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Are aquatic life sustainable with current policies? Microbial pollution in swimming seasons: A 12-year retrospective study on the bathing waters of Sinop, Turkey

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The study aimed to examine the characteristics of the beaches of Sinop Province, monitor the faecal pollution trend in the years 2011 – 2022, examine its causes, comparison with studies conducted in Turkey, awareness of people regarding pollution in the seas, and the compatibility of the classification system of the Ministry of Health with the WHO. A total of 2503 samples collected from 29 beaches in Sinop Province during the years 2011 – 2022 were evaluated. Descriptive statistics like Mann-Whitney U and Kruskal-Wallis tests were used to summarize the data and concordance analyses was used to compare the groups. The highest microbial pollution in beach water was observed in 2020. When the source of pollution was examined for the cause, the most evident (40.0 %) was "pollution from wild animals". When the microbial quality assessment of the World Health Organization for recreational waters and the assessment of the Ministry of Health were examined, it was found that there was a low-medium level of agreement. In some beaches of Sinop Province, certain indicators of bacteriological pollution have reached poor levels within twenty four day period from 2011 to 2022. In the follow-up of bathing waters, classification and measurements should be based on differences between provinces, prioritizing public health.

[**Keywords**: Bathing beaches, Beach pollution, Faecal indicator bacteria, Health risk, Recreational water, Water quality]

Introduction

Bathing water is used to describe streams, lakes, dams, and seawater where swimming is permitted or where a large number of people swim[1]. Recreational water refers to water where a person comes into direct contact with water, such as boating, fishing, surfing, bathing, diving, and other water sports-related activities[2]. Recreational water is more inclusive than bathing water. However, people engage in many recreational activities while bathing in water without being aware of this distinction. Performing various activities in recreational waters that meet microbiological quality criteria positively affects the health and well-being of people[3-7]. The best way to protect, develop, and improve public health and ensure its sustainability in aquatic life is to adopt a common understanding of the classification system of bathing waters, implement policies to improve water quality, have a strict framework, and ensure regular monitoring and inspections.

In the Anthropocene era, the increase in human activities and the noticeable effects of climate change, especially in the summer, brought the problem of pollution on many beaches and waters to the agenda. Moreover, public health is adversely affected by a lack of infrastructure in cities, inability to properly remove wastewater, lack of a national recreational/ bathing water framework, poor management of popular beaches, flexible classifications, and inadequate inspections. If people swim in unhealthy waters, engage in various activities, and accidentally swallow water, they are at the risk of developing diseases, such as acute gastrointestinal diseases, acute febrile respiratory diseases, eye-ear infections, and diarrhoea[2,3]. This is an important public health problem because recreational water is used by the majority of society, and the health of the affected people is at risk[4]. To carry out such activities in a healthy and safe manner and ensure continuity of income from the tourism sector[5], countries such as Turkey need to make more efforts to adapt to the national recreational water framework.

Faecal Indicator Bacteria (FIB), such as total coliform, faecal *Streptococcus*, and intestinal enteroccoci, are

generally used to evaluate the microbiological quality criteria of the recreational waters[6]. There is no consensus on the diversity and limit values of these indicators[6-8], which vary by country. While the World Health Organization (WHO) and the United States Environmental Protection Agency (US EPA) recommend intestinal enteroccoci for monitoring the recreational waters[2,6], emphasize regular monitoring of recreational waters, taking measures to reduce pollution, and communicating to the public about health risks in a timely manner[9]. Due to the fact that sanitation infrastructure and human activities can affect FIBs[10], great importance should be given to more frequent monitoring of bathing water; especially in tourism places that the infrastructure facilities of the relevant places are sufficient and strong.

Sinop is very popular in terms of sea tourism in the Black Sea region, it welcomes visitors almost five times the city's population every year in the summer[11]. The fishing industry is developed in the Sinop Province, and aquaculture activities can also affect coastal pollution. In addition, the sewerage system within the borders of the Sinop municipality provides services at approximately 90 %, with septic tanks in the remaining parts. It is still awaited to establish a sewerage system in some villages that have not yet attained the status of a neighborhood but are located within the adjacent areas of the municipality. It is still awaited to establish a sewerage system in some villages that have not yet attained the status of a neighborhood, but are located within the adjacent areas of the municipality. Three treatment plants in the Sinop center are still under construction and not in operation. There is one deep-sea discharge facility in Ayancik district, but it was damaged in the flood disaster of 11/08/2021, and its repair works are continuing. Therefore, domestic wastewater in Sinop is treated and discharged to the receiving environments, such as seas and rivers, at a rate of 70 %. According to a study conducted by the Turkish Statistical Institute, an average of 26,00,000 m^3 of domestic wastewater has been discharged into the sea, and 18,00,000 m^3 into the streams annually since 1994 in the Sinop Province[12]. In addition, Sinop Province has the highest proportion of the elderly population in Turkey[13]. In this city, where human mobility increases in summer and there is no actively developed treatment facility, it is aimed to examine the beaches of Sinop Province for the above reasons. Since almost all of the studies carried out in Turkey since 2007 have focused on the Aegean, Mediterranean, and Eastern Black Sea region[14-23], there are limited studies on Sinop, which is located in the Western Black Sea region. In addition, no epidemiological studies have examined the trend of FIB pollution in the bathing waters. In this planned study, in Sinop Province: (i) defining the characteristics of the beaches of Sinop Province, (ii) monitoring the trend in FIB pollution indicators over the years, (iii) determining the causes of FIB pollution, (iv) comparing the FIB pollution status with previous studies, (v) examining the awareness of the people in Sinop regarding pollution in the bathing water, and (vi) examining the compatibility of the bathing water classification system in Turkey with the WHO were evaluated.

Material and Methods

Study sites and data

Sinop Province is located between 41°12' and 42°06' N and 34°14' and 35°26' E coordinates on Boztepe Cape and its peninsula, and 175 km of its 475 km long borders are on the sea[24]. Located at the northernmost tip of Turkey, Sinop has numerous promontory, bays and gulfs (İçliman, Dışliman, Akliman and Hamsilos bays) and protected ports (Gerze, Sinop inner and outer ports, Akliman, Sarıkum and Ayancık ports)[16]. Sea tourism is lively in the summer months because of its natural beauty, hosting the most reliable bathing waters in the Black Sea region and shallow beaches.

In this descriptive-retrospective epidemiological study, data obtained from the Republic of Turkey, The Ministry of Health General Directorate of Public Health and the Sinop Governorate Provincial Directorate of Environment, Urbanization, and Climate Change were used in this study. The study population was from a public beach in Sinop Province. In the province of Sinop, the districts of Ayancık, Türkeli, and Gerze, especially in the centre of Sinop, have coastlines. Bathing water was analyzed at regular intervals during the bathing season in the coastal areas of Turkey by the General Directorate of Public Health of the Ministry of Health of the Republic of Turkey. The bathing water analysis results were based on FIB monitoring data collected from routine beach monitoring stations.

In addition to the data used in the study, all information related to the lengths of Sinop province's beaches, sea floor, and beach structure was obtained from the website of the Ministry of Health of the

Fig. 1 — Sampling points in Sinop Province

Table 1 — Bathing water quality classification and analysis methods, Turkey

Years	Parameters	Guideline values (cfu/100 ml)	Mandatory values (cfu/100 ml)		Method of analysis and inspection
2006–2015[ref. 26]	TC	1.000	10.000		Membrane filtration method
	FC	200	2.000		
	FS	100	1.000		
2015–2019[a ref. 31]	TC	500	10.000		
	FC	100	2.000		
	FS	100	1.000		
		Good[b]	Moderate[b]	Poor[c]	
2020–2022[ref. 1]	IE	≤100	101-369	≥370	ISO 7899-1 or ISO 7899-2
	E. coli	≤100	101-999	≥1000	ISO 9308-3 or ISO 9308-1

Abbreviations: TC = Total Coliform, FC = Faecal Coliform, FS = Faecal *Streptococcus*, IE = Intestinal Enteroccoci. Note: Bathing water quality evaluation criteria were included during the season for the years 2020 – 2022. [a] - Provisional Article 1: 10 years after the entry into force of this regulation; the value of 1000/100 ml for TC is 500/100 ml and for FC 200/100 ml is applied as 100/100 ml; [b] - Based on 95 % evaluation; and [c] - Based on 90 % evaluation

Republic of Turkey[25]. The number of samples in each province varied depending on the bathing season. The bathing season in Sinop is between June 15 and September 15. The sampling frequency was determined to be at least seven, except for an extraordinary situation that threatens public health.

A total of 29 beaches, which are frequently used by the public in Sinop Province, were selected as sampling points by the Ministry of Health, Sinop General Directorate of Public Health. These sampling points were marked on the map according to the district (Fig. 1).

These sample points were distributed as 14 beaches in the Sinop centre, three beaches in Türkeli, and six beaches each in the Ayancık and Gerze districts (Table 1). Recreational water quality indicators for beaches in Sinop Province, covering the bathing seasons of 2011 – 2022, were individually extracted from the Health Ministry System and transferred to Excel. Cross-checks were performed to avoid confusion during the data transfer of microbiological analysis results of 2520 samples collected during bathing seasons on these beaches. In some of the analysis results, 17 datasets were excluded from the

analysis for reasons such as duplicate measurements on the same day, including different values, and not sharing the daily sample results. In addition, because the monitoring of bathing water on some beaches started after 2011, 2503 data results were used.

The number of complaints made by people in Sinop to the authorized units regarding the pollution in the seas was received by official correspondence on 14/10/2022 from the Sinop Governorate Provincial Directorate of Environment, Urbanization and Climate Change. The Republic of Turkey Sinop Governorate, Provincial Directorate of Environment, Urbanization, and Climate Change have the authority to evaluate incoming complaints and issue warnings or administrative fines to institutions that cause pollution, when necessary in accordance with relevant regulations is not found.

Sampling procedure

Samples in the years 2011 – 2019 were collected in sterile brown neutral glass bottles, preferably 30 cm below the water surface, from locations where the average daily number of swimmers was the highest. Sterile samples are collected in amber-neutral glass bottles, with a volume of at least 350 – 450 ml. The bottle mouths are sealed with stoppers of sterile glass, rubber, etc. The samples were kept in the thermo-isolated boxes with cooling moulds at +4 °C and delivered to the laboratory within 24 h. Analyses of the samples delivered to the laboratory were performed on the same day[26].

Samples for the years 2020 – 2022 were taken from the water at a depth of at least 1 m at the sampling points and 30 cm below the water surface using sterile containers made of transparent and colourless materials, such as glass, polyethylene, or propylene. The mouth of the bottle with a sampling capacity of at least 250 ml was dipped at the sampling depth, with the mouth part down and the mouth part turned upward at the sampling depth. Various precautions have been taken to protect samples from exposure to direct sunlight during transportation and prevent contamination. In case of more than 4 h delivery time to the laboratory, the samples were stored in a heat-proof/thermo-isolated container or cooler at 4±3 °C. Samples delivered to the laboratory were preferably analyzed on the day they were taken[1].

Faecal pollutants were analyzed using the membrane filter method from 2011 – 2019(ref. 26). In 2020 – 2022, in accordance with the regulations, ISO 7899-1/ISO 7899-2 analysis methods were used for the determination of intestinal enteroccoci and ISO 9308-3/ ISO 9308-1 analysis methods were used for the determination of *Escherichia coli*[1].

Regulatory framework

There are two bathing water regulations in Turkey issued in 2006 and 2019. The information contained in the "Bathing Water Quality Regulation" dated 09/01/2006 and numbered 26048 and the "Regulation on the Management of Bathing Water Quality" dated 25/09/2019 and numbered 30899 were examined[1,26]. Although there were some changes in the regulations, classification is emphasized here. Until 2019, total coliform, faecal coliform, and faecal *Streptococcus* were considered as microbiological parameters in bathing water[26]. Since 2019, the equivalent of faecal coliform, *E. coli* and the equivalent of faecal *Streptococcus*, intestinal enteroccoci have been followed[1]. The guideline values for faecal contaminants have decreased over the years (Table 1).

Within the framework of harmonization with the European Union acquis, Turkey published Regulation on the Management of Bathing Water Quality No. 30899 in the Official Gazette in 2019. This regulation was prepared by considering the Directive of the European Parliament and the Council on the Management of Bathing Water Quality No. 2006/7/EC. In the regulations, different approaches were presented for evaluating the bathing season. First, evaluation of bathing water quality can also be performed based on datasets collected during only three bathing seasons. Second, bathing water can be classified as poor, adequate, good, or excellent at the end of the bathing season using the bathing water dataset collected for each bathing season, together with the previous three bathing seasons. The parameters and standards related to bathing water quality in Turkey comply with the European Union Bathing Water Directive (2006/7/EC). According to the requirements of this published regulation, the first classification will be made after September 2023(ref. 1). In addition, the regulation states that the criteria in Table 1 will be considered in the evaluation during the season.

Statistical analyses

Statistical analyses were performed using the SPSS software version 23 (IBM Corp., Armonk, NY, USA). The conformity of the bacteriological analysis results to the normal distribution was examined using visual (histograms and probability plots) and analytical

methods (Kolmogorov-Smirnov/Shapiro-Wilk's test). Homogeneity of variances was checked using the Levene's test. Descriptive statistics such as numbers and percentages were used to summarize the data. Descriptive analyses were presented as means and standard deviations (min – max values) for normally distributed variables and median (interquartile range) for non-normally distributed variables. Bacterial numbers and distribution did not meet the criteria for normal distribution. Therefore, unless mentioned otherwise, the median, interquartile range (Q1-Q3 range), and minimum-maximum values were used to summarize faecal contaminants. The data were reviewed by updating the mandatory guideline values following changes in bathing water quality regulations over the years. The Kruskal–Wallis test was used to compare FIB distributions among the Sinop districts. Pairwise comparisons were made using the Mann-Whitney U test and evaluated using Bonferroni correction. Kendall's Tau_c analysis was performed to examine the compatibility of the WHO recreational water classification system and the Ministry of Health of the Republic of Turkey.

Results

Characteristics of Sinop beaches

In Sinop Province, coastal areas are at the centre of the Sinop, Ayancik, Gerze, and Türkeli districts. The beach width is C_5, with a minimum of 4 m, and C_{10} beach, with a maximum of 100 m width. The maximum number of swimmers on the Sinop beaches was 40 on C_{10} beaches and 400 on C_3 beaches.

The seafloor structure of 58.6 % of the beaches in Sinop Province and the beach ground structure of 62.1 % are sandy. A total of 17.2 % of beaches have lifeguards and are usually on duty for eight hours. Regarding social facilities, 48.3 % had showers, 62.1 % had restaurants, 37.9 % had changing rooms, and 6.9 % had beaches that allowed people with disabilities to access the sea. Toilets were on 75.9 % of the beaches. In addition, 48.3 % had a sewerage system, and 44.8 % had toilets connected to the sewer system (Table 2).

Trend monitoring in FIB indicators over the years

In samples taken from beach waters during 2011 – 2019, total coliform level did not exceed the mandatory values; however, it was above the guideline values and below the mandatory value in 0.8 % of the samples. When microbiological indicators were evaluated within the scope of the relevant current regulations for the years 2011 – 2022, it was determined that 0.6 % of 2503 samples for *E. coli* and 0.3 % for intestinal enteroccoci were above or worse than the mandatory value. Exceeding the mandatory value for intestinal enteroccoci occurred only at beaches located in the centre of Sinop, and this difference was statistically significant ($p = 0.003$) (Table 3).

On evaluation of the sample results according to the years, in terms of total coliform value, the highest amount of pollution was seen in 2019 [53.5 (25.0 – 104.8)], but it reached the highest value in 2018 (9200). However, it has been determined that it does not exceed the mandatory values for all years. *Escherichia coli* bacterial density increased [20.0 (5.0 – 120.0)] in 2021, reaching the highest value of 10000 in 2020. It was determined that intestinal enteroccoci bacterial contamination was highest in 2011 [22.0 (6.0 – 120.0)] and reached the highest level with a value of 9000 in 2020 (Fig. 2).

The results obtained were statistically significant at the $p < 0.001$ level (FIB statistics values: 1837.310, 147.448, and 177.443). When all years and beaches are evaluated together, the median values of total coliform, *E. coli* and intestinal enteroccoci bacteria were found to be 10.0 (IR: 0 – 45), 10.0 (IR: 0 – 40) and 6.0 (IR: 0 – 26), respectively (values not given in the table).

Total coliform pollution was highest in the Sinop centre [35.0 (10.0 – 80.8)] in 2019, Gerze [55.0 (0 – 240.0)] in 2011, Ayancik [85.0 (10.0 – 200.0)] in 2012, and Türkeli [115.0 (12.5 – 150.0)] in 2011. *Escherichia coli* bacterial contamination was highest in Sinop centre [37.5 (10.0 – 127.5)] in 2021, Gerze [55.0 (0 – 240.0)] in 2011, Ayancik district [85.0 (10.0 – 200.0)] in 2012 and Türkeli district [115.0 (12.5 – 150.0)] in 2011. The locations with the highest intestinal enteroccoci bacterial density in 2011 were Sinop centre with a value of 24.0 (8.0 – 150.0), Gerze with a value of 40.0 (0 – 200.0), Ayancik with a value of 40.0 (4.0 – 137.5), and Türkeli with a value of 16.0 (4.0 – 34.0) in 2019 (Fig. 3).

Total coliform reached its highest levels in C_5 (9200 cfu/100 ml) beaches in 2018, while *E. coli* and intestinal enteroccoci reached the highest levels in C_8 beaches in 2020 (10000 cfu/100 ml and 9000 cfu/100 ml, respectively). In the analyses, FIB density was the highest in the beaches located in the centre of Sinop among the districts, and it was statistically significant (96.711, 34.187, and 79.077, respectively; $p < 0.001$).

Table 2 — Distribution of some characteristics of Sinop beaches

Characteristics	Sinop Central		Ayancık		Gerze		Türkeli		Total	
	n	%	n	%	n	%	n	%	n	%
Sea floor structure										
Sand	12	70.6	3	17.6	-	-	2	11.8	17	58.6
Gravel			3	30.0	6	60.0	1	10.0	10	34.5
Rock	2	100.0	-	-	-	-	-	-	2	6.9
Beach ground structure										
Concrete	-	-	-	-	1	100.0	-	-	1	3.4
Sand	13	72.2	3	16.7	-	-	2	11.1	18	62.1
Gravel	1	10.0	3	30.0	5	50.0	1	10.0	10	34.5
Lifeguard presence										
Yes, there is	3	60.0	-	-	1	20.0	1	20.0	5	17.2
No not	1	33.3	1	33.3	1	33.3	-	-	3	10.3
Unspecified	10	47.6	5	23.8	4	19.0	2	9.5	21	72.4
Shower facility										
Yes, there is	9	64.3	2	14.3	1	7.1	2	14.3	14	48.3
Unspecified	5	33.3	4	26.7	5	33.3	1	6.7	15	51.7
Restaurant										
Yes, there is	9	50.0	5	27.8	1	5.6	3	16.7	18	62.1
Unspecified	5	45.5	1	9.1	5	45.5	-	-	11	37.9
Changing room										
Yes, there is	5	45.5	2	18.2	2	18.2	2	18.2	11	37.9
Unspecified	9	50.0	4	22.2	4	22.2	1	5.6	18	62.1
Access for Persons with Disabilities										
Yes, there is	1	50.0	-	-	-	-	1	50	2	6.9
Unspecified	13	48.1	6	22.2	6	22.2	2	7.4	27	93.1
Car parking										
Yes, there is	5	29.4	6	35.3	4	23.5	2	11.8	17	58.6
Unspecified	9	75.0	-	-	2	16.7	1	8.3	12	41.4
Pet entry										
Yes, there is	2	25.0	6	75.0	-	-	-	-	8	27.6
Unspecified	12	57.1	-	-	6	28.6	3	14.3	21	72.4
Toilet										
Yes, there is	10	45.5	5	22.7	4	18.2	3	13.6	22	75.9
Unspecified	4	57.1	1	14.3	2	28.6	-	-	7	24.1
Presence of sewerage system										
Yes, there is	10	71.4	-	-	2	14.3	2	14.3	14	48.3
No, not	4	26.7	6	40.0	4	26.7	1	6.7	15	51.7
Toilets are connected to the sewer system										
Yes, connected	9	69.2	-	-	2	15.4	2	15.4	13	44.8
No, not connected	5	31.3	6	37.5	4	25.0	1	6.3	16	55.2
TOTAL	14	48.3	6	20.7	6	20.7	3	10.3	29	100.0

Identification of faecal contamination causes

The faecal coliform/faecal *Streptococcus* (FC/FS) ratio is one of the most preferred and useful methods for detecting sources of faecal pollution in the sea[27]. A detailed classification system has been developed according to the level of evidence, although there are minor differences in opinions[28,29] regarding the estimation intervals of the pollution source. Regarding the causes of faecal pollution, a value of > 4.0 is accepted as a strong evidence that the pollution is of human origin, and a value of < 0.7 is of animal origin. The most limiting aspect of this method is that the results obtained are valid for 24 hours[29]. The classification system was expanded by dividing the value of < 0.7 into two more subgroups, accompanied by the existing information. "< 0.1: Strong evidence of the predominance of wild animal; 0.1 – 0.6: Strong evidence that pollution is of animal origin (domestic animal); 0.7 – 2.0: Good evidence of the predominance of domestic animal wastes in mixed pollution; 2.0 – 4.0: Good evidence of the predominance of human wastes in mixed pollution;

Table 3 — Distribution of some microbiological indicators by districts

Some microbiological indicators	Sinop Central		Gerze		Ayancık		Türkeli		Total	
	n	%	n	%	n	%	n	%	n	%
Total coliform[a]										
Below guideline/ Good	848	46.1	382	20.8	394	21.4	214	11.6	1838	99.2
Above guide value and below mandatory value/ Moderate	8	53.3	4	26.7	1	6.7	2	13.3	15	0.8
Above required value/ Poor	-	-	-	-	-	-	-	-	-	-
Total	856	46.5	386	20.8	395	21.3	216	11.7	1853	100.0
E. coli[a]										
Below guideline/ Good	1038	46.4	478	21.3	477	21.3	246	11.0	2239	89.5
Above guide value and below mandatory value/ Moderate	123	49.6	41	16.5	48	19.4	36	14.5	248	9.9
Above required value/ Poor	12	75.0	2	12.5	-	-	2	12.5	16	0.6
Total	1173	46.9	521	20.8	525	21.0	284	11.3	2503	100.0
Intestinal Enterococci[a]										
Below guideline/ Good	1083	45.9	498	21.1	505	21.4	271	11.5	2357	94.2
Above guide value and below mandatory value/ Moderate	82	59.4	23	16.7	20	14.5	13	9.4	138	5.5
Above required value/ Poor	8	100.0	-	-	-	-	-	-	8	0.3
Total	1173	46.9	521	20.8	525	21.0	284	11.3	2503	100.0

[a] - The classifications were evaluated by combining the updates in the official newspaper

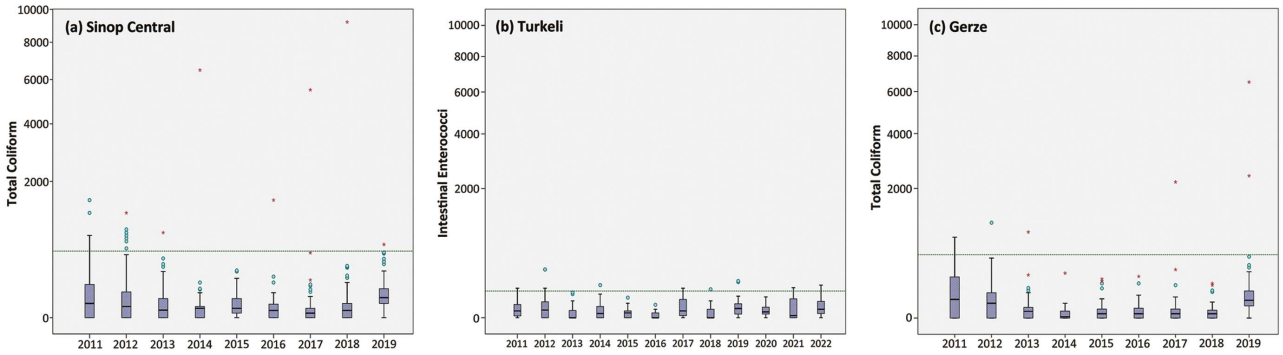

Fig. 2 — Distribution of total coliform, *E. coli* and intestinal enteroccoci levels in Sinop Province by years

and > 4.0: Strong evidence that pollution is of human origin"[34].

The minimum and maximum FC/FS ratios in the Sinop Province of Sinop between 2011 – 2022 were in the range of 0 – 200. The most common causes of faecal pollution on the beaches of Sinop Province were "pollution from wild animals" (40.0 %), "good evidence that pet waste predominates in mixed pollution" (21.5 %), and "strong evidence of human-induced pollution" (13.7 %) (data is not given in the tables).

The sources of pollution on the basis of districts are seen as a result of "human wastes and activities" in Sinop centre and Türkeli districts (FC/FS ratio > 2.0); whereas, "animal sourced pollution" (FC/FS ratio < 0.7) is more dominant in Ayancik and Gerze districts (Fig. 4).

Comparison of faecal pollution status with previous studies

Compared with other studies, the total coliform value found in this study was generally lower than that of some stations in the Mediterranean and Aegean regions. The highest total coliform value was recorded in 2009 at the Katranci Island East Station in Aegean, with an average of 930[15]. *Escherichia coli* levels were highest in samples from Fethiye Inner Bay[21], followed by Sinop Central beaches, Türkeli district beaches and Gerze district beaches. Intestinal enteroccoci were the most common indicator among FIBs, and the highest average value was reached in Fethiye Harbor, followed by Katranci Island East[15], Selçuk Sürmeli Efes Beach[17], Kale[22], and Sinop Central beaches (Table 4).

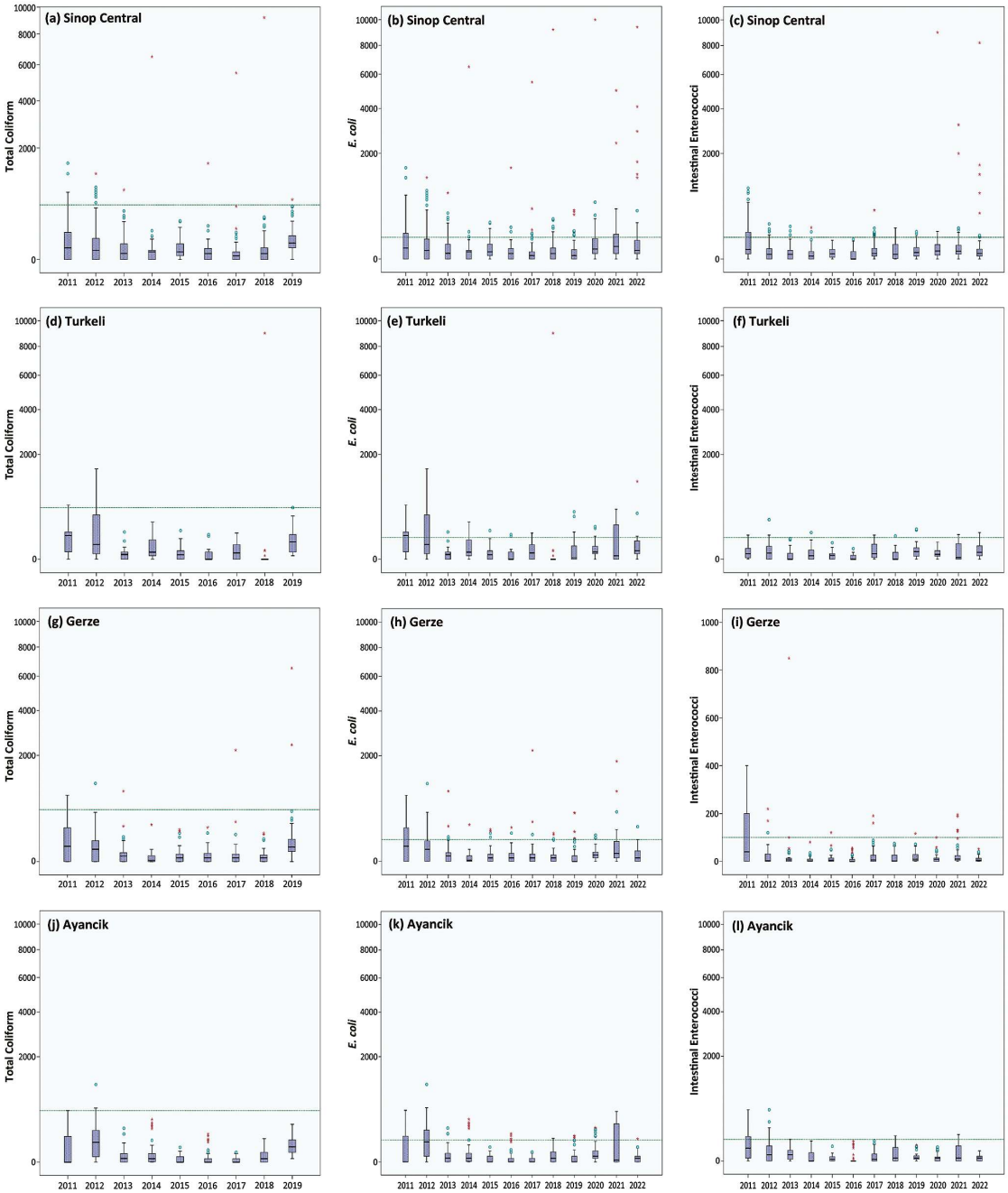

Fig. 3 — Distribution of faecal pollution indicators according to locations and years at sample points, Sinop

Awareness of people in Sinop to pollution in bathing waters

In 2018 – 2022, people in Sinop complained the most about the pollution they observed in the seas in 2019. It was concluded that these searches made by conscious people were mostly from the Sinop centre (n = 44), Gerze (n = 17), and Ayancik (n = 12) districts. While the number of complaints made in the month of July was the highest (26), while it remained lowest in September (Fig. 5).

Concordance of bathing water classification system in Turkey with WHO

According to the WHO directive, 82.4 % of the sample analysis results are in the A (good) category, whereas 0.6 % are classified as D (poor). When this situation was evaluated according to the bathing water quality regulations of the Republic of Turkey, 94.2 % were good, and 0.3 % were in bad category. When the microbial quality assessment of WHO for recreational

Fig. 4 — Faecal pollution causes in Sinop districts

waters and the classification system of the Ministry of Health of the Republic of Turkey were examined, a weak agreement was found (MCc = 0.151, $p < 0.001$) (Table 5).

In addition, when the sample analysis results were compared with the US EPA standards, the water quality, which was evaluated as "good" by 94.2 % of the Ministry of Health, was found to be 82.4 % according to the WHO and 79.4 % according to the US EPA (data not given in the Table).

Discussion

Characteristics of Sinop beaches

Only five of the 29 beaches in Sinop had lifeguarded services; although rip currents are very frequent, especially on some beaches and drowning news is published almost every summer season[30-32]. People caught in the current situation may be at risk of drowning even if they can swim very well[33]. In addition, toilets, showering places, restaurant services, and area arrangements for the disabled were not provided on the majority of the beaches. In such places, which are popular in terms of tourism, lifeguard services should be expanded, and beach opportunities should be increased to ensure the safety of swimmers.

Trend monitoring in FIB indicators over the years

In Sinop, FIB levels have decreased over the years; however, this is an undesirable situation as increase in FIB continue for some years. On some beaches in Sinop Province, FIB values reached their highest in 2018 and 2020. Although it is not common to exceed the guidelines and mandatory values[1,26], this situation has mostly been observed on beaches located in the centre of the Sinop. FIB pollution was the highest in 2019, 2021 and 2011. The FIB densities increased three times at the C_8 and A_2 beaches and twice at T_1 and G_1 beaches. Situations such as extreme climatic events, inadequacy of the infrastructure system, marine litter (packaging waste, domestic waste, and seaweed), fish farms, and the absence of licensed waste reception facilities throughout the province are thought to contribute to faecal pollution. Meteorological warnings were issued by the Sinop Governorate Provincial Disaster and Emergency Directorate in June 2019. Locally strong downpours and thunderstorms (20 – 50 kg/m^2) are expected around Sinop, as are winds/storms at speeds of 50 – 80 km/h in the inner parts of the Sinop[34,35]. In August 2021, a flood disaster caused serious losses in Ayancik district. Extreme events, such as extreme precipitation events, strong winds, and floods,

Table 4 — Comparison of faecal pollution in Turkish beach waters

Location (Sea, City)	Designated areas/ Station	Coordinates/ Sampling number	Sample collection year	Parameters: Total coliform (cfu/ 100ml) Mean±SD	Total coliform Min-Max Value	*Escherichia coli* (cfu/ 100ml) Mean±SD	*Escherichia coli* Min-Max Value	Intestinal enterococci (cfu/ 100ml) Mean±SD	Intestinal enterococci Min-Max Value	Method of analysis and inspection	References
Black Sea, Sinop	Sinop central beaches	14 sampling stations	2011-2022	81.11±445.839 15.00(0-50) [a]	0-9.200	103.44±595.734 15.00 (0-50) [a]	0-10.000	53.89±382.543 10.0(2-32) [a]	0-9.000	Membrane filtration method (2006-2019 years) and ISO 7899-1/ISO 7899-2 and ISO 9308-3/ISO 9308-1 (2020-2022 years)	Present Study
	Gerze district beaches	6 sampling stations		72.81±383.029 5.0 (0-35) [a]	0-6.500	46.68±162.760 5.0 (0-25) [a]	0-2.200	21.31±55.845 6.0 (0-19) [a]	0-850		
	Ayancık district beaches	6 sampling stations		41.74±97.257 5.0(0-30) [a]	0-1.100	38.24±98.274 5.0 (0-20) [a]	0-1.100	21.52±55.633 4.0 (0-16) [a]	0-500		
	Türkeli district beaches	3 sampling stations		112.17±627.658 10.5 (0-70.8) [a]	0-9.000	98.60±552.859 10.0 (0-60) [a]	0-9.000	21.23±39.565 6.0 (0-20) [a]	0-300		
Black Sea, Samsun	Atakum district beaches	17 sampling stations	2016	80[b]	0-800	4[b]	0-360	0 [b]	0-140	Membrane filtration method	Terzi & Sünter[20]
Marmara Sea, İstanbul	Prince Islands' beaches	8 sampling stations	2008	In the range of 5±2-26±55	-	In the range of 4±2-24±50 [3]	-	-	-	Cellulose nitrate membrane filter technique	Aydinol *et al.*[16]
Aegean Sea, Muğla	Fethiye inner Bay	14 sampling stations	March2016-February 2017	298	0-6090	131	0-6090	28	0-800	Membrane filtration method	Yıldırım & Balas[21]
Aegean Sea, İzmir	İzmir Bay	23 sampling stations	2015-2017	-	-	-	1-8.8×10[b]	-	<1-1.1 × 10[c]	Membrane filtration method	Kacar & Omuzbuken[19]
Aegean Sea, Muğla	Kapıdağ peninsula/ Between Kızılkuyruk - Büyükağa Bay	N 36°36′23.0″ E 28°52′09.5″	August 2009	133	-	1	-	3	-	Membrane filtration method	DUEC[15]
	Darboğaz - Domuz Island crossing	N 36°39′12.5″ E 28°54′01.6″		320	-	U	-	1	-		
	Sarsala Bay	N 36°39′42.6″ E 28°51′15.2″		275	-	U	-	3	-		
	Boynuzbükü Bay	N 36°42′41.9″ E 28°54′01.1″		200	-	U	-	18	-		
	Yassıca Island west	N 36°42′19.2″ E 28°55′47.4″		360	-	U	-	10	-		
	Göcek Bay	N 36°45′08.8″ E 28°55′59.9″		370	-	20	-	19	-		
	İnlice Bay	N 36°43′37.9″ E 28°58′13.3″		58	-	U	-	4	-		
	Günlüklü Bay	N 36°42′46.9″ E 29°01′08.0″		33	-	3	-	66	-		
	East of Katrancı Island	N 36°41′23.6″ E 29°01′52.9″		930	-	U	-	119	-		
	Çalış Beach	N 36°40′03.7″ E 29°05′50.6″		150	-	U	-	18	-		
	Fethiye Harbor	N 36°38′52.7″ E 29°06′32.8″		187	-	8	-	770	-		
	Between Gökçe Bay and Bozburun	N 36°35′36.1″ E 29°01′38.6″		69	-	U	-	U	-		
	Darboğaz Bay	N 36°33′24.3″ E 29°03′03.3″		94	-	U	-	U			
	Kalevezi (Soğuksu) Bay)	N 36°33′51.3″ E 29°05′14.9″		430	-	11	-	1	-		
	Belceğiz Bay (Ölüdeniz Location)	N 36°32′39.2″ E 29°07′11.6″		235	-	U	-	4	-		
Aegean Sea, Muğla	Güllük Bay	11 sampling stations	May 2012–February 2013	3x101-2.164x106		0.1x101-1.46x104			0.1x101-2.11x104	Membrane filtration method	Kalkan & Altuğ[18]
Aegean Sea, Muğla	Bodrum Ortakent Beach	N 37°01′58.2″ E 27°33′53.4″	2009-2010 (April-September)	242[d]	-	15[d]	-	5[d]	-	Membrane filtration method	Kacar & Kucuksezgin[17]
Aegean Sea, İzmir	Çeşme Sheraton Beach	N 38°30′75.4″ E 26°36′86.4″	2008-2010 (May-October)	158[d]	-	40[d]	-	25[d]	-		
	Selçuk Sürmeli Efes Beach	N 37°92′29.8″ E 27°27′64.3″	2008-2010 (May-September)	294[d]	-	40[d]	-	60[d]	-		
Mediterrenia, Antalya	Kaş	N 36°11′ 37″ E 29°36′38″	2017	386.36±249.53	10-700	10.82±8.02	0-23	0.18±0.60	0-2	Membrane filtration method	Şener *et al.*[22]
	Üçağız	N 36°11′64″ E 29°50′91″	2017	108.18±74.20	10-250	17.27±13.18	0-40	2.27±3.91	0-10		
	Kale	N 36°11′37.1″ E 29°51′26.5″	2017	541.36±301.77	25-1000	38.18±30.69	0-80	56.91± 178.07	0-620		
Mediterrenia, Antalya	Kemer Elize Beach	N 36°54′32.6″ E 30°55′88.7″	2008-2010 (April-November)	272[d]	-	25[d]	-	42[d]	-	Membrane filtration method	Kacar & Kucuksezgin[17]
	Manavgat magic life beach	N 36°75′29.4″ E 31°44′56.8″	2008-2010 (April-November)	210[d]	-	32[d]	-	10[d]	-		
Mediterrenia, Antalya	Lara Beach	18-22 sampling stations	2001-2005 (April-October)	102	-	28[e]	-	8[e]	-	Membrane filtration method	Tuğrul *et al.*[14]
	Konyaaltı Beach			110	-	17[e]	-	8[e]	-		

- : Not given; U: Undetected; [a]: Presented as median value and interquartile range unless otherwise requested; [b]: Only the median value is shared; [c]: It is stated as the faecal coliform value; [d]: Based on 95 % evaluation; and [e]: It is stated as faecal *Streptococcus* value

Table 5 — Compatibility of the Ministry of Health of the Republic of Turkey and the WHO microbiological water quality criteria

Bathing water Category, T.R.*	Microbial qater quality assessment category, WHO*								Total	
	A (≤ 40)		B (41 – 200)		C (201 – 500)		D (> 500)		n	%
	n	%	n	%	n	%	n	%		
Good	2062	87.5	295	12.5	-	-	-	-	2357	94.2
Moderate	0	-	99	71.7	30	21.7	9	6.5	138	5.5
Poor	0	-	-	-	1	12.5	7	87.5	8	0.3
Total	2062	82.4	394	15.7	31	1.2	16	0.6	2503	100.0

*Kendall's tau-c value: 0.151, $p < 0.001$

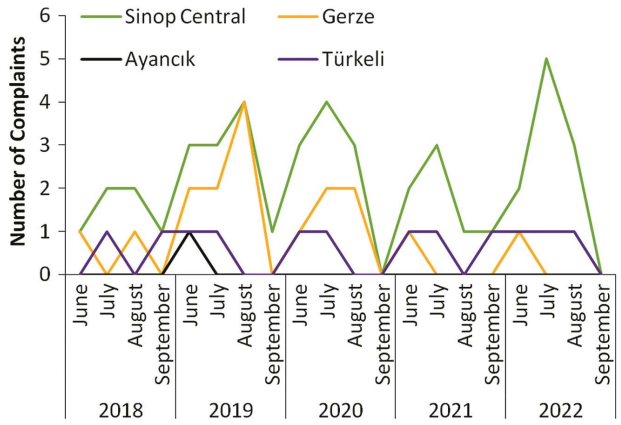

Fig. 5 — Number of complaints about pollution in bathing waters during bathing season

increase pollution in the seas[36-38]. During heavy rainfall, the increasing amount of wastewater reaches levels that cities cannot remove through the existing sewerage infrastructure. Hence, sewerage overflow occurs during and after meteorological events and mediates the transport of FIBs to recreational waters in various ways. Manini *et al.*[43] stated that the water discharged from combined sewerage overflow outlets contained more than 90 % microbial load. According to the Sinop 2021 Environmental Status Report, the main causes of sea pollution are domestic wastewater, pollution caused by sea vehicles, domestic solid waste (waste spilled from an irregular landfill to the sea due to wind, slip, etc.), and waste generated as a result of fishing activities. As a result of fishing activities in Sinop, 2100 kg of packaging waste and 850 kg of domestic waste were collected[12]. In addition, the confluence of streams with seawater close to beaches may have played a role in pollution.

Identification of faecal contamination causes

Recreational water can be heavily polluted by waste from humans, animals, or a combination of both. This is an important factor that reduces the quality of bathing waters[39]. This study provides strong evidence that the majority of the faecal pollution originates from wild animals. The mountainous and rugged nature of Sinop provides shelter to various wild animals. There is good evidence for the predominance of pet waste in mixed pollution. People living in the province retain poultry, cattle, and other small cattle species for various economic reasons. It is known that a large number of dogs and cats abandoned by their owners in the centre live on the streets, animal shelters are full, and the cattles roam on the seaside roads. The deterioration of recreational water quality due to inadequate animal policies adversely affects human health at various levels. The WHO states that animal-derived pollution can be a source of important pathogens and therefore, should not be ignored[2]. In such cases, wild animals may play an indirect role in disease transmission, causing other health hazards[40]. Rodrigues & Cunha[45] studied dangerous faecal-derived microbial forms on contaminated beaches used in recreational activities. They stated that water contaminated with domestic and wild animal waste could cause serious health problems in humans, such as gastroenteritis, hemorrhagic diarrhoea, Legionnaires' disease, leptospirosis, campylobacteriosis, and gastrointestinal system diseases.

In Ayancik district, 'wild and domestic animal pollution' was obtained, and in the Sinop centre, 'strong evidence that human wastes are dominant, but human origin' was obtained. In the scenarios of human-induced pollution in the centre of Sinop, despite the diffuculties of the infrastructure systems in accommodating the urban population even in normal times, various factors such as excess capacity wastewater overflowing into the sea (due to discharge costs) along the coastline, leakage due to deterioration, waste from fishing boats, intense recreational activities, and the increased mobility in summer months leading to a high density of boat trips were considered influential. Spending time for recreational and swimming purposes in waters with high FIB density can lead to illness by being

vulnerable to health-related hazards, increasing the patient load on hospital emergency services, and causing economic losses. Although studies have indicated that animal-based pollution does not pose a serious health problem, however, its impact on specific groups, such as children and the elderly, may be more serious.

To ensure the sustainability of aquatic life on the planet, authorized units need to implement stringent policies to solve existing problems in intersectoral cooperation. The results obtained from this study reveal that municipalities in the province of Sinop should prepare and implement policies for healthy and sustainable marine life in a way that will not put people's health at risk, and animals will not be harmed. In addition, extensive and advanced research on the level of health risks in specific category of pollution of animal origin is required. Because waters with high FIB levels exhibit mixed pollution and hence, faecal source identification technologies should be developed[39]. These should be included in the bathing water monitoring system, and the necessary measures should be implemented immediately.

Comparison of faecal pollution status with previous studies

The FIB load on the coast of Sinop Province was relatively low when evaluated together with the literature. This situation is compared to other provinces and districts, as the industrial sector in the province is not very developed and is located at the northernmost tip of Turkey. The fact that it is a frequent destination for those who prefer the Black Sea region during their summer holidays may be related to the low population.

The increase in FIB levels in the Kaş station, especially in the summer months, may be due to population growth and mobility in tourism. The authors have attributed the higher level of FIB in the sea water sample taken at the Kale location compared to other areas to the presence of a local wastewater discharge in the region at the time of sampling. In addition, the relative increase in microbiological parameters at all locations was evaluated as an anthropogenic input to seawater[22]. Fluctuations in the distribution of total coliform and faecal coliform bacteria were found in Güllük Bay but were not statistically significant. However, it was attributed to the increase in FIB levels with an increase in the population ratio in the station, which may be associated with recreational activities in the summer season and the continuity of point and non-point pollution sources affecting coastal areas during the study[18]. The possible causes of faecal pollution detected in the coastal waters of Fethiye Inner Bay are wastewater, sludge, and animal faeces from intensive anthropogenic facilities[21].

Kaçar & Küçüksezgin[22] suggested that an increase in FIB levels may be related to faecal contamination. It has been stated that many point and non-point sources, such as people using the beach, domestic or wild animals, leaks from the sewerage system or waste storage tanks, illegal discharges from restaurants, cafes, and businesses in the vicinity, nearby agricultural fields, and river inlets, may be effective in this increase. Additionally, the study carried out at Lara and Konyaalti Beach, stated rapid population growth, precipitation, and terrestrial inputs contribute to pollution, and the discharge of wastewater from human activities into the sea negatively affects the water quality[14]. It is thought that the continuity of such studies is very important for comparing the quality of recreational water in Turkey and determining the differences between the regions. Further, to obtain reliable results, it would also be better to express the analysis results in a common units.

Awareness of people in Sinop to pollution in bathing waters

The results of this study are remarkable in terms of evaluating people’s environmentally friendly actions by displaying the citizenship responsible for situations like pollution in the sea. In Turkey, the authority to control marine pollution in provinces rests with the Provincial Directorate of Environment, Urbanization, and Climate Change. People of the Sinop Province have been observed to be partially aware of sea pollution. It is important for people to go beyond the advocacy of environmental issues and engage in activist actions and initiatives[41]. Although the year with the highest number of complaints was 2019, this was not compatible with the year with the highest pollution. This may be related to the fact that complaints were made regarding the visible pollution situations. A study conducted in the United Kingdom found that the majority of participants misunderstood the European Union bathing water quality classification signs and were unaware of information boards or electronic signs[42]. However, public participation is essential for bathing water management. As Sinop has the oldest population in Turkey, it is thought that the media literacy of the people living here may be lower. To involve the public in the

bathing water monitoring process, preparation of more understandable information brochures, placing electronic signs on beaches, introducing the Alo 181 Environment and Urbanization Line, provision of information on what to do in such pollution situations, and notification to the public as soon as possible, is required. Indeed, it is believed that the implementation of the blue-button application could be beneficial.

Concordance of bathing water classification system in Turkey with WHO

The implementation of a classification system for recreational waters that protects national treasure and supports sustainable water management in all countries is a very important and sensitive issue. No study has been found in the literature examining the compatibility of different classification systems for recreational waters. This is the first study in this respect. A weak agreement was found between the classification of coastal and transitional waters during the season in Turkey and the WHO guideline values for microbial quality of coastal and fresh recreational waters. Leading bathing water guidelines differ in several respects. When it comes to human health, it is thought that it would be inconvenient to adhere to a basic directive by ignoring many factors that determine microbial pollution, such as geography, infrastructure systems, waste disposal methods, improvement areas, industrialization, climate, and discharge to receiving environments. In Turkey, rather than the "One Size Fit for All" approach[43], it seems necessary to make appropriate assessments and classifications that do not pose a risk to public health. There is a need for new but stringent policies to be determined by considering the environmental parameters of WHO guidelines, which are leading international organizations in the field of public health. This study revealed that WHO guidelines, which prioritize public health and have clear evidence-based boundaries, should be adopted by countries around the world. In addition to protecting public health, this situation provides an opportunity to leave healthy and reliable water to future generations.

Limitations

In this study, faecal coliform, *E. coli* and faecal *Streptococcus* were expressed as the equivalent of intestinal enteroccoci in accordance with regulations. Although there are concerns regarding this issue, and also there are differences between the methods used to determine the FIB levels. Therefore, this situation should be considered when comparing WHO and Ministry of Health of the Republic of Turkey classification systems. Our second limitation is that the current data are classified according to seasonal evaluation, as the second-level evaluations of the FIB data in the context of the European Union bathing water directive start in 2023.

Conclusıon

In fragile cities such as Sinop, where infrastructure work is insufficient, FIB evaluations should be conducted more frequently, questioning the patients whether bathing and recreational activities are performed in the increasing number of hospital admissions the summer months and investigating the causes of pollution. Moreover it was concluded that placing electronic signboards working with solar or wind energy on beaches, and developing early warning systems. In future studies, it is recommended that the recreational water classification systems of leading organizations and institutions should be compared with those of other countries and evaluated in terms of public health.

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Conflict of Interest

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Data availability

These data are available upon request.

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