of physicochemical indicators. However, the findings also suggest that certain human activities have a measurable influence on water quality in the basin. The results serve as an indication of existing pollution pressures and provide a basis for further investigations on the environmental status of the Drina River.

Keywords: river basin, Drina, surface water, water quality assessment, heavy metals

1. INTRODUCTION

Assesing the quality of surface waters and sediment involves monitoring a broad spectrum of physical, chemical, and biological parameters. The key steps in examining aquatic ecosystems include the classification, modeling, and interpretation of natural water and sediment monitoring data.

Speaking of water quality, first, it is necessary to define the quality classes, which are determined by legal regulations. According to national regulations, watercourses can be classified into five classes, according to the conditions of use for different purposes (Official Gazette of the Republic of Srpska 42/2001 2001):

- Class I - groundwater and surface water that in their natural condition or after disinfection, can be used for drinking or in the food industry, as well as surface water for the fish-farming of high-valuable species (trout);
- Class II - water that, after certain treatment (coagulation, flocculation, sedimentation, filtration, and disinfection), can be used for drinking; in its natural state can be used for bathing, for water sports, for the fish-farming of cyprinid fish species;
- Class III - water that can be used for drinking after extensive treatment (coagulation, flocculation, sedimentation, filtration, ozonation, adsorption on activated carbon, and disinfection), water that can be used in agriculture and industry without special requirements in terms of water quality, and for the fish-farming of less sensitive or less valuable fish species;
- Class IV - polluted water which can be used in areas with water shortages in some industries after appropriate treatment;
- Class V - Heavily polluted water that can hardly be used for any purpose.

Although the secondary legislation regulating the quality classes of surface waters may differ in terms of the number of classes and the prescribed limits of quality parameters, there are essentially no major differences in the national legislation of different countries. Given that the water quality of the Drina River, which territorially extends through three countries, Montenegro, Bosnia and Herzegovina, and Serbia, was investigated, the legal regulations defining the quality of surface waters are summarized in Table 1.

For the river water quality parameter, maximum allowed concentrations, or limit values, are prescribed, and defined in the Regulation on Water Classification and Watercourse Categorization (Official Gazette of the Republic of Srpska 42/2001 2001). The aforementioned Reg-

Table 1. Comparison of water quality classification regulations in Serbia, Bosnia and Herzegovina and Montenegro (JV Cowi et al. 2017).

Serbia	Bosnia and Herzegovina	Montenegro
The ecological status of surface waters and the ecological potential for highly altered water bodies are classified on the basis of physical-chemical and microbiological indicators into classes I to V (excellent to poor). Chemical status is categorized as good or unachieved good status, based on the content of priority, priority hazardous and other polluting substances. Overall status/potential is classified as the worse case of these two.	FB&H: From 2014 the classification is aligned with EU directives. RS-B&H: Five classes of water quality status (I to V) based on physical-chemical, microbiological, and hydro-morphological parameters. It is not fully compliant with EU directives.	Classification according to limit values for physicochemical and biological indicators, depending on the intended use of water: – Water that can be used as drinking water and for food production (class A, A1, A2 i A3) – Water for fish and shellfish farming (class S, Š i C) – Swimming water (class K1 i K2) Categorization of water quality: Class I: A1, S, K1 Class II: A2, K2, C Class III: A3

ulation prescribes limit values for general chemical and physical-chemical parameters, such as pH, electrical conductivity, BOD, COD, total nitrogen, and others, as well as specific quality parameters, such as organic and inorganic toxic substances, metals, and metalloids. Biological (sanitary-microbiological and biological parameters), as well as ecological water status (high, good, moderate, bad, very bad) are also prescribed by this document. The Water Framework Directive (2000/60/EC) is the most important legal act in the European Union related to water policy, and it is designed to improve and integrate Europe's water management. The Water Framework Directive was adopted by the Parliament and the Council of the European Union on October 23, 2000. The Directive established a framework for the action of member states in the field of water policy. The general objective of this directive from the aspect of environmental protection is to achieve "good water status" throughout the European Union by 2027 and to maintain that status further (European Commission and Directorate-General for Environment 2014).

It is often difficult and costly to analyze all prescribed parameters. In the case when we want to quickly and inexpensively obtain information about the chemical quality of open water streams, according to Z. Stevanović, the most suitable parameters are biochemical oxygen consumption (BOD) and ammonia concentration (Stevanović 2011). A large content of organic matter in river water changes its chemical and biological status. The amount of free oxygen decreases, and the amount of reduced nitrogen that turns into harmful ammonia increases.

The Drina River is an international river that belongs to Serbia and Bosnia and Herzegovina, and for the most part of its course, it also represents a natural border between these two countries. The Drina River basin extends over the territory of 3 countries (Montenegro, Serbia, and Bosnia and Herzegovina). The total length of the stream is 346 km, and the average flow is about 370 m^3/s. The Drina River basin is rich in natural resources and has significant development opportunities. The Drina River basin also has significant hydropower potential, but it is estimated that 60% of the hydropower potential is unused. The Drina River basin is rich in biodiversity, with the river itself maintaining predominantly good water quality due to its substantial flow and low levels of pollution, making it abundant in fish. The basin also hosts numerous national parks and protected areas, and its landscape is dotted with unique glacial lakes and canyons, including the Tara River Canyon, a UNESCO World Heritage site. Nearly one million people live within the basin. Water in the Drina basin serves several key purposes, including supply for settlements and industry, irrigation, and hydropower generation. Historically, the abundant water resources in the basin meant there were few conflicts over its use. However, as aspirations for development grow across different countries and economic sectors, coupled with rising pollution and the looming threat of climate change, an integrated approach to water management in the Drina basin has become increasingly essential.

According to the legislation that categorizes the watercourses of Serbia, Bosnia and Herzegovina, and Republika Srpska, the quality of the Drina River water is categorized as class II along its entire course (Official Gazette of the Republic of Srpska 42/2001 2001). The most significant negative impacts on water quality come from municipal and industrial untreated wastewater, municipal solid waste, illegal landfills, industrial waste dumps near the coast, and mining and agricultural activities.

The sampling of the Drina River and its tributaries, and the presentation of the current state of quality in selected sites, aim to encourage the public to protect and preserve the environment and water resources. Speaking of the physicochemical quality parameters, the emphasis was on general parameters and heavy metals. Sampling was done in Foča, Višegrad, Bratunac, Zvornik and Bijeljina. In this way, the quality of the river Drina was monitored in small sections along the course, from the source to the mouth. The results provide an overview of the current water quality of the Drina River and serve as a preliminary basis for future research.

2. SAMPLING SITES AND DETERMINED PARAMETERS

Water sampling of the Drina River and its tributaries was carried out according to a standard sampling method (EN ISO 5667-1) (ISO 2006). A total of 17 current samples from different locations were analyzed. In all samples, water temperature, pH, electrical conductivity, and dissolved oxygen were measured on-site (using a multimeter device), while other selected physical and chemical parameters were determined in laboratories, according to standard laboratory techniques and with standard equipment. For nitrite, nitrate, ammonia and phosphate are used spectrophotometric measures, while selected heavy metals are determined using ICP-OES.

Sampling was carried out in the period June 2023 - September 2024, in the cities of Zvornik, Foča, Višegrad, Bijeljina, and Bratunac, at the following locations:

- Drina, Zvornik – city beach, 300 m upstream from the confluence with the Zlatica River,
- Zlatica, Zvornik – right before the confluence with the Drina,
- Drina, Zvornik – 300 m downstream of the Zlaticas confluence,
- Drina, Karakaj – 300 m upstream of the landfill body "“Tilić Ada“,
- Drina, Karakaj – by the landfill body "“Tilić Ada“,
- Drina, Karakaj – 300 m downstream of the landfill body "“Tilić Ada“,
- Ćehotina, island Brioni, (2 samples)
- Drina, lake HEP Višegrad, sampling site Luke,
- Drina, lake HEP Višegrad, sampling site by landfill Holijaci,
- Drina, before the Mehmed Paše Sokolović bridge,
- Rzav, after the dam, 100 m before the confluence with the Drina,
- Drina, 250 m after the confluence of rivers Drina and Rzav,
- Drina, weekend settlement Popovi, Bijeljina,
- Drina, Fakovići, Bratunac,
- Križevica, street Drinska, Bratunac,
- Drina, sampling site “Rajska plaža”, Bratunac.

Sampling was carried out by taking individual samples, so the obtained results reflect only the current state and a general assessment of the quality of the river water cannot be determined based on this samples. Since the samples of the river Drina and its tributaries were taken from the territory of the Republic of Srpska, the interpretation of the results of the laboratory analysis was carried out following the Regulation on Water Classification and categorization of Watercourses (Official Gazette of the Republic of Srpska 42/2001 2001). According to this regulation, surface waters are classified into five classes, depending on their quality.

3. RESULTS AND DISCUSSION

Considering the scope of the research parameters, the results will show only the summary of the selected general and specific parameters in all localities where sampling was carried out. Table 2 summarizes the obtained concentrations.

Based on the results shown in Table 2, it can be seen that most of the analyzed parameters for the Drina River relate to the I and II quality class, which corresponds to a high and good ecological status of surface water. Among the analyzed general parameters, suspended solids and phosphorus showed the highest number of elevated concentrations compared to class I and II, and this is more distinct in tributaries and locations with possible anthropogenic influence. In addition, from the general parameters that were measured in situ, increased concentrations of electrical conductivity were recorded at the "Tilić ada" site next to the abandoned landfill in Zvornik. The registered value of conductivity at the location next to the landfill body corresponded to the II quality class (the measured value is close to the lower limit). In the samples taken upstream and downstream of the landfill, the electrical conductivity was at the level of the I quality class. Figures 1 and 2 show the measured concentrations of suspended solids and phosphorus, respectively, at selected measuring sites.

Table 2. Summary presentation of concentrations for selected general physicochemical parameters in analyzed samples

Date	Sampling site	Parameter (mg/dm^3)								
		Susp. solids	Dissol. O_2	BOD_5	COD	N-NH_4	N-NO_2	N-NO_3	N	P
20.6.2023.	Drina, before Zlatica	0,17	9,3	-	-	0,009	-	-	-	0,0136
	Zlatica	0,88	6,6	-	-	0,03	-	-	-	0,0527
	Drina, after Zlatica	0,19	8,1	-	-	0,01	-	-	-	0,0173
	Drina, before a landfill	0,25	9,15	-	-	0,009	-	-	-	0,0171
	Drina, by a landfill	0,13	9,1	-	-	0,0302	-	-	-	0,0195
	Drina, after a landfill	0,27	9,1	-	-	0,01	-	-	-	0,021
21.10.2023.	Ćehotina 1	0	12	0	0	0,006	0	0,003	0,01	0,004
	Ćehotina 2	0	12	0	0	0,013	0	0,003	0,019	0,005
23.5.2024.	Drina, Luke	2,3	7,12	0,2	0,46	0,0	0,001	0,006	0,037	0,007
	Drina, Holijaci	6,47	6,2	0,25	0,6	0,0	0,025	0,04	0,16	0,6
	Drina, MPS bridge	2,9	8,9	0,7	1,15	0,02	0,001	0,001	0,03	0,002
	Rzav, the dam	8,8	7,6	1,4	2,15	0,03	0,003	0,001	0,038	0,015
	Drina, after Rzav	2,9	8,5	0,9	1,85	0,025	0,002	0,001	0,033	0,002
10.9.2024.	Drina, Popovi	2	8,12	2,8	7,5	0	0,001	2,55	2,68	0,0114
11.9.2024.	Drina, Fakovići	1	9	0,3	0,9	0	0,0013	1,688	1,92	0,0021
	Križevica	10	5,7	2,1	7	0,017	0,097	0,61	1,14	0,0123
	Drina, "Rajska plaža"	5	8,5	0,6	1,5	0	0,0019	2,357	2,61	0,007

Legend:

→ Class I
→ Class II
→ Class III
→ Class IV
→ Class V

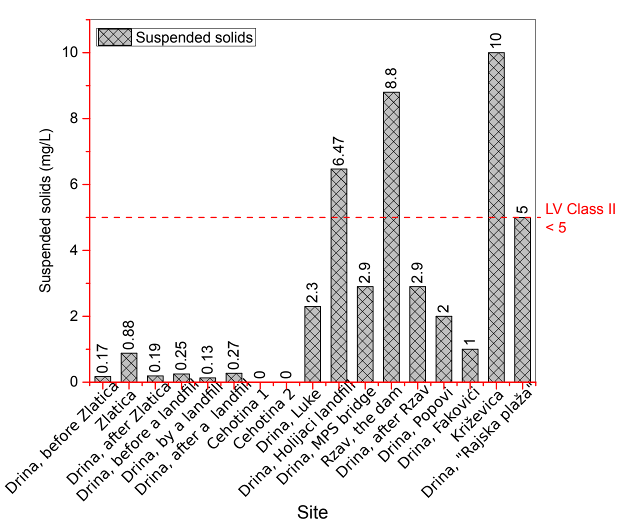

Figure 1. Concentration of suspended solids (mg/L).

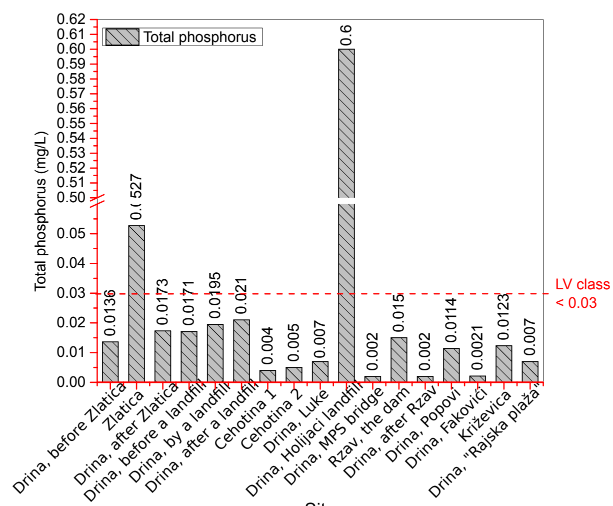

Figure 2. Concentration of total phosphorus (mg/L).

Elevated concentrations of the mentioned parameters may be the result of anthropogenic activities in the river basin. When it comes to the increased values of the concentration of suspended solids, they were mostly recorded at the Rzav and Križevica tributaries, as well as near the Holijaci landfill on the Višegrad lake. The highest concentration of total phosphorus was also recorded in the same locality. This indicates the existence of a negative impact of municipal waste disposal in the vicinity of the Drina River. Surface runoff and leachate from illegal landfills impair the quality of the water bodies which are recipients, as shown by the results of the analysis of samples taken at selected localities.

The high concentration of phosphorus at the site of the Zlatica stream, Zvornik (0.0527 mg/dm^3, IV class), can result from the impact of municipal wastewater discharges and the low self-purifying power of that watercourse. In contrast, in the case of the Holijaci site, the high phosphate content (0.6 mg/L, V class) can be attributed to the influence of leachate from the landfill located directly on the shore of Lake Višegrad (Holijaci landfill). The phosphorus content in the water of Višegrad Lake from the Holijaci location exceeded even 200 times the maximum allowed concentration for the II quality class.

When it comes to the specific parameters analyzed at the selected locations, Table 3 shows the summary results for the selected heavy metals.

The results shown in Table 3 show that the content of heavy metals in most of the analyzed samples corresponded to the I class of surface water quality. However, the concentration of chromium, nickel, and aluminum in some samples was at the level of III to V class of quality. A graphical representation of the content of these three metals (Cr, Ni, Al) in the analyzed samples is shown in Figures 3, 4, and 5.

The chromium content at the Holijaci location (Drina River near the landfill) corresponded to the quality class V and exceeded the maximum concentration allowed for the II quality class by about 3.5 times. It is important to note that a significantly high concentration of total phosphorus was also registered at the same location. This leads to the assumption that leachate from the Holijaci landfill to a certain extent reaches the Drina River and impairs its quality.

Extremely high concentrations of nickel were recorded at the mouth of the Drina tributary Rzav, as well as in the Drina downstream of Rzav. Although the concentration of nickel in the Drina downstream of Rzav was even 6 times lower compared to the concentration recorded in Rzav, it still corresponded to Class V of surface water quality. The nickel content in Rzav was 19 times higher than the maximum allowed concentration prescribed for the II quality class. The high concentration of nickel in Rzav may be a consequence of the significant presence of nickel ore deposits in Mokra Gora.

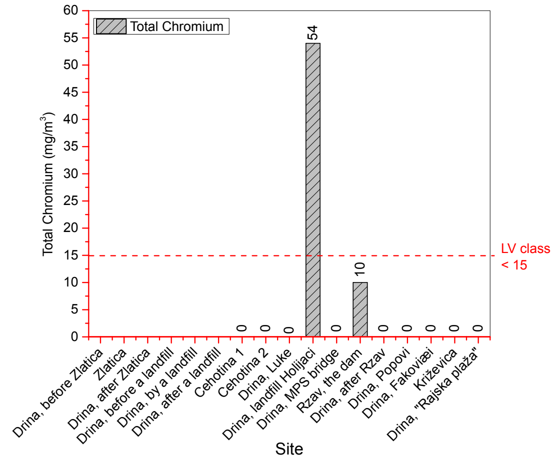

Figure 3. Concentration of chromium (mg/L)

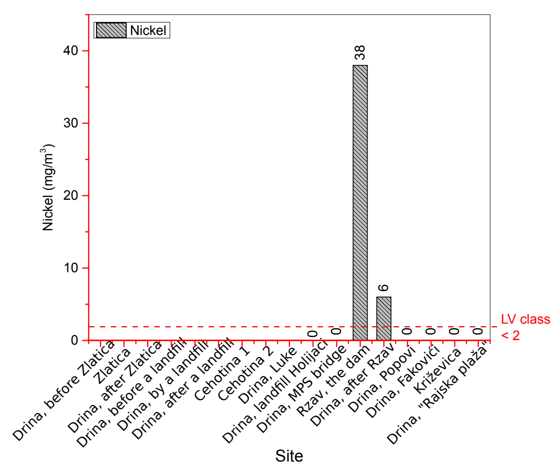

Figure 4. Concentration of nickel (mg/L).

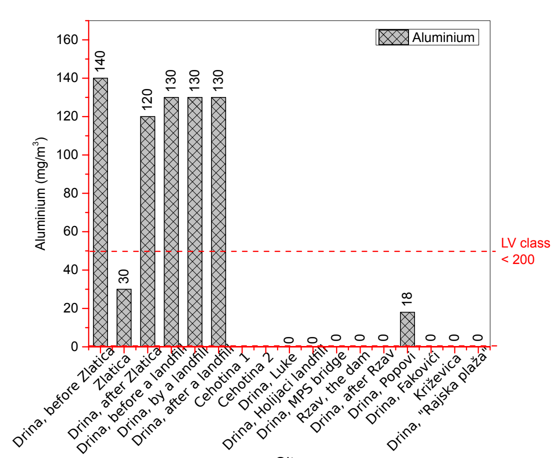

Figure 5. Concentration of aluminium (mg/L).

Table 3. Summary of the concentration of selected heavy metals in the analyzed samples

Date	Sampling site	Parameter (mg/m^3)									
		As	Cd	Cr	Cu	Mn	Ni	Pb	Al	Bi	Fe
20.6.2023.	Drina, before Zlatice	-	-	-	-	30	-	-	140	230	180
	Zlatica	-	-	-	-	10	-	-	30	200	80
	Drina, after Zlatice	-	-	-	-	30	-	-	120	220	160
	Drina, before a landfill	-	-	-	-	30	-	-	130	230	180
	Drina, by a landfill	-	-	-	-	30	-	-	130	220	180
	Drina, after a landfill	-	-	-	-	30	-	-	130	220	180
21.10.2023.	Ćehotina 1	0	0	0	-	18	-	0	-	-	51
	Ćehotina 2	0	0	0	-	21	-	0	-	-	56
23.5.2024.	Drina, Luke	0	0	0	0	26	0	0	0	0	0
	Drina, Holijaci	0	0	54	0	13	0	0	0	0	10
	Drina, MPS bridge	0	0	0	0	5	0	0	0	0	0
	Rzav, the dam	0	0	10	0	5	38	0	0	0	10
	Drina, after Rzav	0	0	0	0	5	6	0	0	0	0
11.9.2024.	Drina, Popovi	0	0	0	0	0	0	0	18	0	38
11.9.2024.	Drina, Fakovići	0	0	0	0	0	0	0	0	0	0
	Križevica	0	0	0	0	26	0	0,5	0	0	79
	Drina, “Rajska plaža”	0	0	0	0	29	0	0,15	0	0	7

Legend:

→ Class I
→ Class II
→ Class III
→ Class IV
→ Class V

It is indicative that the concentration of aluminum in the Drina River was the highest in the examined samples in the area of the town of Zvornik and corresponded to Class III surface water quality. This may be the result of surface runoff from the highway along the Drina River, which is the main road for bauxite ore transportation from the nearby Milići mine to the alumina factory ”Alumina” LTD Zvornik. In addition, elevated aluminum concentration was also registered at the location of the abandoned landfill ”Tilić Ada”, which may be the result of the inflow of the river Hoča in Karakaj, which also stretches along the route of the road by which bauxite is delivered to the Alumina factory.

The results of previous research on the quality of the river Drina at the location of the abandoned sanitary landfill ”Tilića Ada” (Sredić, Knežević, & Milunović 2024) did not show the presence of lead, manganese, and aluminum in the river Drina next to the landfill and downstream. During this research, the presence of iron was registered at the I-class level.

4. CONCLUSION

Screening analysis of the quality of the Drina River was carried out by sampling at selected locations along its course in the territory of Bosnia and Herzegovina. Selected general quality parameters and specific parameters (heavy metals) were analyzed. To assess the current quality of the Drina River, in the period June 2023 - September 2024, 17 samples of the Drina River and selected tributaries were collected and analyzed. Sampling was carried out in Foča, Višegrad, Bratunac, Zvornik and Bijeljina.

The analysis showed that the water quality of the Drina through the city of Zvornik is preserved, despite the discharge of untreated municipal wastewater into the river. All tested parameters, except aluminum, in the samples of the river Drina upstream and downstream of the mouth of the stream Zlatica, corresponded to quality class I and II. The aluminum content corresponded to quality class III, total phosphorus, and iron to class II, while the other tested parameters were at the level of class I. Although the content of examined heavy metals (Mn, Al, and Fe) in the Zlatica stream was lower than in the Drina River, in general, it seems that the quality of the Zlatica stream is slightly worse compared to the water quality of the Drina river, which indicates that the Zlatica stream has a lower self-purification power compared to the Drina river and that it is more difficult to resist the influence of untreated municipal wastewater that reaches it. Nevertheless, the quality of the Zlatica stream did not disrupt the Drina River quality, and the chemical status of the Drina River through the town of Zvornik could be characterized as good.

Based on the results of the Drina River from the "Tilić Ada" location, it was observed that no impact of the landfill on the water quality of the Drina River was registered. All analyzed parameters, in all three tested samples (before, next to, and after the landfill), except for electrical conductivity (for a water sample taken next to the body of the landfill), total phosphorus, aluminum, and iron, corresponded to the first quality class. The content of phosphorus and iron in all three samples from the location "Tilić Ada" corresponded to quality class II, and aluminum to quality class III. In general, the chemical status of the Drina River at all analyzed locations could be characterized as good.

During the sampling in Foča, the sampling was carried out on the Ćehotina, the left tributary of the Drina River, considering that the Ćehotina River is heavily loaded with pollutants in its course through Montenegro, due to communal, mining, and energy activities in the basin, and there are indications that this load is introduced into the Drina river. Sampling of the river Ćehotina was carried out at the location of the river island Brioni. Two samples were taken from both river branches around the island. Based on the analyses performed and the results presented, it can be seen that the quality of the Ćehotina River is at a high level and that all the tested parameters corresponded to the first quality class, as well as that the water quality in both branches is approximately the same. All this points to the high chemical status of the Ćehotina River at the location of Brioni Island, despite the heavy load to which the river is exposed on the territory of Montenegro.

During the sampling in Višegrad,the most of the tested parameters in the samples of Višegrad Lake, Drina, and Rzav rivers were at the level of the I and II quality classes, while a minor number of parameters corresponded to the III quality class. The values of total and suspended solids in the water sample from the "Landfill" location corresponded to quality class III, and the content of total chromium and phosphorus at the same location corresponded to quality class V. The values of electrical conductivity, total solids, suspended solids, BOD5, COD, dissolved oxygen, sulfate, nitrogen, phosphorus, and iron in the water sample from the "Landfill" location were higher compared to the water sample from the "Luke" sampling site.

The content of suspended matter in the Rzav River, 100 m before the confluence with the Drina, corresponded to the III quality class, and the nickel content in the Rzav and the Drina below the confluence of the Rzav exceeded the prescribed upper limit for the IV quality class many times over. Other tested water quality parameters of the Drina River, at the locations near Mehmed Paša Sokolović Bridge and 250 m downstream from the mouth of the Rzav River into the Drina River, were within the limits prescribed for the I and II quality classes. The values of the parameters BOD5, COD, and phosphate content, in the water from Rzav, were higher than those measured in the Drina River, but they were within the values reported for the first class.

In the sample of the river Drina from the location Popovi (weekend settlement near the Pavlović bridge), Bijeljina, the examined quality parameters were within the limit values specified for the I and II quality classes. The presence of aluminum and iron was registered in the sample, and the measured concentrations of Fe and Al were within the permissible limits specified for the first quality class. The examined water quality parameters of the Drina River, at the location of Fakovići, near the school, were within the limits defined for the I and II quality classes. The presence of manganese, lead, zinc, and iron was registered in the water sample of the Drina River from the location of "Rajska plaža" in Bratunac. Manganese concentration corresponded to quality class I, while lead concentration corresponded to quality class II. Other tested water quality parameters of the Drina River, at the "Rajska plaža" location, were within the limits prescribed for the I and II quality classes. The presence of manganese, lead, zinc, and iron was registered in the water sample from the Križevica stream. The concentration of lead was between II and III quality classes. The other examined water quality parameters of the Križevica stream were within the limits prescribed for the I and II quality classes, except for nitrite nitrogen, whose content corresponded to the IV quality class.

In general, analyzed affected samples from selected locations showed that the Drina River and its tributaries had predominantly good quality in terms of physical and chemical parameters. However, as only the current samples were analyzed, these results cannot be relevant from the aspect of river water quality assessment, and further detailed investigation with representative samples is needed to be done. These results can indicate only the current impact of certain activities on Drina River water quality.

REFERENCES

European Commission and Directorate-General for Environment. (2014). *The eu water framework directive*. Publications Office. https://doi.org/10.2779/75229

ISO. (2006). *Water quality — Sampling — Part 1: Guidance on the design of sampling programmes and sampling techniques* (No. ENISO 5667-1). International Organization for Standardization.

JV Cowi, Stucky, & Jaroslav Cerni. (2017). *Support to water resources management in the drina river basin* (Project No. A038803). World Bank.

Official Gazette of the Republic of Srpska 42/2001. (2001). *Regulation on Water Classification and Categorization of Watercourses.* Official Gazette of the Republic of Srpska 42/2001.

Sredić, S., Knežević, N., & Milunović, I. (2024). Effects of landfill leaches on ground and surface waters: A case study of a wild lanfill in Eastern Bosnia and Herzegovina. *Archives for Technical Sciences*, *30*(1). https://doi.org/10.59456/afts.2024.1630.097S

Stevanović, Z. (2011). *Menadžment podzemnih vodnih resursa*. Beograd: Univerzitet u Beogradu, Rudarsko-geološki fakultet.