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Water Quality of the Bosna River

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Abstract

Analysis of the Bosna River water samples from the spring to Kakanj city was performed with the aim of assessing the quality of the Bosna River water and comparing the obtained values with the national, EU regulations and guidelines of the World Health Organization. Samples were collected at eight selected locations, during two sampling periods: unstable weather conditions (precipitation), and stable weather conditions (without precipitation). The following parameters were analysed: pH, electrical conductivity, temperature, residue on evaporation at 105 °C, chloride and phosphate content, and metal content: Cr, Cu, Mn, Pb, Fe, Ni, Cd, Zn, Ca, Mg and Na. The metal content was determined by flame atomic absorption spectrometry (FAAS) and atomic emission spectrometry (AES), phosphate by UV/Vis spectrophotometry, chloride by volumetric method, and evaporation residue by gravimetric method. In the case of metals, the concentrations of which were below the limit of detection of the method used (FAAS), a preconcentration method using an ion-exchange resin was applied. The results showed that the Bosna River in the investigated part of the stream meets most of the parameters required by the regulations and guidelines. In order to obtain a complete status of the impact of numerous factors on the pollution of the Bosna River water, it would be necessary to perform passive sampling, and biological and microbiological analysis of water.

Keywords

Bosna River, pollution, metals, AAS, chlorides, phosphates, preconcentration

1 Introduction

Monitoring and assessment of water pollution has become a very important area in scientific research, especially from the aspect of pollution by heavy metals.[1,2,3] In this way, it is possible to obtain data on the impact of pollution on the plant and animal life in aquatic environments, as well as its impact on human beings and the quality of life.[4] In addition, although some metals, such as Fe, Cu and Zn, are essential micronutrients, they can exhibit a detrimental effect on the physiology of living beings at higher concentrations.[5]

The Bosna River Basin covers the largest area of B&H, and the country's most developed and industrialized regions can be found along the river. Wastewater from communities and industrial facilities that is discharged directly into the river without treatment, is a major source of pollution of the river Bosna.

Industrial development and the increase in global population result in the release of various substances that may pollute natural ecosystems. Industrial wastewater contains heavily degradable, toxic organic compounds as well as heavy metals whose presence in the environment is undesirable. Toxic organic compounds and heavy metals cannot be discharged into the environment without proper treatment.[6] In accordance with the EU Water Framework Directive, the physical and chemical quality of river systems includes organic and inorganic pollutants, as well as the main conventional parameters, such as nutrients, temperature, oxygen and pH.[7]

In this paper, Bosna River water samples, collected at eight sampling locations, were analysed. The following parameters were investigated: pH value, electrical conductivity, temperature, and residue on evaporation at 105 °C, chloride and phosphate content and metal content: Cr, Cu, Mn, Pb, Fe, Ni, Cd, Zn, Ca, Mg and Na.

2 Experimental

2.1 Sampling locations

Of all the rivers that spring and flow in Bosnia and Herzegovina, the largest river is Bosna River. The Bosna River springs at the foothills of Mt. Igman, near Sarajevo, and after flowing 270 km, it enters the Sava River near Bosanski Šamac. The site of the spring itself is called Vrelo Bosne and is partially included in the water supply system of Sarajevo. There are several places with waterfalls and river rapids. The valley of Bosna River is the most populated region of Bosnia and Herzegovina and an

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industrial centre with almost one million inhabitants. The valley includes the cities of Sarajevo, Visoko, Kakanj, Zenica, Zavidovići, Žepče, Maglaj, Doboj, Modriča, and Bosanski Šamac.[8] Potential sources of pollution of the river are wastewater from households, agricultural activities, illegal landfills, and a large number of industrial zones that discharge its purified wastewater into the river.

Given the above, the following locations were selected: (1) Kakanj – the sampling site is located 2 km from the city centre, underneath the bridge over which ore is transported to the Kakanj Cement Factory, as well as other transports including the transport of vehicles to the industrial zone. The cement factory itself is about 1 km upstream from the sampling location; (2) TE Kakanj – the sampling was carried out near Kakanj Thermal Power Plant, where the tributary of the Trstionica River flows into the Bosna River. Trstionica flows through the populated areas and pours effluents from the illegally constructed sewage systems. These areas are rich in arable land. Trstionica also flows along the coal mine of Kakanj, a factory section in Haljinići, where exploitation and transportation takes place. All waste originating from potential polluters along the Trstionica River, flows directly into the river Bosna; (3) Dobrinje – near this location, the most significant potential polluter is the meat processing plant. The sample was taken in an uninhabited area. Along the river there is arable land. In the vicinity of the sampling site extends the A1 motorway; (4) Visoko – sampling was carried out at a location 1 km from Visoko city centre. This municipality has a developed industry that may contribute to environmental pollution, and some of the most important potential polluters are: textile industry, leather processing industry, and well developed food processing industry (meat production and processing, animal feed production, *etc.*); (5) Ilijaš – at this location, the sample was collected at a short distance from the Ilijaš forge, which has been closed for a long time. In its surroundings, the sale and purchase of secondary raw materials is carried out. Six kilometres upstream from this location the Ljubina River flows into the Bosna River. Ljubina flows through the fields rich in lead and manganese ore; (6) Rajlovac – sampling was carried out near the A1 motorway. About 3 km upstream from this location there is a wastewater treatment plant Butila. The plant was reopened in 2016, and before its commissioning, all wastewater was discharged directly into Miljacka River, and then to the Bosna River. At a similar distance from this location there is the estuary of the Miljacka River into the Bosna River; (7) Rimski most – The Roman Bridge is 2.5 km away from the spring of the Bosna River. River Bosna flows through the water protection zone between the two locations, so there are no potential polluters. The sampling site is near the local road; (8) Vrelo Bosne – a sample taken from the spring of the Bosna River. There are no recorded potential polluters in this part of the stream. The location of Vrelo Bosne is a protected zone.

2.1.1. Sampling of river water

Sampling was carried out at eight selected locations along the Bosna River, on two days: day I – Nov. 6, 2016. (unstable weather conditions, very cold and rainy), and day II – Nov. 25, 2016. (stable weather conditions, sunny and warmer). The water samples were taken in clean plastic containers.

After determination of pH and electrical conductivity, the samples were preserved by adding 2 ml of concentrated HNO_3 to each sample bottle (2 l).

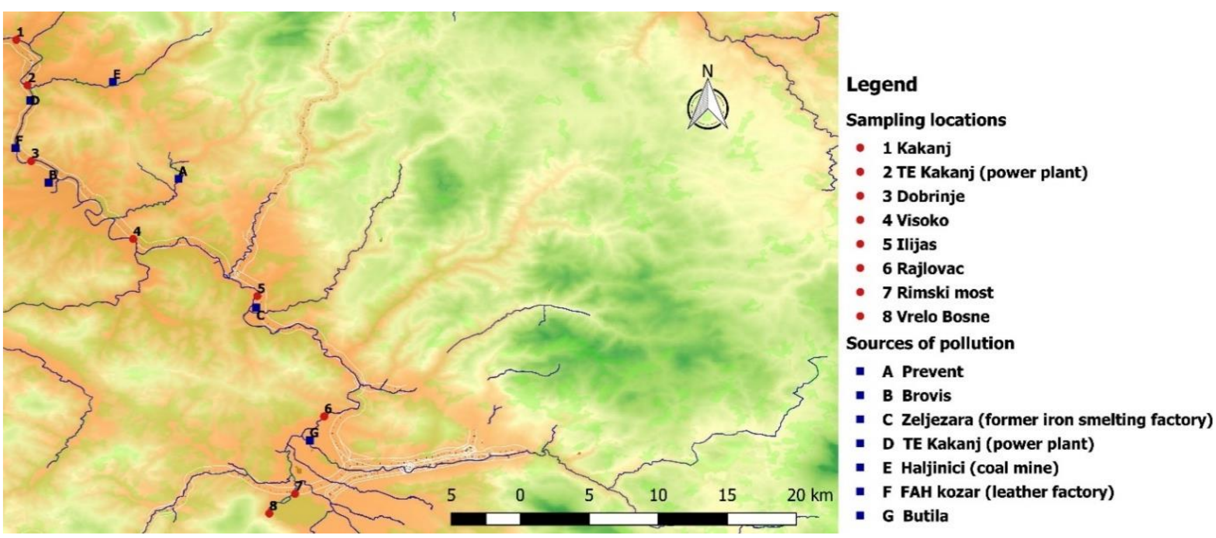

Fig. 1 – Sampling locations and potential sources of pollution
Slika 1 – Mjesta uzorkovanja i potencijalni izvori onečišćenja

2.2 Examination of the physicochemical parameters of the Bosna River water samples

Measurement of the temperature and pH of the river water samples was carried out on site using a calibrated mercury thermometer or field pH meter (HI98103, Checker Hanna Instruments, Inc., USA). A pre-calibrated conductometer (HI8733, Hanna Instruments Inc., USA) was used to determine electrical conductivity.

Determination of the residue on evaporation at 105 °C was carried out as follows: 200 ml of the river water sample was evaporated in a porcelain bowl, previously brought to a constant weight, on a water bath at a temperature of 100 °C. The residue after evaporation was weighed and dried at 105 °C to a constant weight.

All used reagents were of analytical grade. Milli-Q water was used throughout the complete experimental work, and it was also used as a blank.

The content of phosphate in the tested water samples was determined by UV/Vis spectrophotometric method (Carry 50, Varian, Australia) with ammonium molybdate and ascorbic acid, with the formation of a blue coloured complex and measurement of the absorbance at 880 nm.[9]

To determine the concentration of metals in the river water samples, atomic absorption spectrometry was used: flame technique (FAAS) for determination of Cr, Cu, Fe, Mn, Ni, Pb, Zn, Ca, and Mg, and atomic emission spectrometry (AES) for determination of Na. In both cases, the same instrument was used (AA240FS, Varian, Australia). The FAAS settings used for analysis of Cu, Mn, Fe, Ni, Cd, Pb, Zn, Mg, Ca and Na were; flame type: air/acetylene; air flow: 13.5 l min^{-1}; acetylene flow 2.00 l min^{-1}. The FAAS settings used for analysis of Cr were; flame type: air/acetylene; air flow: 13.5 l min^{-1}; acetylene flow 2.90 l min^{-1}. Additional instrument conditions are presented in Table 1.

Table 1 – Wavelength and slit width parameters of AA240FS instrument used in the analysis
Tablica 1 – Širina pukotine i valna duljina, parametri instrumenta AA240FS koji se upotrebljavaju u analizi

Element	Cr	Cu	Mn	Fe	Ni	Cd	Pb	Zn
wavelength valna duljina / nm	357.3	324.8	279.5	248.9	232.0	228.8	217.0	209.9
slit width širina pukotine / nm	0.2	0.5	0.2	0.2	0.2	0.2	1.0	1.0

Single-standard stock solutions containing 1000 mg l^{-1} of Cr, Cu, Mn, Pb, Fe, Ni, Cd, Zn, Ca, Mg, and Na (CertPur, Merck, Darmstadt, Germany) were used. Standard solutions were prepared daily by diluting stock solutions.

The method detection limits (LOD) were calculated as three times the standard deviation of the blank signal, as previously published by *Nesimović et al.*[10] The LOD values were: Cr (0.006 mg l^{-1}), Cu (0.003 mg l^{-1}), Mn (0.002 mg l^{-1}), Fe (0.006 mg l^{-1}), Pb (0.01 mg l^{-1}), Ni (0.01 mg l^{-1}), Cd (0.002 mg l^{-1}), Zn (0.001 mg l^{-1}), Ca (0.001 mg l^{-1}), Mg (0.0003 mg l^{-1}) and Na (0.0002 mg l^{-1}).

In the case of metals (Cr, Cu, Pb, Cd and Ni, and Zn sampling during the day II) the concentrations of which were below the limit of detection of the method used (FAAS), a preconcentration method using an ion-exchange resin (Ion Eexchanger I, 4.5 W g^{-1}, 45–55 %, MERCK (Darmstadt, Germany) was applied. The resin was packed into a glass tube, and the samples of the river water were poured onto the top of this column, which contained a solid material capable of binding metal ions from the solution. Before samples were eluted through the cation ion-exchange resin, column was regenerated with 4 mol l^{-1} hydrochloric acid. Upon the regeneration process, column was washed with Mili-Q water until effluent showed neutral reaction. Samples of river water were then eluted through the columns, whereby effluent was collected and analysed for the presence of selected heavy metals.

3 Results and discussion

A variety of factors is included in contamination of groundwater as much as surface water. As for surface water, these factors can be direct and indirect. Direct factors are sewage and septic systems (legal and illegal, very common along the Bosna River course); leaks and spills from industrial incidents; construction sites along the river's banks. Indirect factors include agricultural sites and leaching of phosphates and nitrates through the soil and into the river (also very common along the banks of Bosna, due to numerous agricultural properties and fields); factory dumping of chemicals and wastewater into surface waters; landfills (legal and illegal, located in great numbers along the rivers of B&H, which is a major ecological and safety issue). Results of analysis for Bosna River are presented in Tables 2, 3 and 5.

3.1 Physicochemical parameters of the Bosna River water samples

During both sampling days, the water samples temperature was between 5 and 13 °C, and gradually decreased as we approached the spring. The lowest temperature was at the spring itself, which is located at the foothills of Mt. Igman. The pH value of the samples showed no significant variations and was in the range from slightly acidic to slightly alkaline. According to the Regulation on Natural Mineral and Spring Waters (Official Gazette B&H, No. 26/10, hereinafter referred to as Regulation A)[11] the pH should be within the range of 6.5–9.5, and according to the Regulation on Drinking Water Quality (Official Gazette B&H, No. 40/10, hereinafter referred to as Regulation B)[12], the pH should be within the range of 6.8–8.5. The pH values of Bosna River samples were within of the limits prescribed by Regulations A and B. Electrical conductivity also decreased as approaching the spring, where the lowest value was recorded. According to Regulation A[10], the maximum allowed value for conductivity in $S\,cm^{-1}$, at 20 °C is up to 2.50 (25000000 $\mu S\,cm^{-1}$), and according to Regulation B[12], the maximum allowed value at 20 °C in $mS\,cm^{-1}$ is up to 1.00 (1000 $\mu S\,cm^{-1}$). All of the values for conductivity in measured samples were satisfactory, *i.e.*, below the legal maximum. As for the total evaporation residue, the sample from Visoko exhibited the highest value (0.123 $mg\,l^{-1}$), and sample from Vrelo Bosne the lowest (0.021 $mg\,l^{-1}$). According to Regulation B[12], for physical and physicochemical parameters of bottled drinking water, maximum allowed evaporation residue is up to 500.00 $mg\,l^{-1}$. Since the water from Bosna River is partially used in the water supply system of Sarajevo, its tributaries are used for water supply of Visoko and Kakanj, and the water from Bosna river basin is used for the irrigation of agricultural fields and properties along its course, it was decided to compare obtained values with drinking water parameters. Based on all the previously results, it can be seen that the values of most of the parameters were lower during sampling day II, *i.e.*, during stable weather conditions. Results for physicochemical parameters are presented in Table 2.

Table 2 – Physicochemical parameters, chlorides and phosphates content in water samples from Bosna River
Tablica 2 – Fizikalno-kemijski parametri, sadržaj klorida i fosfata u uzorcima vode iz rijeke Bosne

Location Lokacija	Altitude Nadmorska visina / m	Temperature Temperatura / °C		pH		Conductivity Vodljivost / $\mu S\,cm^{-1}$	Evaporation residue Isparni ostatak / $mg\,l^{-1}$		Chlorides Kloridi / $mg\,l^{-1}$		Phosphates Fosfati / $mg\,l^{-1}$	
		I	II	I	II	I	I	II	I	II	I	II
Kakanj	375	13	8	7.28	7.68	527	0.105	0.045	123.2	97.06	0.113	0.066
TE Kakanj	394	12	9	6.94	7.71	525	0.100	0.034	108.3	63.46	0.108	0.045
Dobrinje	397	12	9	7.00	6.70	517	0.106	0.028	104.5	74.66	0.120	0.080
Visoko	412	11	9	6.86	6.58	365	0.123	0.035	153.1	126.9	0.125	0.078
Ilijaš	443	12	9	7.08	6.99	446	0.090	0.026	115.7	149.3	0.126	0.098
Rajlovac	484	9	5	7.70	7.66	450	0.101	0.025	113.5	108.3	0.128	0.107
Rimski most	491	9	6	7.14	7.25	298	0.059	0.023	156.8	112.0	*ND	*ND
Vrelo Bosne	502	8	5	7.67	7.0	285	0.069	0.021	169.5	138.1	*ND	*ND

*ND – not detected; I (sampling date 6. 11. 2017.); II (sampling date 25. 11. 2017.)

3.2 Chlorides and phosphates content in the Bosna River water samples

Almost all natural water contains significant amounts of chlorides in compounds, such as NaCl, $CaCl_2$, $MgCl_2$, *etc*. Therefore, we decided to compare our results with parameters of drinking water, since the Bosna River is partially used in the water supply system, in order to determine to what extent it was possible to compare surface water quality (in this case River Bosna) with the requirements for drinking water quality.

Most of the drinking water contains 30.00 $mg\,l^{-1}$ of chlorides and the maximum allowed concentration should not exceed 250.00 $mg\,l^{-1}$ of chlorides, because it becomes salty.[13] State and EU regulations prescribe a maximum allowed content of chlorides of 250.00 $mg\,l^{-1}$. MAC of chlorides according to Regulation A[11] is 250.00 $mg\,l^{-1}$, whilst Regulation B[12] and WHO[14] allow 200.00 mg l⁻¹. Content of chlorides in all of the samples from Bosna River did not exceed the limits prescribed by state and EU regulations.

According to Regulation B[12], MAC for phosphates is 0.03 mg l⁻¹. For two of the samples (Rimski most and Vrelo Bosne), phosphate content was below detection limit of the method used. These results indicate that, in this part of Bosna River course, no major pollutants containing phosphates, such as human and animal waste or manures, flow into the river. For all the other samples, the phosphates content was above legally acceptable values.

3.3 Content of metals in Bosna water samples before preconcentration

Results of analysis for metals are presented in Table 3. Content of Cd, Pb, Ni, Cu and Cr, and Zn during sampling day II was below limits of detection of method applied, so a preconcentration method was used. The remaining six metals were analysed directly from the samples. Analysis of alkaline and earth alkaline metals was conducted only in original samples.

Table 3 – Content of metals in the Bosna river water samples before the preconcentration
Tablica 3 – Sadržaj metala u uzorcima vode iz rijeke Bosne prije prekoncentriranja

Location Lokacija	Mn / mg l⁻¹		Fe / mg l⁻¹		Zn / mg l⁻¹		Na / mg l⁻¹		Ca / mg l⁻¹		Mg / mg l⁻¹	
	I	II	I	II	I	II	I	II	I	II	I	II
Kakanj	0.107	0.043	0.54	0.20	0.016	*ND	2.66	1.78	120.0	227.9	10.63	11.40
TE Kakanj	0.097	0.044	0.46	0.19	0.013	*ND	2.93	2.33	116.2	220.3	10.46	11.68
Dobrinje	0.094	0.045	0.50	0.17	0.019	*ND	2.73	2.27	116.5	228.8	10.27	11.52
Visoko	0.128	0.055	0.92	0.20	0.019	*ND	3.54	1.66	115.2	223.4	10.25	11.35
Ilijaš	0.111	0.041	0.83	0.18	0.016	*ND	3.25	1.33	204.2	232.1	10.57	10.81
Rajlovac	0.052	0.021	0.46	0.15	0.009	*ND	4.08	2.36	218.3	237.2	9.97	11.49
Rimski most	0.002	*ND	0.51	*ND	0.009	*ND	0.76	1.66	201.1	193.5	9.21	9.48
Vrelo Bosne	0.007	*ND	0.13	*ND	0.006	*ND	0.71	1.03	203.9	216.7	9.18	7.50

*ND – not detected; I (sampling day 6. 11. 2017.); II (sampling day 25. 11. 2017.)

Table 4 – MAC based on the regulations used in this paper
Tablica 4 – MAC na temelju propisa koji se primjenjuju u ovom radu

Regulation Propis	Zn / mg l⁻¹	Na / mg l⁻¹	Ca / mg l⁻¹	Mg / mg l⁻¹	Cr / mg l⁻¹	Cu / mg l⁻¹	Pb / mg l⁻¹	Mn / mg l⁻¹	Fe / mg l⁻¹
Regulation A[11]	no data	200	no data	no data	0.05	2.00	0.01	0.05	0.20
Regulation B[12]	3.00	200	200	50	0.05	2.00	0.01	0.05	0.20
WHO	5.00[16]	200[17]	N.D.	N.D.	0.05[18]	2.00[19]	0.01[20]	0.05[21]	N.D.[22]
ICPDR[15]	no data	no data	no data	no data	0.05	0.02	0.005	no data	no data

N.D. – not defined by regulation

Comparing the results between locations, one can see that locations in industrial areas have higher content of Mn, Fe, and Zn, followed by locations in less industrialized areas, which is expected. Compared to other locations, samples from Visoko showed highest content of Mn, Fe, and Zn for both sampling days. Also, manganese and iron could not be detected in two samples located closest to the river source (Vrelo Bosne and Rimski most) and collected during stable weather conditions, when the river was clear. Generally, samples from these two locations showed the lowest content for all the analysed metals, during both sampling days, with the exception of calcium.

In regards to prescribed MAC, Ca content in the Bosna River water samples closer to the spring were above legally accepted values. Content of Mg in all of the samples was below values legally accepted and regulated. For the Na, the lowest content was in the samples closest to the spring, and Na content in all of the other samples was well below prescribed MAC. Zn values do not exceed prescribed MAC values. Highest content of Mn was in the samples from Ilijaš and Visoko, located in the areas rich in manganese ore (site Čevljanovići, Ilijaš municipality), such as pyrolusite and rhodochrosite.[23] Considering this fact, one cannot ignore geological influence on the elevated content of some metals in the river water samples. In addition, content of Mn, Fe, Zn, and Na was higher on the first sampling day (unstable weather, rainfall), content of Ca was higher on the second sampling day (sunny weather), and Mg content was uniform throughout both sampling days.

3.4 Content of metals in Bosna water samples after preconcentration

Analysis showed that some of the metals in the samples could not be determined directly by AAS from the original samples, so preconcentration using ionic exchange method was used for their quantification. Results are presented in Table 5. After the preconcentration, it was possible to detect Pb, Cr and Cu, and Zn from second sampling day. Two of the metals, Ni and Cd had concentrations below limits of detection even after the preconcentration , which may indicate that this part of the river contains no major pollutants which could cause elevated content of Ni and Cd in water samples.

Table 5 – Content of metals in the water samples from Bosna River after preconcentration
Tablica 5 – Sadržaj metala u uzorcima vode iz rijeke Bosne nakon prekoncentriranja

Location Lokacija	Zn / mg l^{-1}	Cr / mg l^{-1}		Cu / mg l^{-1}		Pb / mg l^{-1}	
	II	I	II	I	II	I	II
Kakanj	0.027	0.002	0.002	0.083	0.083	0.005	0.005
TE Kakanj	0.028	0.004	0.004	0.096	0.087	0.006	0.006
Dobrinje	0.035	0.007	0.003	0.089	0.086	0.008	0.005
Visoko	0.032	0.0003	0.0001	0.112	0.095	0.006	0.008
Ilijaš	0.034	0.0006	*ND	0.106	0.107	0.009	0.009
Rajlovac	0.031	0.002	*ND	0.098	0.087	0.006	0.005
Rimski most	0.034	0.004	*ND	0.114	0.107	0.006	0.006
Vrelo Bosne	0.027	*ND	0.001	0.074	0.087	0.006	0.004

*ND – not detected; I (sampling date 6. 11. 2017.); II (sampling date 25. 11. 2017.)

After preconcentration of the river water samples, it was possible to detect Cr in all the samples, except the one from the spring itself (sampling day I) and the three samples taken on sampling day II. Content of chromium in the samples detected after preconcentration was below legally permitted values. If we compare the results with the WHO data, where it is stated that the majority of surface waters contain between 1 and 10 μg l^{-1} Cr, it can be seen that the samples from Bosna River are within these values.[18] As for Cu, its content was below MAC values for all the locations analysed. Content of lead was also below legally permitted values for all the samples, in comparison with Regulation A, Regulation B and WHO (Table 4). All of the metals showed uniform values throughout both sampling days.

4 Conclusion

Based on the analysis of physicochemical parameters for Bosna River water samples, estimation of water quality for eight analysed locations was conducted. Results showed that Bosna River, from its source to the city of Kakanj, satisfies most of the parameters required by regulations and international standards. Although it was expected that samples from Visoko show elevated content of heavy metals, such as chromium and lead, because of its leather and processing industries, the content of these metals was very low, suggesting that water released to the river from these industries is well purified, and contains no chromium or lead.

The concentration of chloride in all measured water samples of the Bosna River was lower than the maximum permitted levels prescribed by national legislation. Higher phosphate content at all sampling locations may be attributed to agricultural activities in the vicinity of Bosna River, except at two locations in a water protection zone, where phosphate was not detected by UV/Vis spectrophotometry.

However, for more reliable results, passive sampling technique should be applied, as well as the continued monitoring of river water, since changes in water quality can have a detrimental effect on rivers.

List of abbreviations and symbols
Popis kratica i simbola

AES	– atomic emission spectrometry – atomska emisijska spektrometrija
B&H	– Bosnia and Herzegovina – Bosna i Hercegovina
FAAS	– flame atomic absorption spectrometry – plamena atomska apsorpcijska spektrometrija
LOD	– limit of detection – granica detekcije
MAC	– maximum allowed concentration – maksimalna dopuštena koncentracija
UV/Vis	– ultraviolet/visible spectrometry – ultraljubičasta/vidljiva spektrometrija
WHO	– World Health Organization – Svjetska zdravstvena organizacija

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SAŽETAK

Kvaliteta vode rijeke Bosne

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Analiza vode rijeke Bosne od izvora do grada Kaknja izvršena je s ciljem procjene kakvoće vode rijeke Bosne i usporedbe dobivenih vrijednosti s nacionalnim pravilnicima, pravilnicima EU-a i smjernicama Svjetske zdravstvene organizacije. Uzorci su sakupljani na osam odabranih lokacija, tijekom dva razdoblja i to kada su bili nestabilni vremenski uvjeti (padaline) i stabilni vremenski uvjeti (bez padalina). Analizirani su sljedeći parametri: pH, električna vodljivost, temperatura, isparni ostatak na 105 °C, sadržaj klorida i fosfata te sadržaj metala: Cr, Cu, Mn, Pb, Fe, Ni, Cd, Zn, Ca, Mg i Na. Sadržaj metala određivan je plamenom atomskom apsorpcijskom spektrometrijom (FAAS) i atomskom emisijskom spektrometrijom (AES), sadržaj fosfata spektrofotometrijom UV/Vis, sadržaj klorida volumetrijom, a isparni ostatak gravimetrijskom metodom. U slučaju metala čije su koncentracije bile ispod granice detekcije primijenjene metode (FAAS) provedeno je prekoncentriranje na ionoizmjenjivačkoj smoli. Rezultati su pokazali da rijeka Bosna u dijelu ispitivanog toka zadovoljava većinu parametara zahtijevanih pravilnicima i smjernicama. Kako bi se dobila potpunija slika o utjecaju mnogobrojnih faktora na onečišćenje vode rijeke Bosne, nužno bi bilo provesti pasivno uzorkovanje te biološke i mikrobiološke analize vode.

Ključne riječi

Rijeka Bosna, onečišćenje, metali, AAS, kloridi, fosfati, prekoncentriranje

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