INFLUENCE OF THE NUMBER OF VISITORS ON THE QUALITY OF BATHING WATER AT THE KRAVICA WATERFALL (BOSNIA AND HERZEGOVINA)

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ABSTRACT

This paper analyses the results of microbiological analyses of bathing water at the Kravica Waterfall during 2018 and 2019 and the impact of bathers on bathing water quality. The microbiological analysis of the samples was performed by the Federal Institute of Public Health in Mostar in accordance with the regulations of Directive 2006/7 EC for management of quality of bathing water. Faecal streptococci were determined using the membrane filtration method BAS EN ISO 7899-2:2003. *Escherichia coli* was determined using the membrane filtration method for waters with low bacterial background flora BAS EN ISO 9308-1:2015. The quality of bathing water is assessed on the basis of parameters determined by the current Directive 2006/7/EC. The number of visitors does not have a significant impact on the quality of bathing water; the reason is that of the total number of visitors there is a small percentage of bathers. During the bathing seasons in 2018 and 2019, the bathing water at the Kravica Waterfall was of excellent quality.

Keywords: *Kravica Waterfall, bathing water, microbiological parameters, faecal streptococci, Escherichia coli*

INTRODUCTION

The river Trebižat, i.e., the watercourse Tihaljina - Mlade - Trebižat in the length of 51 km, from the source in Peć Mlini to the confluence with the Neretva River, forms a unique hydrological unit. It flows through three municipalities: Grude, Ljubuški, and Čapljina, and two counties: The West Herzegovina County and The Herzegovina-Neretva County. The mentioned watercourse is a part of the watercourse of Matica and Vrljika. The waters collected on the Tribistovo plateau feed the Prološko blato natural preserve and the Utopišće spring in the Republic of Croatia underground. The Vrljika river drains water from Prološko blato, and then the river Matica, sinks in the area of the Imotsko-Bekijsko Field and springs again in Peć Mlini. After springing in Peć Mlini, a 20 km long watercourse flows under the name Tihaljina. On a section about 8 km long in the

area of Ljubuški field, it flows under the name Prokop or Mlade. For the next 23 km, it flows under the name Trebižat all the way to the confluence with the Neretva River at Struge [1].

The natural phenomenon of sinking and the appearance of water is characteristic of karst rivers, and is conditioned by a high-permeable karst soil. Due to the composition of the geological soil, i.e., a large number of cracks and caverns located in the inside, the permeation and flow of the water is enabled. Tihaljina - Mlade - Trebižat is a large karst river that receives large amounts of water rich in calcium carbonate by underground gravity. On its course through the karst area, it created smaller and larger travertine cascades, beaches and waterfalls, of which the most attractive are: Koćuša, Čevelјuša, Kravica, Božjak, and Struga [2].

Kravica Waterfall is located on the 51 km long course of the river Trebižat, in Studenci near Ljubuški. It was created by the work of the travertine river Trebižat. The height of the waterfall ranges from 26 to 28 m, with a water amphitheatre below the waterfall with a diameter of 120 m [3]. Grass, moss, algae and lichens grew over the tuff layer from the bottom to the top of the waterfall. Hemp, figs and poplars sprouted along the waterfall. Numerous mills and cloth-rolling pillars were active along the waterfall. The travertine areas around the Kravica waterfall belong to the natural geological monuments of Bosnia and Herzegovina. During small water courses, there is no water flow over a large part of the Kravica waterfall. In these parts of the waterfall, the already formed travertine dries out, creating cracks and fractures. With the arrival of a large water wave, the cracks widen and deepen. By changing such conditions, during a certain period, there is a phenomenon of tearing and collapsing pieces of travertine at the pedestal of the waterfall. In summer, due to the lower water level of the river, the pool below the waterfalls offers the enjoyment of swimming and water sports. At any time of the year, due to large changes in the water level and vegetation, Kravica waterfall provides different and unique experiences [4]. Figure 1 shows the location of Kravica Waterfall on the map of Bosnia and Herzegovina.

Figure 1. Location of Kravica Waterfall on the map of Bosnia and Herzegovina [5]

According to Article 8 of the West Herzegovina County Communal Economy Act [6], Article 26 of the West Herzegovina County Administration Body Act [7] and Article 120 of the Statute of the Municipality of Ljubuški [8], the Municipal Council of Ljubuški, on XI. session held on 19th July 2013, made a decision to entrust public authority to the Public Company "Parkovi" d.o.o. Ljubuški for the cleaning and maintenance of the tourist zone of the Kravica, the "facility of extraordinary natural beauty and natural rarity", and for the collection of entrance and parking fees and other services there [9].

Accordingly, the Public Company "Parkovi" d.o.o. Ljubuški during the bathing season regularly analyses bathing water at the Kravica bathing area in accordance with the current Directive 2006/7/EC, because Bosnia and Herzegovina is in the process of preparing a rulebook that defines parameters of bathing water [10].

Nature swimming pools are an alternative to conventional swimming pools which utilise chemical water treatment methods. The water in nature swimming pools is not cleaned chemically. This difference has benefits in the form of a healthy bathing environment, which

does not have any negative impact on human health because no chlorine is used [11].

The quality of bathing water is of increasing importance, and public awareness of the impacts of poor bathing water quality on health risk has increased in recent years. Beach closures now frequently occur due to the non-compliance of water quality to the required standards [12].

Some types of water use have specific requirements for water quality (surface water for drinking purposes, water for crop irrigation, water suitable for life and reproduction of indigenous species and natural bathing waters). The suitability of water for a particular use purpose depends on whether its quality is in accordance with particular set of water quality parameters and corresponding limit values [13].

In this paper, the results of microbiological analyses of bathing water at the Kravica Waterfall during 2018 and 2019 and the impact of bathers on bathing water quality were analysed.

EXPERIMENTAL

For the analysis of bathing water at the Kravica Waterfall during the bathing season samples were taken from June to September. According to Article 3 of the Bathing Water Quality Management Directive 2006/7/EC [14], samples should be taken at locations within the boundaries of bathing water where most bathers are expected, or where, according to the bathing water profile, the greatest risk of contamination is expected.

Accordingly, water samples for analysis were taken at two measuring points: measuring point 1 - below the waterfall and measuring point 2 - next to the bridge.

According to the Directive [14], one sample must be taken just before the start of the bathing season, and at least four samples must be taken and analysed during the bathing season.

The bathing season at the Kravica Waterfall starts in July and lasts until September, so the first samples for analysis were taken at the end of June, and other samples were taken during the bathing season and analysed every 15 days. Microbiological analysis of the samples is done by the Federal Institute of Public Health in Mostar in accordance with the regulations of Directive 2006/7/EC for management of water quality [14]. Faecal streptococci were determined using the membrane filtration method BAS EN ISO 7899-2:2003 [15]. *Escherichia coli* was determined using the membrane filtration method for waters with low bacterial background flora BAS EN ISO 9308-1:2015 [16, 17].

Sampling was carried out in accordance with Annex 5 of the Directive, which requires that samples have to be taken 30 cm below the surface in water at least one meter deep. Water samples were poured in sterile 500 mL bottles and stored in a dark place at 4 °C until analysis. Processing and analysis of samples was performed no later than 24 hours after sampling (Federal Institute of Public Health in Mostar).

RESULTS AND DISCUSSION

The quality of bathing water is assessed on the basis of the parameters specified in the current Directive 2006/7/EC [14] (Table 1). The microbiological indicators monitored in bathing water are interstitial enterococci (faecal streptococci) and *Escherichia coli*.

Table 2 shows the results of microbiological analysis of bathing water at the Kravica Waterfall sampled in 2018 during the bathing season at two measuring points (1 - below the waterfall, 2- next to the bridge).

Table 1. Bathing water quality monitoring parameters - inland waters

Indicator	Excellent quality	Good quality	Satisfying quality	Reference methods of analysis
Intestinal enterococci (cfu/100 mL)*	200**	400**	330***	ISO 7899-1 or ISO 7899-2
Escherichia coli (cfu/100 mL)	500**	1000**	900***	ISO 9308-3 or ISO 9308-1
(*) colony-forming units per millilitre (**) based upon a 95-percentile evaluation (***) based upon a 90-percentile evaluation				

Table 2. Microbiological analysis of samples from 2018 (measuring unit cfu/100 mL)

Date	Indicator	Measuring point 1	Measuring point 2
June 22, 2018	Faecal streptococci	20	32
	Escherichia coli	20	40
July 6, 2018	Faecal streptococci	25	20
	Escherichia coli	140	90
July 18, 2018	Faecal streptococci	20	20
	Escherichia coli	100	90
August 10, 2018	Faecal streptococci	35	23
	Escherichia coli	50	50
August 29, 2018	Faecal streptococci	84	60
	Escherichia coli	40	110
September 19, 2018	Faecal streptococci	10	40
	Escherichia coli	50	50

The results presented in Table 2 show that the values for faecal streptococci during the bathing season range from 10 to 84 cfu/100 mL, while the values for *Escherichia coli* range from 20 to 140 cfu/100 mL. When these values are compared with the values for the assessment of bathing water quality shown in Table 1, it can be concluded that the bathing water at the Kravica Waterfall during the entire bathing season in 2018 was of excellent quality.

According the number of visitors shown in Figure 2, and comparing the values of the examined microbiological parameters shown in Table 2, it can be seen that the highest values of faecal streptococci and *Escherichia coli* were recorded during July and August.

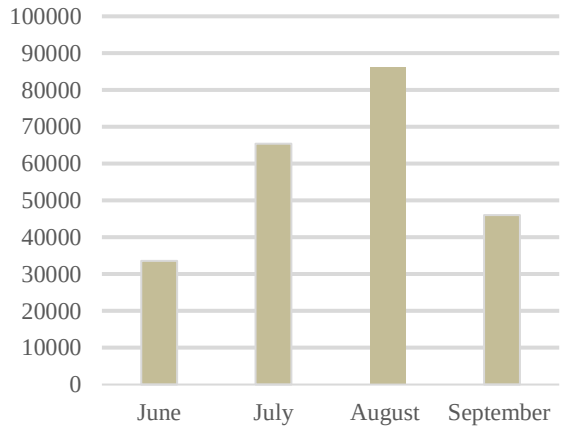

Figure 2. Number of visitors during the bathing season in 2018

Also, comparing the values of these microbiological parameters obtained at two measuring points, it can be seen that the values at the measuring point 1 (below the waterfall) are in most cases higher than values at the measuring point 2 (next to the bridge).

Considering the fact that faecal streptococci ranged from 10 to 84 cfu/100 mL and *Escherichia coli* ranged from 20 to 140 cfu/100 mL (well below the maximum allowable limit for excellent water quality, Table 1), it can be seen that throughout the bathing season in 2018 the Kravica Waterfall was in the category of excellent water quality according to Directive 2006/7/EC and that the number of visitors did not have a significant impact on the quality of bathing water.

Table 3 shows the results of microbiological analysis of bathing water at the Kravica Waterfall sampled in 2019 during the bathing season at two measuring points (1 - below the waterfall, 2- next to the bridge).

Table 3. Microbiological analysis of samples from 2019 (measuring unit cfu/100 mL)

Date	Indicator	Measuring point 1	Measuring point 2
June 26, 2019	Faecal streptococci	100	150
	Escherichia coli	50	50
July 11, 2019	Faecal streptococci	12	90
	Escherichia coli	30	50
July 30, 2019	Faecal streptococci	37	35
	Escherichia coli	160	120
August 13, 2019	Faecal streptococci	120	130
	Escherichia coli	30	30
August 28, 2019	Faecal streptococci	120	150
	Escherichia coli	90	50
September 11, 2019	Faecal streptococci	100	70
	Escherichia coli	70	50

The results presented in Table 3 show that the values of faecal streptococci during the bathing season ranged from 12 to 150 cfu/100 mL, while the values of *Escherichia coli* ranged from 30 to 160 cfu/100 mL. When these values are compared with the values for assessing the quality of bathing water shown in Table 1, it can be concluded that the bathing water at the Kravica Waterfall during the entire bathing season in 2019 was of excellent quality.

According the number of visitors shown in Figure 3, and comparing the values of the examined microbiological parameters shown in Table 3, it can be seen that the highest values of faecal streptococci and *Escherichia coli* were recorded during July and August.

Also, comparing the values of these microbiological parameters obtained at the two measuring points, it can be seen that the values at the site next to the bridge (measuring point 2) are generally higher than the values at the site below the waterfall (measuring points 1).

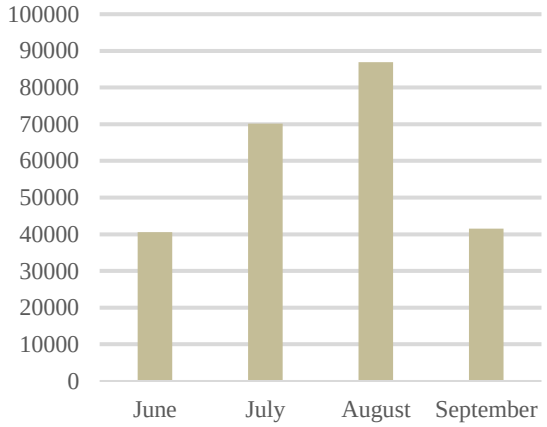

Figure 3. Number of visitors during the bathing season in 2019

Considering the fact that faecal streptococci ranged from 12 to 150 cfu/100 mL and *Escherichia coli* ranged from 30 to 160 cfu/100 mL (well below the maximum allowable limit for excellent water quality, Table 1), it can be seen that throughout the bathing season in 2019 the Kravica Waterfall was in the category of excellent water quality according to Directive 2006/7/EC and that the number of visitors did not have a significant impact on the quality of bathing water.

Pearson's correlation coefficient was calculated between all measured values of faecal streptococci and *Escherichia coli* to show the interdependence in incidence. The value of the coefficient is -0.27487.

CONCLUSION

Microbiological analyses of the Kravica Waterfall throughout the two bathing seasons in 2018 and 2019 show that values of faecal streptococci ranged from 10 to 150 cfu/100 mL, and values of *Escherichia coli* ranged from 20 to 160 cfu/100 mL.

Based on the analysed microbiological parameters in the bathing water samples from the Kravica Waterfall during the bathing seasons in 2018 and 2019 and their comparisons with the values of bathing water quality parameters determined by the current Directive 2006/7/EC for management of

quality of bathing water, it can be concluded that, throughout the bathing seasons in 2018 and 2019, bathing water was of excellent quality.

The highest values of examined microbiological parameters during 2018 and 2019 were recorded during July and August.

The number of visitors to Kravica Waterfall for the observed period was highest in August 2019. The number of visitors does not have a significant impact on the quality of bathing water. The reason is that the percentage of bathers is lower than the total number of visitors.

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