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# Analytical and Environmental Control of Water Quality of the Bjelica River

**Jelena M. Maškoviću[1,*], Goran Marković[1], Pavle Z. Maškoviću[1]**

[1]*University of Kragujevac, Faculty of Agronomy, Cara Dušana 34, 32000 Čačak, Serbia*

Corresponding author: *jelenav@kg.ac.rs*

**Abstract:** This paper presents the main water quality characteristics of the Bjelica River before and after the discharge of Lučani wastewaters. The objectives of the research included analytical and environmental testing and assessment of the water quality of the Bjelica River before and after the discharge of wastewaters from the Lučani town collector. The results of the physicochemical analysis of major water quality indicators were used. Testing was conducted in July and October 2015, and January, May and July 2016. Assays were performed at the Public Health Institute, Čačak and at the Laboratory of the Faculty of Agronomy, Čačak. The water quality of the river was assessed as moderate ecological status or Class III category of surface waters. The results of the river water quality analysis indicated that the quality of the river water was better before the inflow of effluents from the town collector.
**Keywords**: Bjelica River, water quality, ecological status, analytical control, physicochemical parameters

## Introduction

Water is important for the life and health of people. It is the basic resource for the needs of the economy, energy, transport, agriculture and other activities (Baras*et al*, 2009). Surface waters (streams, rivers and lakes) are large reservoirs of clean water. Surface waters can be irreversibly destroyed by waste substances of different origin. Their chemical composition is variable, depending on the

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origin of water, the background through which they flow, the presence of different organisms, and the impact of anthropogenic activities that often aggravate their quality (Bricker *et al*., 1995; Singh*et al*., 2005; Dixon et *al*., 1996).

The "good status" of surface waters is determined by "good ecological and chemical status", which implies low pollution and a healthy ecosystem. When assessing this status, all factors that affect aquatic ecosystems must be taken into account. In addition to pollution, these are hydromorphological changes, such as dam construction, river flow regulation and other activities. It is necessary to take into account the rational use of water for industry and irrigation as this may jeopardize the functioning of the ecosystem.

The development of industry, agriculture and other economic and communal activities has resulted in growing amounts of polluted wastewaters, consequently leading to a reduction in clean water resources. Water can be contaminated with various harmful substances (pollutants), which are physicochemical or biological contaminants. Water pollutants are grouped into substances subject to biodegradation processes (most organic and inorganic compounds) and contaminants that do not dissolve or slowly dissolve through microbiological processes (heavy metals, plastics, pesticides, etc.) (Schwarzenbach *et al*., 2006). The discharge of wastewaters has numerous negative effects on the structure and functioning of aquatic ecosystems. Therefore, it is necessary to purify wastewaters (Gavrilović *et al*., 2006).

Self-purification is one of the most important processes for maintaining the quality of natural waters. In nature this process remains functional until the occurrence of major disorders causing natural disasters (earthquakes, floods, fires, etc.) or extensive man-made pollution. If the level of inorganic contamination is within the range of biological tolerance, water can be purified by self-purification. If the amount of pollution exceeds the compaction power of the watercourse, water cannot be purified by this process, resulting in complete and irreversible destruction of the ecosystem. Pollution of natural watercourses leads to disruptions in the functioning of ecosystems, as well as to a reduction in the quantity of drinking water. The degree of water pollution depends on the type of pollutants, the physical and geographical characteristics of the environment, and other conditions. Water pollution can cause primary, secondary and tertiary changes (Jain *et al*., 2005).

The Municipality of Lučani (surface area 454 $km^2$) is located in western Serbia. It overlooks the geographical area between the Ovčar-Kablar Gorge, Mount Jelica and the Bjelica River. The Bjelica is the right tributary of the Zapadna Morava (West Morava). The direct course of the river is 41 km, and its land area 376 $km^2$. It springs at 930 m a.s.l and flows into the West Morava near Gugalj Bridge (Dljin Village, 299 m a.s.l.). In its upper course, the Bjelica is a mountain river, with a deep and narrow cliff valley. The watercourse is of a very torrential character, frequently spilling over the banks onto the road

infrastructure, residential buildings and agricultural areas. The ecosystem of the river often has a load of wastewaters coming from the Milan Blagojević Chemical Plant and Guča and Lučani communities. Earlier studies have detected the presence of contaminants, such as nitrogen and nitrate (Đurić, 1991), cadmium (Lazić et al., 2003) and other heavy metals (Obradović and Filipović, 2009) in the river water.

## Material and methods

Water samples of the Bjelica River were taken before (Figure 1) and after (Figure 2) the discharge of wastewaters from the Lučani town collector into the river. The town collector is at a distance of about 1.7 km from the mouth of the Bjelica into the West Morava. The waste waters generated by technological processes in the Milan Blagojević Chemical Plant are pumped into the Bjelica 200 m downstream of the town's collector.

*Figure 1.*Sampling location before the discharge of wastewaters from the Lučani collector

In accordance with valid regulations, changes in the properties of basic physical and chemical parameters of water required for the classification and determination of water quality were monitored. Testing was conducted in July and October 2015, and January, May and July 2016. Analyses were performed at the Public Health Institute, Čačak and at the Laboratory of the Faculty of Agronomy, Čačak. Physicochemical analyses of major water quality indicators were carried out using standard laboratory methods at the Public Health Institute, Čačak. At the laboratory of the Faculty of Agronomy, volumetric methods of analysis (acid-base titration, precipitation, complexometric titration, oxido-reduction titration) and gravimetry were used for the quantitative analysis of water. The analyses were performed under the Ordinance on Parameters of

Ecological and Chemical Status of Surface Waters and Parameters of Chemical and Quantitative Status of Groundwaters (Official Gazette, Issue No. 74/2011).

*Figure 2.*Sampling location after the discharge of wastewaters from the Lučani collector

## Results and discussion

Results on the physicochemical analyses performed on 1 July 2015, 7 October 2015, 13 January 2016 and 30 May 2016 at the Public Health Institute, Čačak are presented in Table 1. River water was sampled and analyzed before and after the discharge of effluents from the Lučani town collector into the Bjelica River. The analyses were performed under the Ordinance on Parameters of Ecological and Chemical Status of Surface Waters and Parameters of Chemical and Quantitative Status of Groundwaters (Official Gazette, Issue No. 74/2011). The results of the river water analysis indicated that the quality of the river was better before the discharge of effluents from the town collector.

*Table 1.* Results on the physicochemical analysis of the Bjelica River water before and after the discharge of effluents from the urban waste water collector (01/07/2015, 10/7/2015, 13/01/2016, 30/05/2016)

| Date | 01/07/2015 | | 07/10/2015 | | 13/01/2016 | | 30/05/2016 | |
|---|---|---|---|---|---|---|---|---|
| Parameter | Before | After | Before | After | Before | After | Before | After |
| t (°C) | 15.5 | 15.7 | 15.9 | 16.5 | 2.4 | 2.5 | 17.7 | 18.0 |
| pH | 8.0 | 8.0 | 7.1 | 7.2 | 7.9 | 7.8 | 8.0 | 7.9 |
| Sulfates ($mg/dm^3$) | 22.8 | 29.2 | 207.8 | 169.2 | 29.5 | 32 | 24.9 | 25.8 |
| Chlorides ($mg/dm^3$) | 6.5 | 6.5 | 8.6 | 10.1 | 8.3 | 8.6 | 7.9 | 8.3 |
| Nitrites ($mg/dm^3$) | 0.03 | 0.04 | 0.45 | 0.47 | 0.01 | 0.01 | 0.02 | 0.03 |
| Nitrates ($mg/dm^3$) | 2.2 | 2.3 | 14.3 | 15.5 | 3.4 | 3.5 | 1.9 | 2.0 |
| $NH_4^+$ ion ($mg/dm^3$) | 0.25 | 0.3 | 0.5 | 0.9 | 0.15 | 0.16 | 0.3 | 0.3 |
| Orthophosph. ($mg/dm^3$) | 0.05 | 0.06 | 0.02 | 0.03 | 0.02 | 0.02 | 0.01 | 0.02 |
| Iron ($mg/dm^3$) | 220 | 230 | 110 | 160 | 240 | 340 | 80 | 90 |
| Electroconductivity (µS/cm) | 306 | 305 | 700 | 687 | 274 | 282 | 365 | 369 |
| Dissolved $O_2$ ($mg/dm^3$) | 8.5 | 8.6 | 7.0 | 5.1 | 10.4 | 10.3 | 8.4 | 8.3 |
| Total organic carbon | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| $BOC_5$ ($mg/dm^3$) | 7 | 8 | 2 | 5 | 4 | 5 | 4 | 5 |
| COD ($mg/dm^3$) | 10.5 | 13.5 | <5 | 10.8 | 17.6 | 21 | 11.9 | 16.6 |
| Total phosphorus ($mg/dm^3$) | 0.06 | 0.07 | 0.03 | 0.04 | 0.03 | 0.03 | 0.02 | 0.03 |
| Total nitrogen ($mg/dm^3$) | 3.2 | 3.4 | 17.8 | 19.1 | 4.1 | 4.9 | 2.7 | 3.0 |
| Suspended substances ($mg/dm^3$) | 28 | 42 | 22 | 48 | 30 | 38 | 18 | 26 |
| Phenols (µg/dm$^3$) | <1 | <1 | 2 | 3 | 3 | 2 | <1 | <1 |
| Detergents (µg/dm$^3$) | 0.02 | 0.03 | 0.05 | 0.11 | 0.03 | 0.03 | 0.02 | 0.02 |
| Chromium (µg/dm$^3$) | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 |
| Copper (µg/dm$^3$) | 4 | 4 | 10 | 12 | 5 | 4 | 7 | 4 |
| Zinc (µg/dm$^3$) | 6 | 6 | 5 | 5 | 13 | 5 | 2 | 3 |
| Manganese (µg/dm$^3$) | 40 | 33 | 101 | 50 | 44 | 43 | 14 | 31 |
| Arsenic (µg/dm$^3$) | 1 | 1 | <1 | <1 | 1 | 2 | <1 | <1 |
| Oxygen saturation (%) | 94.4 | 95.6 | 76.7 | 56 | 109.3 | 108.1 | 92.3 | 91.2 |

The water quality analysis conducted on 7 October 2015 showed significant differences in the quality of river water before and after the discharge of Lučani sewage waters. In the absence of data on the quantity and chemical composition of waste waters in the town collector, the results suggested that the waste waters

were heavily loaded with organic pollutants. Ammonium ion content (0.5 mg/dm$^3$ before the discharge and 0.9 mg/dm$^3$ after the discharge), dissolved oxygen (7.0 mg/dm$^3$ before and 5.1 mg/dm$^3$ after), $BOD_5$ (2.0 mg/dm$^3$ before and 5.0 mg/dm$^3$ after) and COD (<5 mg/dm$^3$ before and 10.8 mg/dm$^3$ after) confirmed a high level of pollution with organic pollutants coming from the town's collector. The relatively high temperature of the water allowed the biochemical oxidation of organic compounds (primarily proteins) by microorganisms and other organisms present in the collector water, as well as in the river water. It is noteworthy that the Bjelica River water was also contaminated in the upstream due to wastewaters coming from the Guča municipality, rural households and agricultural activities in the catchment area.

The results of the analysis conducted on 13 January 2016 indicated a more uniform quality of the river water before and after the discharge of wastewaters. This was most likely due to the lower organic load of the water in the town collector, but also due to the considerably lower temperature of the river water, which prevented the degradation of proteins and other organic compounds potentially present in the water.

The results of the analyses performed on 1 July 2015 and 30 May 2016 showed similar values. The quality of the river water was assessed as moderate ecological status or class III of surface waters.

During the annual hydrological cycle, the quality of surface waters depends on atmospheric precipitation, deposits, i.e. soil erosion in the basin, population and industrial development in the catchment area. In addition, seasonal changes in temperature, and the mixing of different types of waters affect the chemical composition of surface waters (Dalmacija *et al*., 2004).

Sampling of the Bjelica River water for the chemical analysis at the Faculty of Agronomy, Čačak was performed on 4 July 2016. The mean value of three measurements was used for all calculations. The results on major physicochemical parameters of the Bjelica River surface water assessed at the Laboratory of the Faculty of Agronomy, Čačak are presented in Table 2.

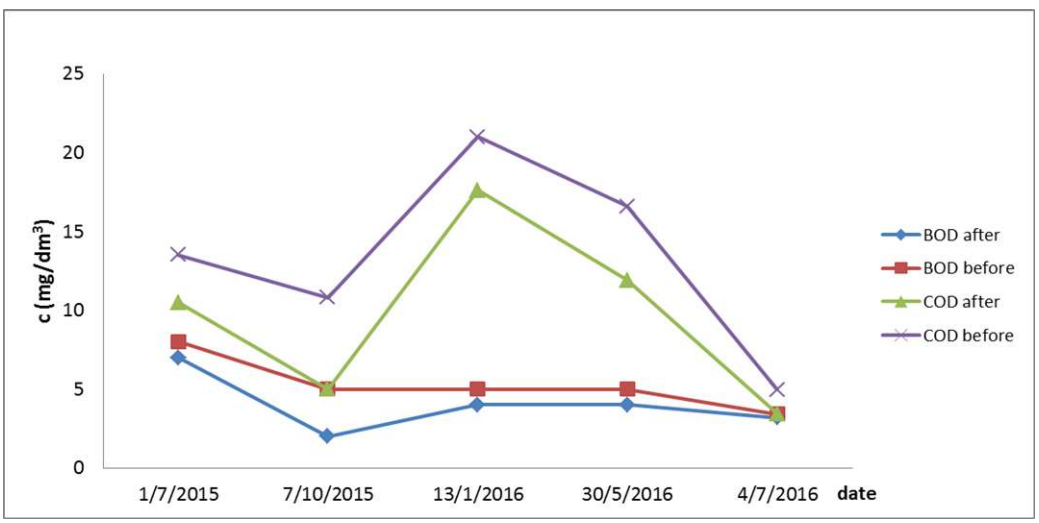
Chemical oxygen demand and biochemical oxygen demand were used as indicators of organic pollution of water. Chemical oxygen demand (COD) is the quantity of oxygen consumed for the complete oxidation of organic substances in the water, and is a direct indicator of water pollution with organic substances. Biochemical oxygen demand ($BOD_5$) is the quantity of oxygen consumed by microorganisms for the dissolution of organic substances in the water. The levels of COD and $BOD_5$ were better before the discharge of wastewater effluents; the river water quality was classified as Class 2. After the discharge of sewage waters and during July 2015, the values indicated the third ecological class. Values for COD and $BOD_5$ before and after the discharge of wastewaters from the Lučani urban collector across water sampling dates are graphically presented (Figure 3). The BOD/COD ratio is a measure of degradability of a substance or mixture. Organic matter in water with BOD values slightly different from COD

values is biodegradable. Materials with distinctly different values of BOD and COD are non-biodegradable (Agbaba, 2004).

*Table 2.* Analytical results of Bjelica River water samples (4 July 2016)

| *Parameter*<br>*Average value* | Before | After |
|---|---|---|
| pH | 6.96 | 7.00 |
| Dissolved $O_2$ (mg/dm$^3$) | 10.80 | 11.40 |
| $BOC_5$ (mg/dm$^3$) | 3.20 | 3.40 |
| COD (mg/dm$^3$) | 3.45 | 4.97 |
| Electroconductivity (µS/cm) | 156.5 | 167.2 |
| Chlorides (mg/dm$^3$) | 23.04 | 24.80 |
| Sulfates (mg/dm$^3$) | 391.00 | 220.60 |
| Alkalinity (mg $CaCO_3$/dm$^3$) | 157.64 | 127.61 |
| Acidity (mg $CaCO_3$/dm$^3$) | 10.01 | 10.01 |
| $Ca^{2+}$ (mg/dm$^3$) | 95.79 | 127.80 |
| $Mg^{2+}$ (mg/dm$^3$) | 39.38 | 26.25 |
| Amount of an annihilated residue (mg/dm$^3$) | 324 | 86 |

*Figure 3.* Levels of COD and $BOD_5$ before and after the discharge of wastewaters from the Lučani urban collector across water sampling dates



## Conclusion

The paper presents basic characteristics of the Bjelica River water before and after the discharge of Lučani wastewaters. The results of the physicochemical analysis of major water quality indicators were used. Testing was performed at the Public Health Institute, Čačak and at the Laboratory of the Faculty of Agronomy, Čačak

The Bjelica River is the right tributary of the West Morava and the central watercourse in the Municipality of Lučani. Significant quantities of untreated wastewaters generated by municipal, agricultural and industrial activities are being discharged into the watercourse.

Differences in the degree of organic pollution of the Bjelica River before and after the discharge of Lučani sewage waters were observed. Since these waters primarily comprise municipal waste (food waste, faeces, chemical hygiene waste etc.), their concentration and quantity have a major impact on the quality of river water in some seasons. The degree of degradation due to incoming pollution is dependent on overall hydroecological characteristics of the recipient watercourse (primarily temperature and water flow).

The watercourse of the Bjelica River is also contaminated in the upstream, as confirmed by elevated values of some quality parameters. The presence of toxic substances, such as phenol (at concentrations of 2-3 $\mu g/dm^3$) and arsenic, as well as of surfactants (detergents) make the water of the Bjelica river unsuitable for irrigation of agricultural crops and other anthropogenic activities.

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# ANALITIČKA I EKOLOŠKA KONTROLA KVALITETA VODE REKE BJELICE

Jelena M. Mašković[1,*], Goran Marković[1], Pavle Z. Mašković[1]

[1]Univerzitet u Kragujevcu, Agronomski fakultet, Cara Dušana 34, 32000 Čačak, Republika Srbija

## Rezime

U ovom radu prikazane su glavne karakteristike vode reke Bjelice pre i posle uliva otpadnih voda Lučani. Cilj istraživanja bio je da se ispita analitička i ekološka kontrola i procena kvaliteta vode reke Bjelice pre i posle ispuštanja otpadnih voda iz gradskog kolektora Lučana. Korišćeni su rezultati fizičko-hemijskih analiza osnovnih pokazatelja kvaliteta rečne vode. Testiranje je sprovedeno u julu i oktobru 2015. godine i u januaru, maju i julu 2016. godine. Analize su obavljene u Zavodu za javno zdravlje u Čačku i u laboratoriji Agronomskog fakulteta u Čačku. Kvalitet rečne vode ocenjen je kao umeren i pripada III klasi površinskih voda. Rezultati analize rečne vode pokazali su da je kvalitet rečne vode bolji pre uliva otpadnih voda iz gradskog kolektora.

**Ključne reči:** reka Bjelica, kvalitet vode, ekološki status, analitička kontrola, fizičko-hemijski parametri