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Professional paper

EVALUATION OF SEAWATER QUALITY ALONG THE COASTLINE OF SOUTH ADRIATIC, ALBANIA

Aurora BAKAJ[1], Hajdar KIÇAJ[2], Mariola ISMAILAJ[3], Xhuljana ARAPAJ[4], Kejsi ÇIZMJA[5]

[1] Department of Biology, Faculty of Technical and Natural Sciences, University "Ismail Qemali" of Vlora, Albania*
[2, 3, 4, 5] Department of Biology, Faculty of Technical and Natural Sciences, University "Ismail Qemali" of Vlora, Albania
[*]Corresponding Author: e-mail: aurora.bakaj@univlora.edu.al

Abstract

Coastal tourism has a great role in the Albanian economy. In recent years, there has been an increase in public awareness regarding seawater quality. Beach water quality is affected by a point source (such as sewage outfalls) and a non-point source of contamination (such as stormwater runoff, sand resuspension, animal fecal inputs, and human bather shedding). Contaminated seawater could cause several health consequences for beach users. International regulations usually assess water quality by the quantification of fecal indicator bacteria. This study aimed to evaluate the seawater quality in eight beaches along the Southern Adriatic. *Settings and Design:* The, microbiological and physic-chemical analysis of recreation seawater. Water samples were taken monthly from January to December 2021 in eight stations and eventually distributed on this coastline. *Methods and Material:* Fecal bacteria is determined using MPN techniques and EC media, while physic-chemical parameters were estimated using standard methods. *Results:* High values of coliform bacteria were observed in four sampling stations, beaches classified as: urban, near harbors, and delta river. *Conclusions:* According to the obtained data, monitoring programs have to be focused especially in urban areas and in tourist beach sites. This could enhance microbiological water quality and consequently, beachgoer's safety and touristic beach attractiveness to international visitors.

Keywords: Indicator bacteria, seawater quality, physic-chemical parameters, MPN techniques.

1. Introduction

The tourism sector mainly coastal tourism plays a very important role in the country's economy. Coastal tourism starts in April, culminates in August, and declines in the autumn months. The most important aspects in this sector are safety, facilities, sand, and water quality. Coastal waters in Albania are mainly used for recreational purposes. In recent years, health protection from the risks associated with environmental pollution has become a public concern due to the increase of anthropogenic pressure in these environments.

Water bodies can be affected by different types of physic-chemical and microbiological pollutants, resulting in a low quality of recreational waters. The different sources of pollution, such as industry, agricultural activities, port activities, cleaning plants, etc., have an important influence on the alteration of values. Not to be neglected are other factors such as sewage discharges, the density of the recreational population that uses water in the summer season (excretions or spills), livestock farms (cattle, sheep, etc.), domestic animals as well as wild animals (Elmir et al. 2007; Heaney et al. 2009, 2012; Plano et al. 2011; Hong et al. 2018).

All these factors constitute potential sources in the content of pathogenic, or non-pathogenic microorganisms in recreational waters. Pathogenic organisms can cause infections of the skin, eyes, ears, and nasal cavity (Yau et al., 2009), infections of the upper respiratory tract (Shuval, 2003), gastrointestinal diseases, etc. Often these infections can worsen, making it more difficult to attribute them to exposure to microbiologically polluted recreational waters. However, targeted epidemiological studies have evidenced a series of cases of health diseases (gastrointestinal and respiratory infections) related to the use of recreational waters contaminated with pathogenic microorganisms (viruses, bacteria, parasites) (Prüss, 1998; Zhu et al., 2011).

With the increase in the level of use of coastal waters for recreational purposes, the importance of monitoring different physic-chemical and microbiological parameters of these waters has also increased (Abeygunawardena, 2017; Botero et al., 2015; WHO, 2021). The importance of their quality, especially the microbiological quality, has been improved and continues to be the object of improvement changes by the World Health Organization (World Health Organization, 2021), as well as the European Community through various directives (2006) with measures to protect public health.

The microbiological quality of recreational waters is evaluated based on the degree of contamination from fecal waste. The use of bacteria as an indicator to assess the microbiological quality of surface and underground waters is essential (Graboww 1996; Djuikom et al., 2006) since fecal pollution causes various infections in beach users (Griesel & Jagals 2002; Graboww 1996; Bezuidenhout). et al., 2002; Germs et al., 2004; Lin et al., 2004; Sibanda et al., 2013; Amisah & Nuamah 2014). Fecal pollution is often attributed to waterfowl, and wild and domestic animals (mainly dogs) (Wright et al., 2009; Converse et al., 2012; Goodwin et al., 2016). Bacterial indicators used to determine the degree of water contamination are total coliforms (TC), fecal coliforms (FC), and fecal streptococci (FST) (World Health Organization, 2021; Anon 1976; Sibanda et al., 2013; Evanson & Ambrose 2006). The direct association of fecal indicators with different waterborne pathogens represents the main reason for their use in the evaluation of the general pathogenicity of water. Fecal indicators can survive and grow in different environments such as soil, sediment, beach sand, aquatic plants as well as underwater reefs or near seashores (Field and Samadpour, 2007; Harwood et al., 2014). As a result, there is a need to track different sources of pollution to facilitate the assessment of the health risk and, at the same time, which of the recreational waters.

Fecal indicators show changes in values as a result of the influence of abiotic and biotic factors, which also change depending on the climate. Meteorological factors such as temperature, salinity, humidity, UV light, and turbidity have been shown to limit the stability of bacterial indicators (Fujioka and Byappanahalli 2003, Solic and Krstuvolic 1992; Godwin et al. 2001). Different physic-chemical parameters including pH, biological oxygen demand (BOD), total suspended solids (TSS), and conductivity also affect the quality of recreational waters (Daud et al., 2017; Khan et al., 2021) It has been shown that temperature affects bacterial diversity and growth on beaches, so its change in different seasons is reflected in the characteristics of marine microbial populations (De Roda Husman and Schets 2010). Rainfall also affects the increase in the concentration of fecal indicators in surface waters (Lipp et al. 2001; Garcia-Aljaro et al. 2017, Reischer et al. 2008, Shrestha et al. 2020b, Staley et al. 2018)

This paper's primary goal was to assess the microbiological quality of the seawater at the beaches in the northwest of Vlora Gulf. The measurement of fecal indicators in seawater was done using culture-based techniques. In addition to the microbiological analysis, the physic-chemical parameters and relationships with beach characteristics based on natural and anthropogenic dimensions were also examined. Aspects like beach typology (Williams and Micallef 2009), the presence of facilities, and streams and artificial channels were all taken into consideration.

The outcomes reported here can be contrasted with the requirements set out in international literature, guidelines, and/or beach awards programs (such as the Blue Flag). This report is a preliminary study that can act as a starting point for further investigation in a region with pertinent environmental and degradation issues that are primarily caused by human pressure.

This study's experimental strategy aids in identifying microbiological health risks in a bathing-intensive area that lacks previous surveillance data. For local coastal managers and administrators, the information obtained that links water quality to beach typology and other aspects of human interventions and impacts is especially helpful in identifying coastal sites that require primary attention, such as a thorough monitoring program, and sound management actions, such as the regulation of human interventions, in order to improve safety conditions for beachgoers and beach tourist appeal.

The gathered data and the methodology employed are easily transferable to other coastal regions in Albania or other continents with comparable environments, and as a result, they can be used to optimize monitoring programs that are time-consuming, frequently too expensive, and too complicated for local administrations in developing countries.

2. Material and methods

2.1. Study area: The study area, which is about 27 km in length, is located in the northwest section of Vlora Gulf and spans from Old Beach in the city of Vlora to Seman Beach in the district of Fieri. The Adriatic Sea's southwestern coastline has been continuously changed by deposition of alluvium brought by Vjosa River water and Adriatic Sea swell (Budillon et al., 2011).

The research region has a Mediterranean climate with wet winters and hot, dry summers. The temperature of the sea ranges from 11°C to 27°C. Local climatic variables and general conditions in the Mediterranean Sea affect weather patterns in the Adriatic Sea.

The region experiences light winds and occasional storms until June, while July and August are relatively calm months with frequent thunderstorms. However, it's important to remember that weather patterns can be unpredictable, so it's best to stay up-to-date with the latest forecasts and warnings (climateknowledgeportal.worldbank.org).

Starting in September, the winds in the region become very strong. The sea currents are influenced by several factors including wind, pressure, temperature, and salinity variations. These currents can be either horizontal or vertical. In the Adriatic Sea, the currents flow counterclockwise starting from the Strait of Otranto in the north, then down along the Albanian coast and back up the Italian coast. On average, the speed of the current is around 0.5 knots. The salinity of the Adriatic Sea is on average 38.30 per mill, which means that there are 38.30 grams of salt dissolved in one kilogram of water. However, due to the impact of the Po river, the salinity in the northern part of the Adriatic Sea is slightly lower than in the central and southern parts (climateknowledgeportal.worldbank.org).

The more we leave Vlora city in the northern direction, the more we notice the fading of the existence of services and facilities along the coast. This fact is particularly important since it affects the maintenance of ecological qualities and biodiversity of the area (Kashta 1988; Kashta et al., 2005, 2007). Consequently, the northern portion of the area seems virtually virgin and with a biodiversity of flora and wildlife (Kashta 1988; Kashta et al., 2005, 2007). Consequently, in addition to the attractive environment, the southern section offers more services, facilities, and the lifestyle of a bustling metropolis in the summer season.

The research region is represented by lengthy beaches with a reasonably high usable sand surface. The sand is thin and gritty, rich in iodine. The low portion of the coastline gives the potential for youngsters to play easily on it (Artegiani et al., 1996).

2.2. Sites Characteristics: During sampling, information regarding the properties of the beaches was gathered. The presence of streams/artificial channels outflowing in the area, the presence of beach facilities (bars, restaurants, kiosks, etc.), and beach typology, which was determined using the Bathing Area Registration and Evaluation (BARE) classification system (Williams and Micallef 2009), are also characteristics of the beaches. On an anthropogenic dimension, this method categorizes beaches as distant, rural, village, urban, or resort, considering factors such as environmental conditions, accessibility, habitation/accommodation level, and community services (Williams and Micallef 2009).

The following are the categories identified in this paper: the difficulty of access (typically by boat or on foot—a 300-meter or longer walk) defines remote regions. They have very little summer temporary housing and cannot be accessible by public transportation. During the holidays, a few people who may reside there permanently may occupy a very small number of restaurants and second homes (Williams and Micallef 2009). Rural areas are positioned away from urban and rural areas. They have hardly any facilities and are difficult to access by public transportation. Rural places have a limited supply of housing that is either temporary (during the holiday season) or permanent, but lacks community focal points. Beachgoers prize them for their serenity and natural attributes (Williams and Micallef 2009).

Village areas are located away from the major urban area but are still accessible by public transportation and have a small but permanent population that participates in organized community service. The village setting would also include "tourist villages," which are mostly visited during the summer and winter holidays (Williams and Micallef 2009). Large populations are served by established public services in urban regions. Commercial activities like fishing/boating harbors and marinas are typically situated close to the majority of significant urban regions. Urban beaches are those that are found inside or close to a city (Williams and Micallef 2009).

2.3. Sampling collection: This study was carried out within the time frame of January - December 2021, where the samples were sampled at eight stations along the coastline of the Old Beach - Seman Beach (Figure 1). The study area comprises the southwestern border of the Adriatic Sea and is characterized by mainly sandy relief (Artegiani et al., 1996). The area is characterized by successive beaches mainly populated by tourists in the summer season. This research aims to focus on the quality of recreational waters on the southern beaches of the Adriatic Sea, as well as the examination of the impact of physical-chemical factors on the variation of the values of microbiological indicators. Sampling collection was carried out using the latest methodologies for coastal waters, based on the requirements of the European Community and World Health Organization (ISO 5667-6:2020; ISO 19458:2006). For a better assessment of the quality of the monitored beaches, a hygienic-sanitary examination was carried out to establish the sources of contamination and determine the microbiological load of the water.

Figure 1: Study area zoomed in from Vlora (1) and Beach sampled along the study area (2)
(Source: Google maps modified by Bakaj et al., 2023)

2.4. Hygienic-sanitary inspection:

Station 1 – Seman Beach – located in the region of Fier. It is the farthest beach from the city of Vlore, however, it is accessible by tourists through the roads of the surrounding villages. This beach appears almost devoid of facilities for tourists, as human influence is only visible in the summer season. It is about 3.5 km long and about 2 km wide. The usable sand surface is from 20 m to 150 m. In the western part, it is bordered by the pine forest, with a surface of 1468 hectares.

Station 2 and 3 – Vjosa Estuary – also located in the Fier region, there is a very special coastline which mainly consists of very long sandy beaches. The beach itself is several kilometers long and more than 100 meters wide. This area presents great difficulties in terms of access by tourists, so the human influence is very low. However, there are deposits of waste and inert coming from the rapid flows of the Vjosa River.

Station 4 – Hidrovor Beach – is a narrow coastal strip that separates Narta Lagoon from the Adriatic Sea. It lies north of the Gulf of Vlora on the east coast of the Strait of Otranto, consisting of an alluvial dune. It is located within the boundaries of the Vjosa-Narta Protected Landscape and has been recognized as an important bird and plant area of international importance. This place can be accessed by tourists as well as the low presence of facilities. However, a higher impact in the area is represented by the drainage channel of the area. The water coming from the surrounding hills is collected in this channel, so it is of great importance during floods. This canal also connects the Narta lagoon with the sea.

Station 5 – Dalan beach – Dalani Beach follows immediately after Hidrovor Beach and as such is part of the strip of land that separates the Narta lagoon from the Adriatic Sea. This area is also rich in alluvial dunes. It is easily accessible by tourists and is located very close to the Monastery of Zvernec, which is one of the tourist attractions in the country. Despite the lack of facilities, the proximity to the city, as well as the picturesque landscape make this beach one of the most populated, mainly during the summer period.

Station 6 – Zverneci beach – This beach lies near the small village of Narta, it is a sandy beach. This beach can be reached very easily by car. In this area, the influence of man begins to be felt through the various bars and restaurants that operate in the country. The beach is several kilometers long and, in some places, even more than 100 meters wide. The slope of the beach is very low, it is almost flat. Proximity to the city, easy access, the presence of facilities, the presence of dunes, as well as the low part of the sea make this beach highly sought after by family tourists.

Station 7 – Triport, Zvernec – The area of Triport in Zvrnec of Vlora is a small functional fishing port. This port forms the southern border of Zvernec Beach. As an area, it is one of the earliest settlements in the country. According to specialists, traces belonging to several periods from the Middle Paleolithic to the Bronze Age have been found in it.

Station 8 – Old beach – the beaches taken in the study constitute the beach closest to the city. This beach in the northern part is limited by the "Motor Canal" while in the southern part by the city port. The "Motor Canal" is located near the city's water reservoir. This canal discharges sewage from the city's reservoir to the Adriatic Sea. The situation in this area is critical, since in addition to the engine channel that discharges black water into the sea, four small black water channels have also been identified. For many years, no project has been undertaken for the rehabilitation of these canals. Sewage channels are a high source of infection as they are open, dirty, and at the same time a breeding ground for insects, especially mosquitoes. The old beach, located on the outskirts of the city of Vlora, is rich in facilities, as well as bars and restaurants that operate throughout the year, it is very populated, mainly in the summer season.

Table 1: *Geographic coordinates of sampling stations evaluated with GPS device.*

Station	Name	Altitude	Longitude	Stream/ Channel	Beach Facilities	Beach Topology
1.	Seman beach	40.6733824	19’ 3281339	Absence	Presence	Rural
2.	Vjosa estuary	40.6655847	19.3164777	Absence	Absence	Remote
3.	Vjosa estuary	40.6447500	19.3170296	Absence	Absence	Remote
4.	Hidrovor beach	40.5628816	19.3740953	Presence	Presence	Rural
5.	Dalan beach	40.5360602	19.3791177	Absence	Absence	Rural
6.	Zverneci beach	40.5268943	19.3877142	Presence	Presence	Village
7.	Triport, Zvernec	40.4862196	19.4359691	Presence	Presence	Village
8.	Old beach	40.4531020	19.4789036	Presence	Presence	Urban

*(**Source:** Data by Bakaj et al., 2023)*

2.5. Physic – Chemical Analysis: Researchers of this study conducted a microbiological and physical-chemical analysis of seawater regarding the approved method of APHA-AWWA-WEF and Directive 2000/60/EC of the European Parliament and Council (APHA-AWWA-WEF 2005; Council Decision 77/795/EEC).
A total of 9 physicochemical parameters, which include pH, water temperature (T-°C), electrical conductivity (EC-ms/cm), salinity (Sal-PSU), oxidation-conduction potential (ORP- mV), total dissolved solids (TDS-g/l), specific gravity of seawater (SSG – σt), dissolved oxygen (DO - %) and dissolved oxygen (DO – mg/l), from

surface water systems were used for this study. A thermometer was installed at a depth of 10 cm to take the water temperature in situ. The other parameter was measured by employing water probe AQUAREAD 2000. Selecting these characteristics for predicting bacterial contamination was based on numerous factors such as prior understanding of the correlations of explanatory variables to coliform bacteria and prior knowledge in the literature of factors influencing microbiological organisms. Certain factors were also picked according to their availability and relevance. Total and fecal coliforms represented the key variables in this investigation.

2.6. Microbiological analysis: Water samples were collected for microbiological examination following the recommendations given by the World Health Organization's "Water quality - sampling for microbiological analysis" (ISO 5667-6:2020 and ISO 19458:2006). The samples were taken from the top layer of water (10-30 cm) at each station, using sterile 500 ml bottles to guarantee that the samples were not contaminated with microorganisms from the environment or the containers. The samples at the moment of reception were placed in a cooler box and transferred within 2 hours to the laboratory and were evaluated on the same day they were received (ISO 5667–5:1991). These standardized techniques should assist in ensuring that the data acquired from the bacteriological analyses are accurate and dependable.

The microbiological analysis was carried out in the Laboratory of Microbiology at the Faculty of Technical and Natural Sciences, University “Ismail Qemali” of Vlora. The sample and the tests were performed in compliance with the International Standard Methods (ISO 1991; CEC 1978; WHO 1984; ISO 1999; UNECE 1994; Camper et al. 1996). MPN index was utilized for the evaluation of total coliform and fecal coliform in water. Total and. fecal coliform was evaluated by MPN techniques and EC media in a combination of 3 tubes (Bakaj et al., 2017; Bakaj et al., 2022). MPN index was determined using the MPN statistics tables and is reported as the number of organisms per 100 ml (MPN/100 ml).

2.7. Statistical analysis: SPSS version 23.0 (SPSS IMB) was used to conduct the statistical analysis. To ascertain if the sample size or date had an impact on the median values of the indicator species, the Kruskal-Wallis test was utilized. A correlation analysis was done between the water's temperature, salinity, pH, sample time, and the presence of microbiological factors. One-way ANOVA was used to compare the microbial contamination of particular indices across several sampling sites. The correlation between variables was also determined using the Pearson correlation test. Any probability of 0.05 or less was regarded as significant. Every sample that had bacterial counts higher than those allowed by the EU Directive was referred to as a "fecally polluted sample" (Anon 1976).

The study aimed to enhance the precision of annual trends and ensure a consistent sample size by analyzing seasonal fluctuations in bacterial populations and environmental factors across different station locations. Mean values for each month were used to assess seasonal variability. Additionally, box plots were created to compare FC distribution among different beach types and amenities. The water samples from each beach were analyzed to describe their microbiological and physicochemical properties.

3. Results and Discussion

Beaches are coastal environments that are significantly impacted by humans, primarily as a result of the expansion of tourism (Botero et al., 2013). Beachgoers have emphasized five factors while selecting a beach for recreational activities: safety, facilities, water quality, lack of litter, and landscape (Williams et al., 2009;

Milanés et al., 2019). According to Milanés et al. (2019), this metric for water quality covers both visible and invisible elements like turbidity, algae, etc.
The area under investigation has a shoreline that is about 27 km long and is located in the southern Adriatic Sea. The examination of microbiological parameters and their relationships to beach typology and characteristics, such as the presence or lack of beach facilities and streams or channels exiting the beach, was done.

3.1. Beach Characteristics: The study classified beaches based on their typology, with 12.5% considered urban, 37.5% rural, 25% village, and 25% remote (according to Table 1). Urban beaches are found near the city of Vlora in the southern part of the study area, and they have good access roads and many amenities such as restaurants, bars, kiosks, and toilets. However, some of them also have streams that discharge dark and unpleasant-smelling water onto the beach, likely due to the illegal dumping of wastewater from natural freshwater sources. Although water samples were not taken specifically at these streams, they appear to be continuous flows. Rural beaches, situated in the northern and central parts of the study area, are distant from major urban areas and often lack amenities. Streams that discharge wastewater are frequently observed in this area. The village and remote beaches located in the Vjos-Narta protected region have limited tourist arrivals because they are far away from urban centers. These beaches do not have any facilities, and no streams were observed in this area.

3.2. Microbial analysis results: 96 samples were examined microbiologically in the current investigation. Table 2 provides the average and standard deviation for each sampling location as well as the frequency of indicator bacteria expressed as MPN/100 ml.

Table 2: All sampling stations' descriptive statistics (MPN 100 ml^{-1}) are listed in the table

Statistics

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8
N Valid	12	12	12	12	12	12	12	12
Mean	71.083	148.333	345.750	433.333	47.267	38.150	363.433	874.033
Median	43.000	120.000	375.000	290.000	15.000	11.000	210.000	460.000
Mode	43.0	15.0	460.0	210.0[a]	3.0	3.0	210.0[a]	460.0
Std. Deviation	73.2585	145.8725	298.7292	330.3533	70.7211	71.2853	383.3846	964.2641
Variance	5366.811	21278.788	89239.114	109133.333	5001.479	5081.594	146983.744	929805.279
Skewness	2.860	.871	1.388	1.572	2.181	2.563	1.248	1.019
Kurtosis	8.626	.076	2.944	1.437	4.971	6.421	.640	-.748
Minimum	20.0	15.0	43.0	120.0	3.0	3.0	9.2	9.2
Maximum	290.0	460.0	1100.0	1100.0	240.0	240.0	1100.0	2400.0

a. Multiple modes exist. The smallest value is shown

*(**Source**: Data by Bakaj et al., 2023)*

The Beaches 1, 2, 5, and 6 of the research area (Figure 1) showed the lowest FC counts with mean values between 38 and 148 MPN/100 ml, indicating that they are in good condition in terms of the total coliform, according to the findings of the microbiological water tests at the analyzed stations. The greatest FC counts were found at beaches 3, 4, 7, and 8 (Figure 1, 2A), with mean values ranging from 345 to 874 MPN/100 ml. The indicator microorganisms at the investigated sites were compared to established standards (Figure 2A).

At different months during the research year, it was observed that the total coliforms at stations 3, 4, 7, and 8 (Figure 1, 2A, B) were higher than the WHO and EEC standards. At the Old Beach Station, the maximum measurement for total coliforms was 2400 MPN/100 ml. Stations 6, 5, and 1 have the lowest rates of fecal coliforms, respectively (Table 1, 2A).

We may infer from the boxplots of microbiological distribution by beach typology (Figure 3A) and the presence or absence of beach facilities (Figure 3B) that fecal contamination is more common in urban and remote stations than in rural and village areas. According to their typology, microbiological parameters, and the existence of beach facilities and streams, the beaches that were analyzed could be divided into four groups according to cluster analysis (Table 1). Except Hidrovori station (Station 4 Figure 1), beaches in Cluster 1 (Rural 1, 4, and 5) generally displayed low values of microbial indicators. The beach that divides the Adriatic Sea from Narta Lagoon is represented by this station. The FC values at this station are consistent with the greater influence of the drainage channel evidenced also in the findings from other research (Bakaj et al., 2022). We can see that the springtime is when fecal pollution is at its highest levels if we compare the FC values of this station over the several seasons (Table 3, Figure 2B, Figure 3A and B).

To explain the favorable reaction of sand-dwelling FIB to rainfall, several ideas that are not mutually exclusive might be advanced: In response to increasing moisture, bacteria may either (1) be transported from the watershed to the sand by rainfall, (2) be revived from a viable but non-cultivable state, or (3) reproduce (Beversdorf et al. 2007; Whitman and Nevers 2003; Zehms et al. 2008).

Table 3: All sampling months' descriptive statistics (MPN 100 ml^{-1}) are listed in the table

Statistics

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
January	8	43.650	68.8892	24.3560	-13.943	101.243	3.0	210.0
February	8	43.650	68.8892	24.3560	-13.943	101.243	3.0	210.0
March	8	205.525	393.8770	139.2565	-123.764	534.814	3.0	1100.0
April	8	67.200	94.1171	33.2754	-11.484	145.884	3.6	290.0
May	8	116.425	166.5336	58.8785	-22.801	255.651	9.2	460.0
June	8	394.500	823.2908	291.0772	-293.788	1082.788	14.0	2400.0
July	8	902.375	1031.2016	364.5848	40.269	1764.481	27.0	2400.0
August	8	938.375	998.7669	353.1174	103.385	1773.365	27.0	2400.0
September	8	181.075	172.3919	60.9497	36.952	325.198	3.6	460.0
October	8	84.325	106.8365	37.7724	-4.993	173.643	3.6	290.0
November	8	74.400	156.5593	55.3521	-56.487	205.287	3.0	460.0
December	8	74.175	156.6647	55.3893	-56.800	205.150	3.0	460.0
Total	96	260.473	565.8883	57.7557	145.813	375.133	3.0	2400.0

Beaches in cluster 2 (Remote S2 and S3) generally had low values for microbial indicators in terms of microbiological factors, except spring. These stations indicate beaches with poor amenities and limited accessibility, even though we see a negative impact on the water quality. The Vjosa River estuary is the cause of the elevated value of FC in these stations, particularly in the spring. Due to increased runoff from the rainy season and snowmelt, the Vjosa River has stronger flows in the spring.

Sand's moisture content varies greatly depending on the beach's location, the size of the grains, and the distance from the water table. Water can be found in pore water the gaps between sand grains in beach sand. According to several studies, the moisture content of foreshore sand closest to the water typically ranges between 12 and

25% (Alm et al. 2003; Beversdorf et al. 2007; Ishii et al. 2008, 2010; Sampson et al. 2006; Whitman and Nevers 2003).

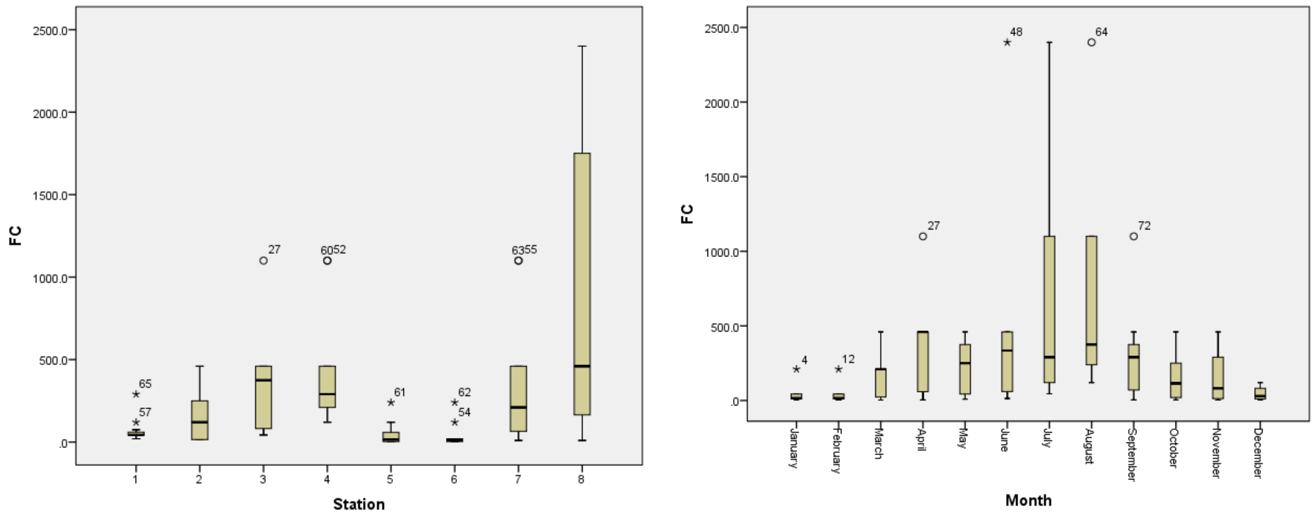

Figure 2: Box plot of microbial distribution in different sampling stations (A) and in different months (B), (**Source**: Data by Bakaj et al., 2023)

Only station 6 Zvernec beach from Cluster 3 (Village 6 and 7) and Cluster 4 (Urban 8) beaches are represented in terms of microbiological criteria with high water quality. The inlet receives raw urban sewage from the surrounding residential settlement, which flows into the ocean.

The city's greatest inlet, which transports wastewater treatment plant effluent to sea, has an impact on the Triporti station and Old Beach station

(Figure 1) in the area. The high rate of pollution entering the sea is brought on by the wastewater treatment plant's improper operation.

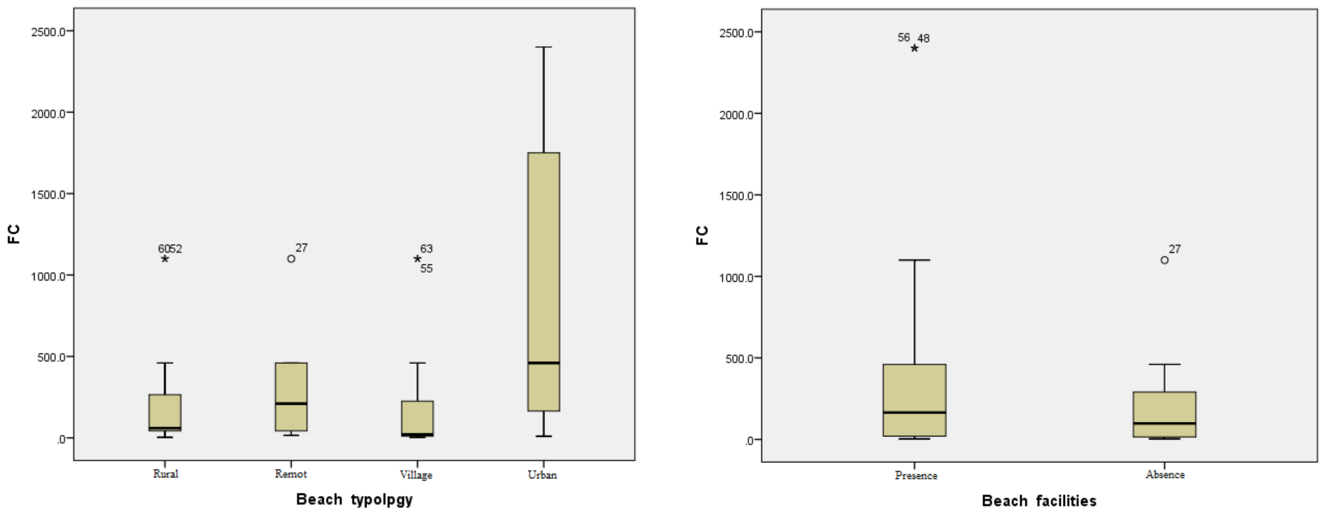

Figure 3: Box plot of microbial distribution according to beach typology (A) and according to presence or absence of beach facilities (B), (**Source**: Data by Bakaj et al., 2023)

The Old Beach Station also has substantial pollutant loads due to surface runoff from nearby residential structures that are close to the water. Because locals frequently go fishing in these areas, they clean and sell their catch on the beach, which has a negative impact on the seaport, and because in most cases, waste is dumped on the beach, which results in the presence of stray dogs. These stations both showed the highest values of FC (Table 2, Figure 2A, B).

Since all of these circumstances contributed to the stations being the most contaminated in terms of microbiological indicators, Triporti and Old Beach stations had the highest levels of the measured indicators during the summer among all the other stations. Both of these stations met the requirements for good service according to the cluster study; Triporti Beach is in Cluster 3 (Village), while Old Beach is in Cluster 4 (Urban). Naturally, microbial contamination rises in the summer as more people use coastal waters for swimming and other activities. Old Beach's water depths are less than those at other sample locations, making it a riskier location for children to swim in the case of water contamination.

The results of the ANOVA test indicated that the microbiological indices at the chosen sampling stations differed significantly from one another. The three indices of total coliforms (P-value = 0.001) and fecal coliforms (P-value = 0.005) showed that this difference was significant. The distribution of microbiological parameters and beach features also showed a correlation between FC counts and beach typology, as determined by the Kruskal-Wallis rank test (p-value 0.006).

3.3. Physicochemical analysis results: The physicochemical examination of 96 samples was conducted. Table 4 displays the overall findings of the analysis performed over a 12-month sampling period. The springtime coastal water temperature ranges from 15.5°C in April to 29°C in August.

Table 4: All sampling stations' descriptive statistics of physic-chemical variables are listed in the table

Statistics

		FC	T	pH	DO	TDS	Salinity	ORP	EC	SSG
N	Valid	96	96	96	96	96	96	96	96	96
	Missing	0	0	0	0	0	0	0	0	0
Mean		260.473	18.316	7.154	92.235	32.378	32.461	190.511	49.921	23.940
Median		43.000	16.000	7.180	91.900	32.930	33.000	220.850	50.400	24.500
Mode		43.0	15.5	6.9	85.5[a]	31.6[a]	33.0[a]	235.0[a]	48.7[a]	24.6
Std. Deviation		565.8883	4.5290	.2454	3.4134	1.3423	2.2615	61.6559	2.0038	1.2477
Variance		320229.574	20.512	.060	11.651	1.802	5.114	3801.452	4.015	1.557
Skewness		3.031	1.155	-.379	-.403	-1.793	-2.411	-1.282	-2.274	-2.124
Kurtosis		8.654	-.017	1.928	-.192	3.768	6.445	-.099	6.005	4.770
Sum		25005.4	1758.3	686.8	8854.6	3108.3	3116.3	18289.1	4792.4	2298.2

a. Multiple modes exist. The smallest value is shown

*(**Source**: Data by Bakaj et al., 2023)*

The multivariate association between fecal coliform and physicochemical concentrations in seawater is shown in Table 4 by a nested model. At both the bivariate and multivariate levels, total suspended solids were statistically significant predictors of fecal coliform in marine water.

In addition to providing nutrients for coliform bacteria, suspended solids shield them from harmful elements such as metal toxicity, UV radiation, and predators (An et al., 2002; Medema et al., 2003). This helps coliform bacteria survive (Pachepsky and Shelton, 2011). This suggested that greater suspended particles and pH levels in surface waters would indicate a lack of fecal coliform contamination.

Table 5: Table of sea water data Pearson product moment correlation coefficients

FC	1							
T	.577**	1						
pH	.388**	.397**	1					
ORP	-.547**	-.913**	-.494**	1				
DO %	.256**	.474**	.663**	-.603**	1			
DO mg/l	-.328**	-.661**	-.261**	.531**	-.089	1		
EC ms/cm	-.315**	-.387**	.066	.434**	.109	.003	1	
TDS g/l	-.216*	-.219*	.001	.338**	.044	-.035	.795**	1

Salinity PSU	-.528**	-.520**	-.307**	.546**	-.289**	.168	.582**	.380**	1	
SSG	-.459**	-.606**	-.194*	.635**	-.132	.266**	.911**	.755**	.622**	1
	FC	T	pH	ORP	DO	DO	EC	TDS	Salinity	SSG
**. Correlation is significant at the 0.01 level (1-tailed).										
*. Correlation is significant at the 0.05 level (1-tailed).										

*(**Sourc**e: Data by Bakaj et al., 2023)*

The survival of fecal coliform bacteria in water is also known to be impacted by pH. According to Pearson et al. (1987), feces coliforms perished more quickly when pH levels were raised above 8.50, even in nutrient-rich settings, indicating the importance of pH for fecal coliform survival in water systems. Fecal coliform distribution and concentration are also influenced by tropical climates (Kagalou et al., 2002) and, to a lesser extent, by the physicochemical properties of the water (Hong et al., 2010).

Salinity and metal toxicity are two elements that have an impact on fecal coliform's ability to survive (Chigbu et al., 2005; Pachepsky and Shelton, 2011). Coliform bacteria typically have a lower survival rate in saline environments. Since salt is frequently dissolved from rocks and minerals in groundwater, it is predicted that saline water will contain dissolved salts. Total dissolved solids may act as a mediator in the association between electrical conductivity and fecal coliform because electrical conductivity depends on the presence of soluble salts in water.

The intricate interplay between biological, physical, and chemical components has an impact on the number of coliform bacteria in water. Distinct aquatic ecosystems have distinct controls over these interactions. The survival and concentration of fecal coliform in surface water can be influenced by various environmental factors such as water temperature, rainfall, tidal conditions, solar radiation, dissolved nutrients, competition with other bacteria, and physicochemical conditions. Studies conducted by Kagalou et al. (2002), Hong et al. (2010), Chigbu et al. (2005, 2004), Pachepsky and Shelton (2011), and Soo et al. (2016) have shown that physical and climatic factors play a significant role in affecting the behavior and growth of this bacteria in surface water.

4. Conclusions

The microbiological quality of the waters along the southern Adriatic coast was evaluated in this study. Based on anthropogenic and natural factors, such as the presence of streams, beach amenities, and beach typology, it was associated with beach features. The assessment was made based on anthropogenic and natural factors, such as the presence of streams, beach amenities, and beach typology and beach features.

Consequently, four groups could be created from the beaches that were studied. For local coastal managers and administrators to create effective monitoring and management actions at each location according to beach typology and local human activity production, this information is of greatest significance.

It should be highlighted that the beaches with the lowest ratings were those that were close to towns and beaches with facilities; therefore, greater attention must be paid in the future to those places to maintain and improve their water quality and build reliable monitoring mechanisms.

All prior findings demonstrated the necessity of putting strategies and regulations in place that support improving beach water quality and more environmentally friendly tourism. Urban regions and sites with beach facilities need to be checked more closely than rural areas since monitoring and water analysis are time- and money-consuming, compared to low- or nonexistent microbiological load areas.
In terms of beach amenities, bars and restaurants situated right on the sand frequently lack restrooms or other such amenities, and those that do often lack sewage system connections, causing effluent to flow directly into the sea. Characterizing stream discharges, which appear to be a source of contamination due to the illegal dumping of wastewater, must also receive special attention. Appropriate wastewater treatment must be developed and improved by local administrations.

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