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Bathing water quality at bathing sites in Kaštela (Croatia) in the period of application of the Bathing Water Directive 2006/7/EC

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We analyzed and discussed bathing water quality at 11 official bathing sites in Kaštela (Croatia) in the period 2009-2022. The results showed spatial and temporal variations in quality. The worst bathing water quality was in the eastern part of the area, at beaches Torac, Kamp and Gojača. Levels of indicator microorganisms at identified sources of fecal pollution near these beaches indicate a significant load of fecal material to these areas. The observed decrease in annual fecal indicator bacteria exceedances, while not statistically significant, indicates a trend toward improvement in water quality. The number of sites with worse annual and final assessment showed a decreasing trend only since 2017 and 2020, respectively, which is not a 'sufficient' time period to draw a clear conclusion about the trend. The improvements are probably the result of intensive work in recent years to improve the sewage system in the area.

In the annual and final assessment, bathing sites from Kaštela with 'poor' water quality accounted on average for more than 27% of all waters with 'poor' quality in Croatia. This implies that additional efforts are needed to eliminate the sources of fecal pollution in the area.

Key words: Bathing water quality; Kaštela; Croatia; Bathing Water Directive

INTRODUCTION

Tourism, as one of the most important economic sectors, has seen continued expansion over time, demonstrating the sector's strength and resilience (UNWTO, 2019). Both tourism and recreation are expected to increase in coming years as marine and coastal areas remain the top tourist destinations in Europe (EEA, 2017). According to World Tourism Organization report for Europe (UNWTO, 2019), Southern and Mediterranean Europe led results, with most destinations enjoying a significant, double-digit growth. Croatia is more dependent on tourism income compared to its Mediterranean competitors, which can negatively affect its economy during years with a worse tourist season. Thus, during the Covid pandemic in 2020, tourism revenues amounted to 8.9% of GDP, a significant decrease compared to the years before the Covid pandemic (2018 and 2019), when it accounted for 19.6% of Croatian GDP (Ministry of tourism of Republic of Croatia, 2020; 2021).

Under normal circumstances, marine and coastal tourism depends on maintaining the health and resilience of the marine environment so that people can continue to enjoy and use it (EEA, 2017). Seawater quality is considered one of the most important reasons tourists choose a destination (PREIßLER, 2009; DODDS & HOLMES, 2018; SLATER & MEARNS, 2018), making it a critical factor for island and coastal communities that depend on coastal tourism (SCHUHMANN *et al.*, 2019).

In the European Union, the management of bathing water quality is regulated by the Bathing Water Directive (BWD) (2006/7/EC). The main purpose of the BWD is to preserve, protect and improve the quality of the environment and to protect human health. According to the BWD, Member States shall ensure that, by the end of the 2015 bathing season, all bathing waters are at least 'sufficient'. In 2021, 'poor' bathing waters constituted 1.5% of all sites in the EU, compared to 2% in 2013 (EEA, 2022). This shows that the management of 'poor' bathing sites in Europe has improved, but also that the goal set has not yet been achieved.

The first official monitoring of coastal bathing water quality on Croatian beaches began in 1989 and has continued ever since, evolving in the number of sites monitored, test methods, indicator microorganisms and water quality management. During the negotiations for accession to the European Union, Croatia had to adopt and implement the body of EU law. Thus, in 2008, five years before its accession to the EU, Croatia adopted the BWD and integrated it into the Regulation on Sea Bathing Water Quality (NN 73/2008). The national Regulation sets somewhat stricter criteria compared to the BWD, all aimed at maintaining the high quality of the sea for bathing in the Republic of Croatia and ensuring the possibility of timely warning of the competent authorities and the involved and responsible services in the event of sudden or short-term pollution. Since the beginning of the application of the criteria of the new Regulation, there has been a very high percentage of beaches with 'excellent' bathing water quality, based on annual and final assessment (includes the results of the bathing season and the three previous bathing seasons). This percentage was about 95% in the first years of monitoring and has remained stable above this value until today. At the same time, the percentage of sites with 'poor' water quality has fluctuated between 0.44% and 1.1%, corresponding to 4-12 bathing sites. This percentage is lower than the EU average, but unfortunately does not show a downward trend, as EU average. The highest number of sites with 'poor' quality was recorded in Kaštela bay, particularly in the area of the town of Kaštela. In the final assessment of 2019, 4 out of 11 official bathing sites in Kaštela were assessed as 'poor' and only four sites as 'excellent'. This represents 33% (4 out of 12) of all Croatian bathing sites assessed as 'poor' in the 2019 final assessment (DŽAL *et al.,* 2021). All this indicates that additional efforts should be made in the area of the City of Kaštela to identify and reduce the sources of pollution of bathing waters if the city wants to position itself as an important tourist destination in this area of the Adriatic.

The aim of this study is to analyze the trend of bathing water quality in the city of Kaštela in the period of application of BWD criteria (2009-2022) and to try to identify the reasons for the worse quality compared to other areas in Croatia.

MATERIALS AND METHODS

Study area and sampling sites

Kaštela is a town on the coast of Kaštela Bay, one of the largest bays on the eastern side of the Adriatic Sea (Fig. 1). The town is about 18 km long agglomeration of seven individual settlements, administered as a single municipality with about 40,000 inhabitants. Thanks to the attractive coast and the many beaches, tourism in Kaštela has a very long tradition. In 1909 the first tourist boarding house with a bathing beach

Fig. 1. The map of study area and sampling sites (R-Resnik, Ga-Gabine, D-Đardin, H-Hotel Palace, M-Miljenko i Dobrila, S-Šoulavy, P-Puntica, B-Baletna škola, T-Torac, K-Kamp, Go-Gojača)

was opened, which is considered the beginning of organized tourism in Kaštela. Over time, sea tourism in Kaštela developed and intensified. In parallel there was a sudden and uncontrolled urbanization and industrialization (meat, cement and chemical industries) of the area, without construction of adequate waste water systems. Consequently, wastewater entered the bathing waters directly through numerous uncontrolled sewage discharges near the coast, making Kaštela Bay one of the most polluted and loaded areas of the Adriatic in the 1980s (KUŠPILIĆ *et al.*, 2015). The new wastewater system was partially put into operation in 2014. The aim of the construction of this modern drainage and treatment system is to create conditions for correct and ecological reception and disposal of sanitary sewage (domestic wastewater) along the coast of Kaštela Bay and to eliminate the main source of existing pollution of the bay. The implementation of the ongoing project for the construction of a system to improve water supply, drainage and wastewater treatment in the Kaštela-Trogir agglomeration will make it possible to increase the connection rate to the public sewage system from the current 36% to 95% of the population of the Kaštela-Trogir agglomeration by the end of the project (2023) and to 98% thereafter (2025). The existing central wastewater treatment plant will be upgraded from mechanical to biological treatment. All the improvements are expected to have a significant impact on bathing water quality in the area. Until then, this area remains subject to sporadic fecal pollution from smaller, local drains and streams that collect fecal matter in their courses.

Although there are almost 20 beaches in the Kaštela area, many of them are small and located close to each other, so bathing water quality is currently monitored at 11 official sampling sites (Fig. 1), with a tendency to increase the number of sites.

Sample collecting and analyzing

During each bathing season, which lasts from the end of May to the end of September, 10 samples (every two weeks) per sampling site are taken and analyzed as a part of official national monitoring. In 2021 and 2022, at the three historically (based on the study DŽAL *et al*., 2021) most polluted sites in Kaštela, Torac, Kamp and Gojača, the sources of pollution were identified and microbiological pollution was quantified within the project "Eurobath". To this end, five additional sites were monitored, including three streams that flow into the bathing waters (S1, S4 and S5) and two sites next to uncontrolled coastal wastewater discharges (S2, S3) (Fig. 1).

Seawater samples were collected 30 centimeters below the surface and transported to the laboratory in cooling boxes. All samples were processed the same day, within 4 hours of sampling.

Both fecal indicator bacteria (FIB) were determined using membrane filtration method. *E. coli* was determined and enumerated using ISO 9308-1. From 2009 to 2014, reference method ISO 9308-1:2000 version was used. Water samples were filtered through 47 mm wide membranes with a pore size of 0.45 μm, transferred to a two-layer media Tryptone Soy Agar/Tryptone Bile Agar (TSA/TBA) and incubated 4 hours at 36 ± 2 °C followed by 20 hours incubation at 44 ± 0.5 °C. After incubation, the membranes were placed on an adsorbent pad saturated with Indol Rapid Reagent for 10-30 min. All red colonies on the membrane filters were counted as *E. coli*. From 2014 to 2017, the reference method ISO 9308-1:2014 was used, while from 2018 we use the temperature-modified method ISO 9308-1:2014. Both methods are based on the same principle, β-D-galactosidase and β-D-glucuronidase activity. While in the reference method the whole incubation (21-24 h) is performed at 36 ± 2 °C, the incubation procedure was changed in the temperature-modified method. Chromogenic Coliform Agar (CCA) was incubated for 4 hours at 36 ± 2 °C followed by 20 hours at 44 ± 0.5 °C (JOZIĆ et al., 2018). In both methods, all dark blue to violet colonies were counted as confirmed *E. coli*. To ensure traceability of data, we have successfully performed equivalence testing of methods.

For enumeration of intestinal enterococci, the standard method ISO 7899-2:2000 was used. The incubation on Slanetz & Bartley agar at 36 °C ± 2°C for 44 ± 4 hours, was followed by additional incubation on prewarmed (44 °C) Bile Aesculin Azide Agar at 44 ± 0.5 °C for 2 hours. All pink, red or brown colonies that developed a brown or black halo on Bile Aesculin Azide Agar were counted as confirmed enterococci

Data collecting, processing and analyzing

The raw data on coastal bathing water quality, FIB counts, are from the official national monitoring database (https://vrtlac.izor.hr/ords/kakvoca/kakvoca). Unlike processed public data, which are used to inform the public about bathing water quality, access to row data is restricted.

Bathing water quality data were processed in accordance with BWD guidelines and national Regulation. The water quality of each water sample (after each sampling) was assessed using national criteria (Table 1).

Bathing water quality categories for annual and final assessment were determined using the 90th and 95th percentiles of row FIB data using national criteria (Table 2).

The upper 90percentile and 95percentile points of the data probability density function are derived according the Equation 1 and 2, as set in Annex II of the BWD:

Upper 90th (th) percentile=antilog(μ+1.282σ) (1)
Upper95th (th) percentile=antilog(μ+1.65σ) (2)

μ - the arithmetic mean of the log10 values of FIB counts
σ - the standard deviation of the log10 values of FIB counts

Table 1. Croatian standards for assessment of coastal bathing water quality after each analysis

Parameters	excellent	good	sufficient
Intestinal enterococci (CFU/100 mL)	≤60	61-100	101-200
E. coli (CFU 100/mL)	≤100	101-200	201-300

Table 2. Croatian standards for annual and final assessment of coastal bathing water quality

Parameters	excellent	good	sufficient	poor
Intestinal enterococci (CFU/100 mL)	≤100*	≤200*	≤185**	>185**(1)
E. coli (CFU/100 mL)	≤150*	≤300*	≤300**	>300** (1)

* Based upon a 95th percentile evaluation
** Based upon a 90th percentile evaluation
(1) Immediate action for each sample, if the number of intestinal enterococci exceeds 300 CFU/100 mL, *E. coli* 500 CFU/100mL

The data on the number of tourists per year are taken from the official website of the Tourist Board of Split-Dalmatia County (https://www.dalmatia.hr/hr/statistike).

RESULTS AND DISCUSSION

Bathing water quality

The annual assessment of bathing water quality at 11 bathing sites in Kaštela in the period 2009-2022 is shown in Fig. 2. Since the final assessment includes the results of the bathing season and the three previous bathing seasons, it is available since 2012. The exception is Puntica beach, which has been monitored since 2014 (Fig. 3).

Both assessments, annual and final, showed a wide range of bathing water quality at 11

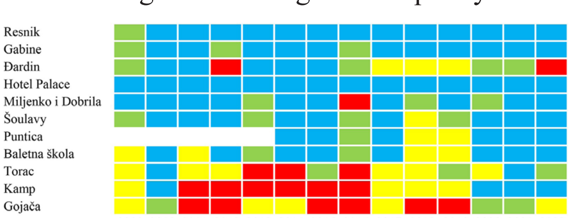

Fig. 2. Annual assessment of bathing water quality at 11 beaches in Kaštela in the period 2009-2022 (Blue-'excellent', green-'good', yellow-'sufficient', red-'poor', white-no data).

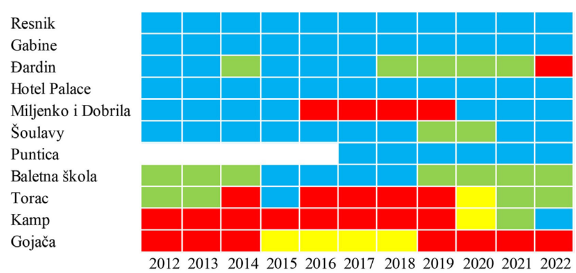

Fig. 3. Final assessment of bathing water quality at 11 beaches in Kaštela in the period 2012-2022 (Blue-'excellent', green-'good', yellow-'sufficient', red-'poor', white-no data).

monitored sites, from 'excellent' to 'poor'. In annual and final assessment water quality in the western part of the area was much better than in the eastern part, although some bathing sites in the western part (Đardin and Miljenko i Dobrila) occasionally had 'poor' or 'sufficient' water quality. Water quality at three sites in the eastern part of the area (Torac, Kamp, and Gojača) was mostly 'sufficient' or 'poor' throughout the study period. The number of poor sites has been decreasing since 2017 in the annual assessment and 2020 in the final assessment. The delay in improvements in the final assessment compared to the annual assessment is due to the fact that the results of the current season and the three previous seasons are taken into account, so it takes three years for the improvements to be reflected.

Comparing the results of the annual and final water quality assessments at the same beaches, occasional ‘inconsistencies’ are observed between these assessments. The annual water quality at Miljenko i Dobrila beach was ‘poor’ only in the 2016 season, while in the final assessment it was ‘poor’ in the entire 2016-2019 period, although ‘excellent’ annual water quality was recorded in two bathing seasons in the same period. Annual water quality at Torac beach was ‘poor’ in 2016, and the ‘poor’ water quality in final assessment continued in the three following bathing seasons. The situation at Kamp beach was similar. Although it seems illogical at first glance, these results are explainable. Indeed, the aim of the final bathing water quality assessment is to show the public the long-term water quality at the bathing site. The final assessment is based on the data from four seasons and thus has a ‘longer memory’ than the annual assessment. Thus, a single exceedance detected in one season can affect the final water quality in the following one to three seasons, depending on the absolute value of FIB that exceeded the upper limit and the distribution of other FIB data. Furthermore, in the national Regulation, unlike in BWD, there is a mechanism for “immediate action” for each sample. If the number of intestinal enterococci exceeds 300 CFU/100 mL or/and *E. coli* exceeds 500 CFU/100 mL (Table 2), the annual water quality for that season and the final assessment for the next three seasons is classified as ‘poor’. The above procedures of assessment are unfavorable for sites with stable, ‘excellent’ water quality with low FIB values and very rare exceedances. On the other hand, the final assessment of bathing water quality at the beaches of Đardin, Puntica and Šoulavy was better than the annual assessment in the same period. Both situations are likely the result of the statistical methods for water quality assessment, both annual and final. The method assumes that FIB data are lognormally distributed and is therefore sensitive to extreme values. It is more suitable for datasets containing more data with ‘moderate’ FIB values. For such datasets, the calculated 90th and 95th percentiles do not deviate significantly from the ‘actual’ percentiles (the data at the 90th an 95th position in descending order of row data used for the calculation). For datasets dominated by low FIB values a single high value can have a significant impact on the 90th and 95th percentiles. Consequently, the calculated value of these parameters can be significantly higher than the ‘real’ value. One of the solutions to this problem, which might benefits bathing sites with ‘excellent’ quality and mainly low FIB counts, is the proposal of WHO (2018). Where the data are not shown to be normally distributed, the Hazen calculation method should be used. This calculation method is not sensitive to extreme values and calculated 90th and 95th percentiles cannot be out of obtained FIB dataset. This measure would also reduce misclassification of bathing sites.

Despite the aforementioned shortcomings, water quality categories are a ‘good’ indicator of bathing water quality when it comes to informing the public and presenting the health risk to bathers. Currently available public information on bathing water quality in Croatia is quite enough. In order to get a comprehensive picture of bathing water quality at a particular site, bathers should consider all available data, assessment of individual samples, annual final assessments, the number of exceedances during the season and beach profile.

However, because the range of values of FIB within a category is relatively wide, information on other parameters, such as the 90th and 95th percentiles of all FIB data and the absolute values of exceedances of FIB, may provide a better picture of bathing water quality. Both the annual and final assessments are based on the 95th or 90th percentiles of two indicator bacteria, *E. coli* and intestinal enterococci (Table 2). The upper limit for the ‘sufficient’ quality category is based on the 90th percentile and is lower than the upper limit for the ‘good’ category, which is based on the 95th percentile. This may be confusing when presenting results to the public. To avoid confusion among the public and those unfamiliar with statistical methods, WHO (2018) suggested using only the 95th percentile in bathing water quality assessments but using new upper limits for ‘sufficient’ and ‘poor’ quality categories, 367 CFU/100 mL for intestinal enterococci and 993 CFU/100 mL for *E. coli*. For this reason, FIB values for each year of the study are presented using only the 95th percentiles.

The 95th percentiles of *E. coli* and intestinal enterococci along with the number of exceedances for each bathing season during 2009-2022 is shown in Fig. 4. The results show that the 95th percentile values of both indicators fluctuated throughout the study period, with no clear trend,

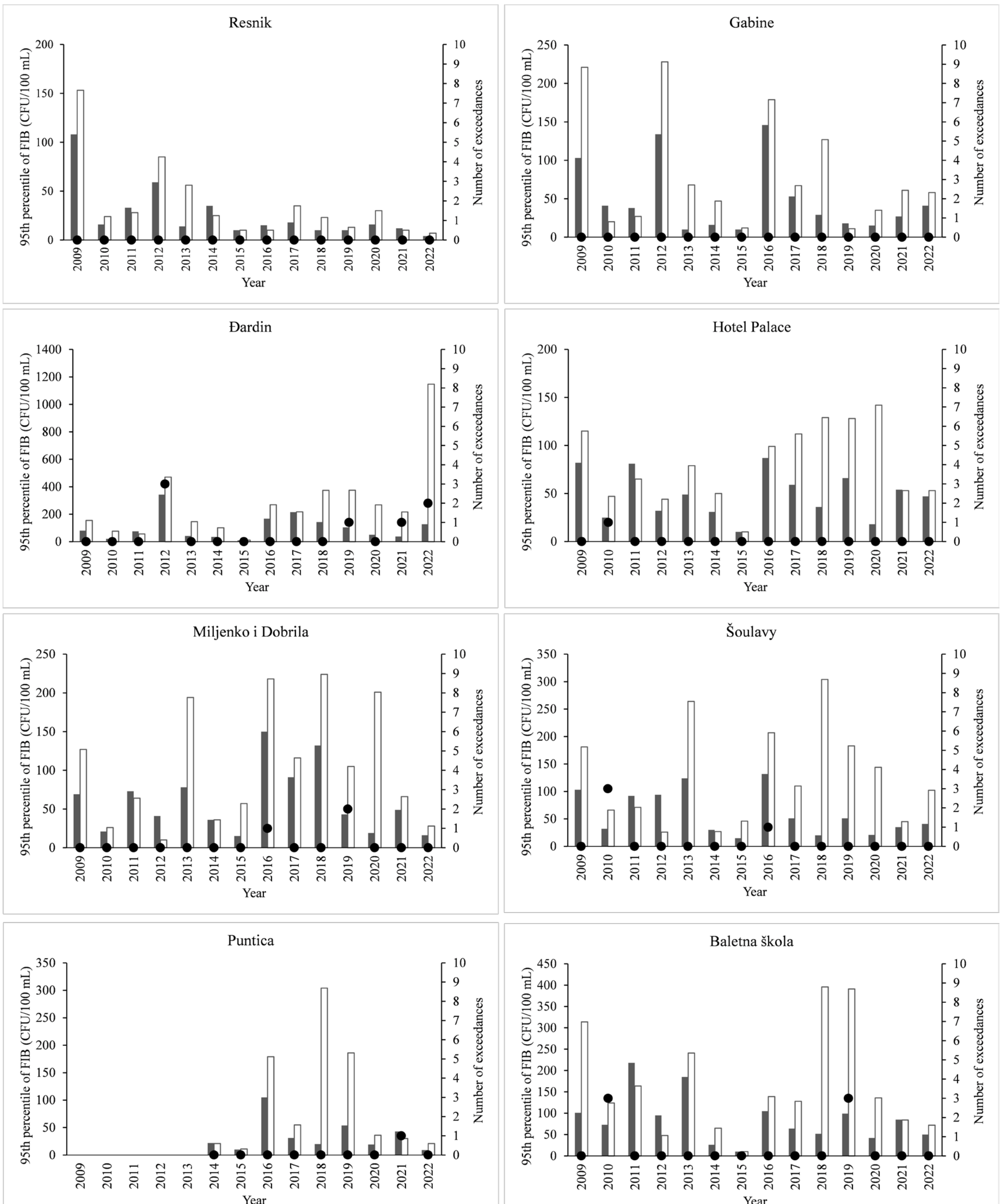

Fig. 4. The 95th percentile of E. coli (white bars) and intestinal enterococci (grey bars) and the number of exceedances (black dots) at bathing waters on beaches in Kaštela in 2009-2022.

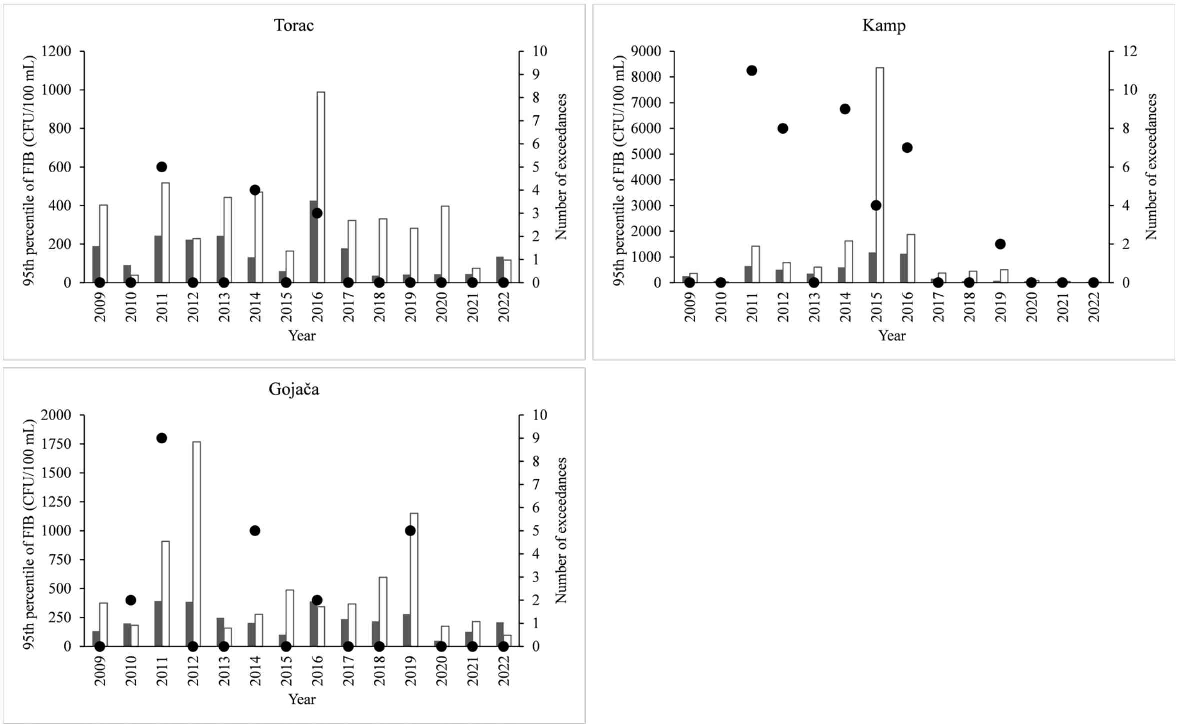

Fig. 4 (continued). The 95th percentile of E. coli (white bars) and intestinal enterococci (grey bars) and the number of exceedances (black dots) at bathing waters on beaches in Kaštela in 2009-2022

even at sites with relative stable bathing water quality. Although percentiles are not always the most representative parameter of actual bathing water quality for the reasons discussed above, a comparison of their values for the same (e.g., 'poor') bathing water quality shows that they can help provide better information about the pollution level and health risk at the site than bathing water quality category. For water quality to be classified as 'poor', percentiles must exceed the upper limit of FIB for that quality category, regardless of their absolute value. However, in terms of bathers' health, swimming and recreation in waters in the same category can pose very different risks. For example, water quality at Đardin beach was 'poor' in 2012 and 2022, but the 95th percentile value for *E. coli* in the 2022 bathing season was significantly higher and indicates a much higher health risk. Similarly, the water at Kamp beach in 2015 and in Gojača in 2012 and 2019.

As expected, most FIB exceedances were found at sites with worse annual and final water quality categories, although a worse quality category (annual) is not always the result of exceedances. For example, Đardin was assessed 'sufficient' in 2017 and 2018 annual assessment, although not a single exceedance was detected. The same is true for Baletna škola in 2018 as well as for some other sites and years. Furthermore, Gojača was assessed 'poor' in 2012, 2015, and 2018 annual assessment, with no exceedances recorded. This is due to a few 'sufficient' quality data in these seasons, which may also result in 'poor' annual or final water quality, depending on the rest of the data in the dataset. The analysis of the results of these seasons showed that most of the exceedances and 'sufficient' data are due to the exceedance of the upper limit for *E. coli*, which can be explained by the much stricter criteria for *E. coli* in the Croatian regulation compared to the BWD. In most cases, the quality would be better at least one category if the BWD criteria for *E. coli* were applied.

On the other hand, there are cases where exceedances were found, but not 'poor' water quality, such as Đardin 2021, Hotel Palace 2010, Miljenko i Dobrila 2019, Šoulavy 2010, 2016, Baletna škola 2010, 2019, Torac 2011, Kamp 2019 and Gojača 2010, 2014. In these cases, the better water quality is due to two main reasons: more FIB data with moderate values resulting in data distribution close to the normal distribution, so that exceedances have not caused percentile values to rise above the upper limits for 'poor' quality; and use of the opportunity to disregard up to 15% of exceedances per year in the case of short-term pollution when an additional sample confirms that the event has ended. Taking into account the number of data per season (10), only one exceedance can be disregarded from the calculation.

Looking at the entire study period, the total number of exceedances at the bathing sites in Kaštela fluctuated from 0 to 25, with a decreasing but statistically not significant trend (R^2=0.1205, p=0.224) (Fig. 5). The decrease in the number of exceedances is the largest since 2017 and coincides with the decrease in the number of sites with poor annual water quality. Besides the fact that most exceedances, on average 41% of the total, were found at three sites in the eastern part of Kaštela (Torac, Kamp and Gojača), confirming the findings of DŽAL *et al.* (2021), the highest FIB counts were also recorded there. Some of the exceedances are well above the lower limit for the 'poor' category, as shown by the high 95th percentile values (Fig. 4), indicating significant fecal contamination.

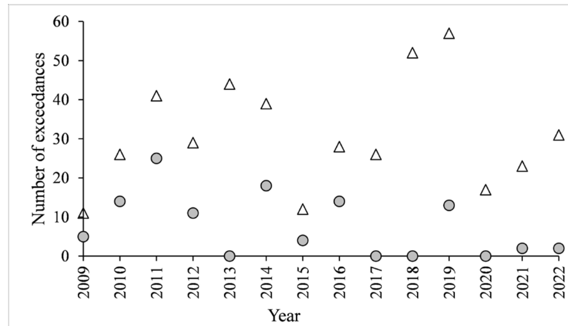

Fig. 5. The annual number of exceedances at 11 bathing sites in Kaštela (circles) and all sites in Croatia (triangles)

Analysis of the identified pollution sources (S1-S5) in these areas revealed relative high levels of FIB, especially at site S2 and S5 (Tables 3 and 4). These sources can affect water quality under favorable meteorological conditions, especially when the wind blows in the direction of the bathing water. Fecal matter in streams (S1, S4 and S5) is released from leaking

Table 3. Descriptive statistics of indicator bacteria (IE - intestinal enterococci, EC - E. coli) (FIB/100 mL) at identified sources of pollution in 2021

Sampling site

	S1		S2		S3		S4		S5	
	IE	EC	IE	EC	IE	EC	IE	EC	IE	EC
Mean	542.0	564.0	3561.0	2929.4	536.1	1261.4	1310.0	1950.0	3508.1	7529.6
Min	110.0	100.0	124.0	14.0	18.0	0.0	460.0	80.0	7	0
Max	1450.0	1320.0	38500.0	22000.0	2300.0	21000.0	4400.0	3400.0	11900	27000
SD	533.7	483.8	7080.7	4954.0	514.8	3860.0	1729.0	1215.6	34453.1	8090.2
n	5	5	32	32	31	31	5	5	31	31

Table 4. Descriptive statistics of indicator bacteria (IE - intestinal enterococci, EC - E. coli) levels (FIB/100 mL) at identified sources of pollution in 2022

Sampling site

	S1		S2		S3		S4		S5	
	IE	EC	IE	EC	IE	EC	IE	EC	IE	EC
Mean	436.7	935.0	312.8	412.8	262.6	1019.4	1356.7	951.7	5425.7	11300.5
Min	150.0	10.0	0.0	0.0	0.0	0.0	310.0	250.0	2	0
Max	750.0	2420.0	2900.0	5600.0	3600.0	16800.0	3600.0	1440.0	26000	82000
SD	148.5	233.3	632.9	1052.7	676.7	3161.4	2382.9	1216.2	7330.2	18422.3
n	6	6	32	32	29	29	6	6	30	30

septic tanks at nearby residences, which could increase pollution of coastal waters during and after rainy periods. However, this has not been confirmed, either because rainfall has no effect or because there was no heavy rainfall during the summer that would affect bathing water quality (ORDULJ et al., 2022). Comparing the results of 2021 and 2022 bathing season, there is a significant decrease in the level of FIB at site S2. This is likely the result of the construction of the wastewater collector, which was put into operation before the 2022 bathing season. Given the prevailing summer winds direction in this area, blowing from the northwest and west during the day and from northeast during the night, reducing this source of pollution is likely to have a positive effect on water quality at Torac and Kamp beaches. Fecal material released in the immediate vicinity of Gojača beach, via a stream (S5) carrying large amounts of microbiological contaminants will continue to affect water quality at Gojača beach as long as discharges of domestic sewage into the stream are not reduced. Given the increase in FIB levels at this pollution source in 2022 compared to 2021 (Table 4) and given the size and nature of the area through which the stream flows, this will be a challenging task.

The effect of water quality in Kaštela on the assessment of water quality in Croatia

In the final assessment of all bathing sites, the trend of the number of 'poor' sites in Croatia and Kaštela in the studied period was similar. The number of 'poor' sites in Croatia was between 6 and 12 per year and has been slightly decreasing since 2020. The number of 'poor' sites in Kaštela fluctuated between 1 and 4, which represented up to 43% (in average 27.3%) of all 'poor' sites in Croatia (Fig. 6). Number of 'poor' sites in Croatia fluctuated between 1 and 10 in the annual assessment during the study period and has been decreasing since 2020. The average share of 'poor' sites in Kaštela in the total number of 'poor' sites in Croatia was the same as the final assessment (27.3%). In 2015 and 2016, all 'poor' Croatian coastal bathing sites were in Kaštela (Fig. 7).

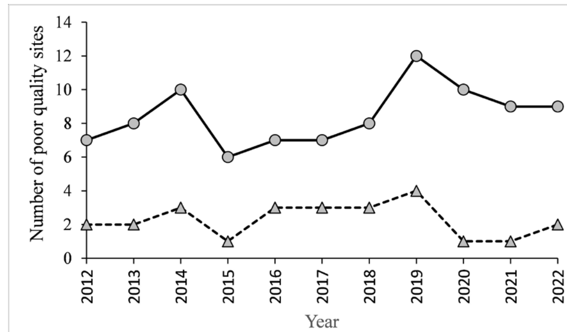

Fig. 6. Number of 'poor' sites in Kaštela (triangles) and Croatia (circles) in the period 2012-2022 (final assessment)

The average share of non-'excellent' sites in Kaštela in the total number of these sites in Croatia is significantly lower than the share of 'poor' sites, both in the final (14.7%) and in the annual (10.2 %) assessment (Fig. 8 and 9). This

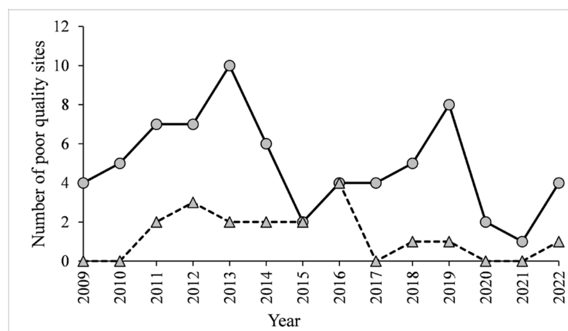

Fig. 7. Number of 'poor' sites in Kaštela (triangles) and Croatia (circles) in the period 2009-2022 (annual assessment)

share of such sites in Croatia fluctuates, while it is relatively stable in Kaštela throughout the study period. The results show that the non - 'excellent' bathing sites in Kaštela, especially the 'poor' ones, significantly affect the total number of these bathing sites in Croatia, considering that the bathing sites in Kaštela represent slightly more than 1% of all bathing sites on the Croatian Adriatic coast. Furthermore, the annual share of exceedances in Kaštela out of the total number of exceedances at all sites in Croatia ranged from 0 to 61%, with an average of 21.5% (Fig. 5). Although the application of the BWD criteria would significantly affect the results of the water quality assessment in Kaštela, as the number of poor waters would decrease by 33% in the annual assessment and by as much as 68%

in the final assessment, this doesn't change the fact that the water quality in Kaštela is still the worst in Croatia. This information is of concern and indicates that, despite all the improvements noted, further efforts are needed to eliminate sources of pollution and improve bathing water management. This is especially important since the quality of bathing water is recognized one of the most important reasons for tourists to choose a tourist destination.

The fact that Kaštela is an interesting tourist destination is also reflected in the number of tourists per season and the hits on the official public website on bathing water quality. The number of tourists in Kaštela is constantly

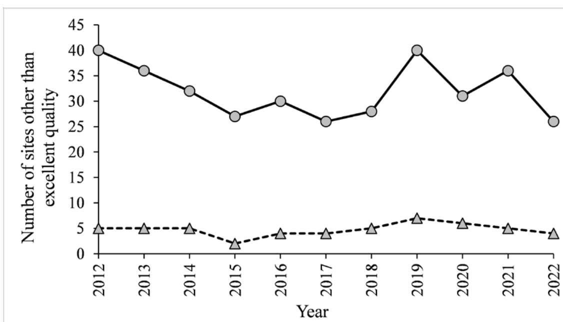

Fig. 8. Number of non-'excellent' sites in Kaštela (triangles) and Croatia (circles) in the period 2012-2022 (final assessment)

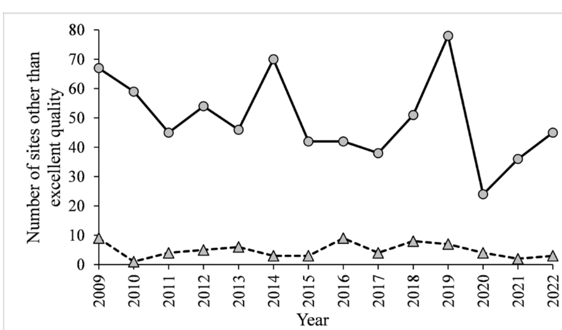

Fig. 9. Number non-'excellent' sites in Kaštela (triangles) and Croatia (circles) in the period 2009-2022 (annual assessment)

increasing and has increased fivefold from 2009 to 2019 (Fig. 10). Due to the pandemic Covid 19, this trend has not continued in 2020, but it is increasing again. The annual average share of tourists in Kaštela in the total number of tourists in Croatia was 0.39%.

The number of hits on the public website is an indirect indicator of interest of tourists in an

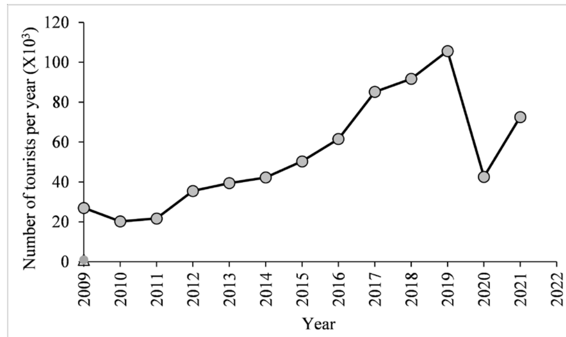

Fig 10. Number of tourists in Kaštela in the period 2009-2022

area. This number for bathing sites in Kaštela is relatively stable and is about 11 thousand per year, with an extreme increase in 2019, the best tourist season in the history of Croatia (Fig. 11).

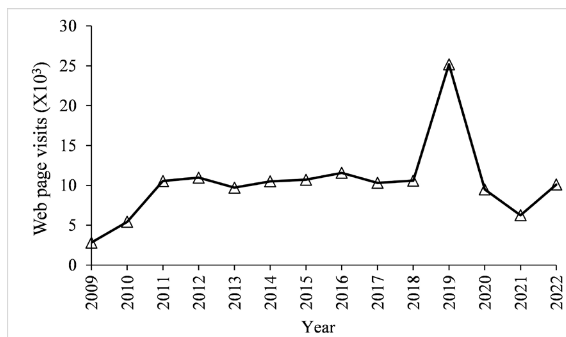

Fig 11. Number of visits of bathing water quality public web page for Kaštela

It accounts for an average of 4.1% of all hits on the public website for all bathing sites in Croatia. The large difference between the share of tourists in Kaštela in the total number of tourists in Croatia and the share of hits on the bathing sites in Kaštela in the total number of hits on all bathing sites in shows that tourists are interested in Kaštela, but this interest does not lead proportionally to a visit to Kaštela. Considering the limited accommodation capacity of Kaštela, one of the reasons is probably the worse quality of bathing water at the bathing sites in Kaštela compared to other destinations in Croatia. Another probable reason is the color of 'poor' quality bathing sites (red) on the map of the public bathing water quality website. Such places are more noticeable and therefore more attractive, which leads to more accesses.

Considering the nature of fecal pollution and relative high number of exceedances and 'poor' water quality sites in Kaštela, we tried to determine the possible relationship between the number the of tourists and bathing water quality. If there are problems with sewage spills, a greater number of tourists generally should result in a greater load on the sewage system and a greater discharge into the marine environment. No correlation was found between the number of tourists and the number of other parameters, exceedances, the number of 'poor' and non-'excellent' sites (p>0.05). This could indicate that the pollution in the identified pollution sources originates from populated areas farther from the coast, where the sewage system is less developed or that the inflow of polluted material is constant, regardless of the load on the sewage system. There is also possibility that continuous improvement of the sewage network compensates for the impact of the ever-increasing number of tourists.

CONCLUSIONS

Bathing water quality at 11 official bathing sites in Kaštela ranged from 'excellent' to 'poor' in the period 2009-2022, depending on the bathing site and bathing season.

The number of sites with poor water quality has been declining since 2017 in the annual assessment and since 2020 in the final assessment, indicating the beginning of a trend toward improving bathing water quality in the area. The quality of bathing waters in the western part of Kaštela was generally better than bathing sites in the eastern part, indicating higher exposure to polluted water from streams or uncontrolled sewage discharges. Although the number of exceedances decreased over the years, the decrease was not statistically significant, but still indicates a slow improvement in water quality

The quality of bathing waters in the Kaštela area has a significant impact on the quality of bathing waters in Croatia. For some identified pollution sources of pollution, recorded FIB levels decreased significantly in 2022, indicating that the completion of the sewage system in some areas brings positive results to the environment.

Despite observed improvements in bathing water quality, the share of 'poor' and non-'excellent' sites in Kaštela in the total number of such sites in Croatia is still high. This shows that additional efforts are needed to eliminate the sources of pollution in the area and to fully complete the wastewater system.

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Kvaliteta mora za kupanje na plažama u Kaštelima (Hrvatska) u razdoblju primjene Direktive o upravljanju kvalitetom vode za kupanje 2006/7/EC

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SAŽETAK

U ovom smo radu analizirali kvalitetu mora za kupanje na 11 službenih plaža u Kaštelima (Hrvatska) u razdoblju 2009.-2022. Rezultati su pokazali prostorne i vremenske varijacije kvalitete. Najlošija kvaliteta mora za kupanje zabilježena je u istočnom dijelu područja, na plažama Torac, Kamp i Gojača. Razine indikatorskih mikroorganizama na utvrđenim izvorima fekalnog onečišćenja u blizini ovih plaža ukazuju na značajno opterećenje fekalnim materijalom u ovim područjima. Iako trend smanjena broja prekoračenja graničnih vrijednosti indikatorskih mikroorganizama tijekom godine nije statistički značajan, ipak upućuje na poboljšanja. Broj lokacija s lošijom godišnjom i konačnom ocjenom pokazuje trend pada tek od 2017. odnosno 2020. godine, što nije dovoljno vremensko razdoblje da bi se moglo jasno zaključiti o trendu. Poboljšanja su vjerojatno rezultat intenzivnog rada na poboljšanju kanalizacijskog sustava na tom području u posljednjih nekoliko godina. U godišnjoj i konačnoj ocjeni, kaštelanske plaže s nezadovoljavajućom kvalitetom mora u prosjeku su činile više od 27% svih plaža nezadovoljavajuće kvalitete u Hrvatskoj. To ukazuje da su potrebni dodatni napori za uklanjanje izvora fekalnog onečišćenja na cijelom području.

Ključne riječi: Kvaliteta vode za kupanje; Kaštela; Hrvatska; Direktive o upravljanju kvalitetom vode za kupanje