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Impact Determination of Municipal Wastwaters on Neretva River Water Quality During Low Level Season by Using Water Quality Indices (WQI) Comparison

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Abstract

River ecosystems receiving wastewater discharges are exposed to pollution by various chemical, microbiological and physical substances. The aim of this study is to assess the water quality of the Neretva River, impacted by wastewaters from the municipality of Jablanica. Water samples collected over a three-year period (2017, 2018 and 2019) during the low-water season were analyzed at sites upstream and downstream from wastewater effluents. Values of a range of chemical and microbiological parameters were determined and the water quality index (WQI) was calculated based on these parameters. In addition to WQI, the biological water quality index (bWQI) was also determined in this study. Data analysis confirms a statistically significant chemical impact on the water quality of the Neretva River, while the bacteriological impact was not statistically significant.

Keywords: Water Quality Index, Waste Water, Bacteriological Load, Neretva River

Introduction

The river Neretva is the longest river that flows into the Adriatic Sea from its eastern coast. The section extending through Herzegovina covers approximately 5,580 km^2 and about 230 km. Only a small part of the river flows through Croatia, with a length of 20 km. It originates in the Dinaric Alps, beneath mount Jabuka in Bosnia and Herzegovina (Zonn *et al.,* 2021) [18]. The Adriatic basin covers an area of approximately 10,500 km^2, with the majority being drained by the Neretva river's hydrographic system. The hydrological characteristics of the Neretva catchment are enhanced by groundwater waters, while the basin is largely composed of limestone and dolomite formations. In its upper catchments, the Neretva river exhibits typical features of a mountain river, with high flow velocity, significant elevation differences, steep gradients and narrow valleys (Variščić, 2004) [2]. In these sections, the water of the Neretva river is of excellent quality.

Changes involving the degradation of the chemical and physical quality of water can be relatively easily detected as long as they are not defined as extreme in terms of ecosystem status. These changes are of anthropogenic origin and may represent an adaptation of aquatic ecosystems. Chemical, biological and physical components of aquatic ecosystems need to be monitored regularly in order to detect extreme situations that lead to irreversible conditions (Scheffers, *et al.,* 2001) [16]. Sanitary waters are waters that contain physiological waste. Combined with household and atmospheric wastewater generated through precipitation in the form of surface runoffs in urban areas, they constitute urban wastewater. These waters have the potential for microbiological degradation decomposition of the organic substances they contain leads to formation of substances and gases with unpleasant smell and appearance (Đukić, Ristanović, 2005; Bitton, 2005) [8, 3].

Escherichia coli and enterococci are bacteria naturally present in the intestinal tract of human and warm - blooded animals. They are released into the environment through fecal matter, and the microbial quality of water is commonly assessed based on their presence. In aquatic systems, the occurrence of these bacteria poses a significant concern and represent a potential risk to public health. Rivers are among the most frequently affected aquatic systems, as these bacteria often originate from wastewater discharges (Lucinda, *et al.,* 2014).

A large number of examined parameters and samples does not simplify the assessment of water quality, although water monitoring for various purposes is well established (Chapman, 1992) [5]. The comparison of analyzed parameters with applicable local standards represent a traditional approach to overall water quality assessment. However, this approach does not provide a comprehensive temporal and spatial representation of overall water quality (Debels, *et al.,* 2005) [7]. Furthermore, the analysis of parameters individually or grouped according to shared characteristics also results in only a partial evaluation of overall water quality (Pesce and Wunderlin, 2000) [13].

The development of the Water Quality Index (WQI) has enabled the conversion of a large amount of data into a single value that reflects water quality and its potential uses (Bordalo, *et al.,* 2001). The WQI facilitates the integration of complex data, improves understanding of the issue and provides results and assessments of water quality. Additionally, WQI indices provide valuable information for the management and preservation of water resources (Cude, 2001) [6]. For water quality assessment, indices commonly used include the National Sanitation Foundation Water Quality Index (NSF-WQI) of the United States, the Canadian Water Quality Index, the British Columbia Water Quality Index, the Oregon Water Quality Index and the Florida Water Quality Index. The aim of this study is to evaluate the water quality of the Neretva river using the Neretva's Water Quality Index (NWQI), developed in 2012 (Riđanović, *et al.,* 2012) [14], while simultaneously analyzing the influence of bacteriological indicators on WQI values.

Wastewater discharged into the Neretva river can negatively affect water quality from a hygienic perspective. Chemical, physical and biological pollution leads to the degradation of water quality, posing a potential threat to human health (Jukić, 2006) [9]. The Neretva river flows through the Municipality of Jablanica after being released from the hydro power plant accumulation. Jablanica lake is located nearby, upstream from the municipality. Wastewater from the surrounding settlements, as well as from the Municipality of Konjic, is discharged into the lake. The lake is a popular tourist attraction and the surrounding land is arable. A common issue is algal blooms due to high levels of organic nutrient. The wastewater from the Municipality of Jablanica is directly discharged into the Neretva river without prior sanitary treatment, which impacts water quality.

Materials and Methods

Wastewater from the Municipality of Jablanica is discharged into the Neretva river at two distinct locations. The sampling was conducted in the immediate vicinity of the discharge points, specifically upstream of the inflow at Location 1 - "Bare" and downstream of the inflow at Location 2 – "Stadion". The locations of the sampling sites are illustrated in Picture 1.

Source: Google Maps

Picture 1: Sampling sites

The locations of the sampling sites, along with their geographic coordinates, are presented in the Table 1.

Table 1: Locations of sampling along with their coordinates

Sampling site	Location	Sampling position	Coordinate (N)	Coordinate (E)
Location 1	"Bare"	Upstream of the wastewater discharge point	43°39,697'	17°45,899'
Location 2	"Stadion"	Downstream of the wastewater discharge point	43°39,109'	17°45,385'

Samples were collected during the low water season over a four year period, from 2017 to 2020, in accordance with applicable standards [10-12].

The chemical analysis included the determination of temperature (°C), pH (1), oxygen saturation (%), conductivity (µS/cm), total phosphorus (mg/l) and total nitrogen (mg/l). The microbiological analysis was based on the determination of *E. coli* concentrations, coliforms and enterococci. While the chemical parameters contributed to the assessment and evaluation of the water quality index (WQI), the microbiological data provided additional information on the bacteriological impact (bWQI). A subindex was determined for each parameter according to the established methodology (Riđanović and Riđanović, 2016) [15]. Water quality was then classified based on the WQI values, as presented in Table 2.

To determine statistical significance, comparisons and statistical analyses were performed for the sampling sites.

Table 2: Classification of water quality

WQI	Classification
10-59	Very bad
60-79	Bad
80 – 84	Acceptable
85 – 89	Good
90 – 100	Excellent

Results and Discussion

Based on the results of chemical and microbiological parameters, the water quality index (WQI) and bWQI were determined. The WQI and bWQI values, along with the results of the microbiological analysis are presented in Table 3.

Table 3: Values of water quality indices and bacteriological load

Year	WQI		bWQI		Total coliforms (100 ml)		Enterococci (100 ml)		*E. coli* (100 ml)	
	upst	dwst	upst	dwst	upst	dwst	upst	dwst	upst	dwst
2017	95,19	94,38	79,37	63,34	4000	4400	200	320	960	1600
2018	93,54	92,84	42,29	41,56	6000	3000	300	500	2000	5000
2019	91,56	90,18	42,28	90,65	25000	4000	300	600	2800	300

The WQI values for all three years were 90 and higher, displaying values of 91,56; 93,54 and 95,19, indicating excellent water quality of the Neretva river based on the chemical parameters. The results for the first year (2017) indicate poor bWQI values at both upstream and downstream sampling sites, with values of 79,37 and 63,34. In 2018, the situation further deteriorated, and a bWQI value of 42, 93 and 41,56 classified the water quality as very poor. In 2019, the river water quality exhibited considerable variation, ranging from very poor do excellent, the upstream site remained characterized by very poor quality with a bWQI value of 42,28, whereas the downstream site recorded a value of 90,65, indicating excellent water quality.
Statistical analysis using the t-test indicates the presence of a statistically significant difference between upstream and downstream WQI values, while the bWQI values for both sites do not show a statistically significant difference ($p < 0,05$). Additionally, the results of the microbiological parameters – total coliforms, *E. coli* and enterococci do not indicate a significant difference between upstream and downstream ($p < 0,05$).

Bacteriological load

A significant bacteriological load of the Neretva river is shown in Figures 1, 2 and 3. All analyzed parameters exceed the legally prescribed limit values for water safety.

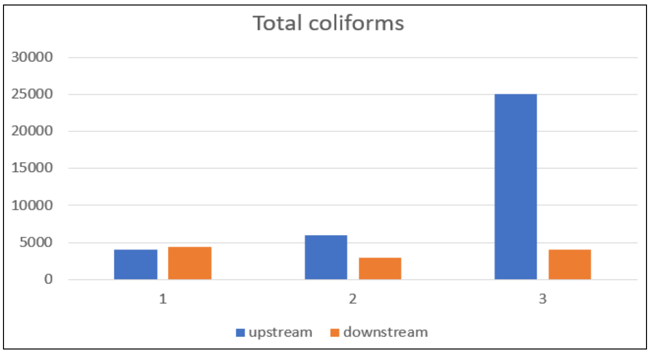

Fig 1: Concentration of total coliform bacteria (100 ml)

Elevated concentrations of bacteriological indicators of water quality suggest possible contamination with pathogenic microorganisms, representing a significant health risk associated with waterborne diseases. A strong correlation was identified between the presence of pathogenic bacteria and increased values of bacterial indicators (Boufafa, *et al.,* 2020) [4].
Previous studies have demonstrated a strong correlation between high concentrations of fecal coliform bacteria and elevated levels of phosphates and nitrogen compounds. This promotes accelerated growth of aquatic organisms, significantly enhancing algal proliferation and stimulating algal blooms and eutrophication (Riđanović and Riđanović, 2016) [15].

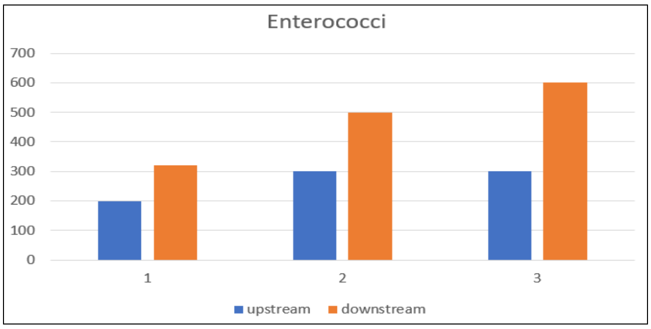

Fig 2: Concentration of enterococci (100 ml)

Swimming in water contaminated with household wastewater can lead to illnesses such as gastroenteritis, irritation of eyes, ears and skin, as well as acute respiratory diseases. Serious infectious diseases may occur if the concentration of fecal coliform bacteria exceed 2000 microorganisms per 100 ml and *E. coli* exceeds 130 microorganisms per 100 ml (WHO, 1996).

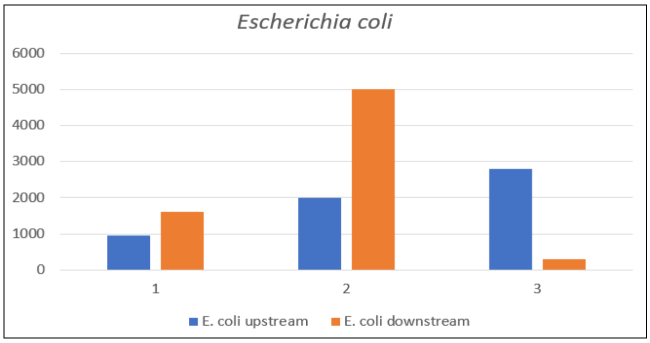

Fig 3: Concentration of *E. coli* (100 ml)

Conclusion

From the results of the present research, the following conclusions may be derived:

- From a chemical perspective, the overall water quality of the Neretva river through the municipality of Jablanica, expressed as WQI, indicates excellent water quality.
- The bacteriological impact, expressed as bWQI, affects water quality causing it to range from excellent to very bad.
- The difference between upstream and downstream WQI values is statistically significant, whereas the bWQI values do not show a statistically significant difference.
- The Neretva river is subject to considerable bacteriological pressure, with all assessed bacteriological parameters surpassing the legally established maximum permissible limits.
- Recreational use of the river Neretva carries a significant risk to human health.
- The obtained results provide a relevant basis for future research aimed at precisely identifying the sources of pollution in the Neretva river and defining effective measures for its mitigation or complete elimination.

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