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Research Article

Investigation of the Levels of Bio-Indicator Bacteria in the Kınalıada Coastal Area, Istanbul, Turkey

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Abstract

Coastal areas have an important place in island ecosystems. These areas, which may be fragile depending on the impact of human activities exposed and other environmental factors and in addition to domestic, agricultural and industrial activities, it hosts intensive touristic use in spring and summer. In this study, the closest contact with the shores of a mainland like Istanbul, among the Prince Islands in the Marmara Sea which is under the influence of the vast majority of the pollution load Kınalıada has been selected as a research area. Total heterotrophic aerobic bacteria (HAB) levels were analyzed using spread plate method. The levels of fecal coliform (FC), total coliform (TC) and intestinal streptococci (IS) examined using Membrane Filtration Technique in the surface water samples. Variable environmental parameters (dissolved oxygen, pH, salinity, temperature) were recorded in situ using the Multiparameter (YSI 556 MPS) in the stations. Nutrients including nitrite (NO_2^-), nitrate (NO_3^-), ammonium (NH_4^+), phosphate (PO_4), trophic level indicator Chlorophyll-*a* were analyzed using spectrophotometric methods. While the highest TC level detected as $96x10^3$ CFU/100 ml, IS and FC levels followed it as, $49x10^3$ CFU/100 ml, $82x10^3$ CFU/100 ml, respectively. The highest HAB level was determined as $92x10^{11}$CFU /ml. Variable environmental parameters recorded for seawater temperature between 25.7-6.89˚C, pH 11.55 -3.60, dissolved oxygen 19.98 -1.66 mg /l and salinity ‰ 29.11-21.18 during the study period. Nutrient salts; nitrite detected to be 0.21-0.01 mg/l; nitrate detected to be 9.90-0.13 mg/l; ammonium detected to be 4.80-0.02 mg/l; phosphate detected to be 22.45-0.01 mg/l. The levels of FC, TC and IS recorded in the sampling area displayed fluctuations depending on the seasons. However, the levels of bio-indicator bacteria, detected above the legal limits, during the study period showed that Kınalıada coastal areas have potential risk for ecosystem and human health.

Keywords: Fecal coliform, Total coliform, Kınalıada, The Sea of Marmara

Introduction

International Oceanographic Commission (IOC) describes water pollution as directly or indirectly damage created by mankind on marine environment regarding human and ecosystem health and deteriorates the quality in the use of sea water as drinking water and all of the factors that reduce its sweetness (IOC, 2018). Bacteriological pollution is one of the most important factors of marine pollution components. Since organic matter input is higher in coastal areas, these areas offer more favorable conditions to bacterial development (Pomeroy and Carlos 1997; Cho, and Azam, 1990; Heissenberger et al.,1996; Altuğ and Bayrak., 2003).

In studies on indicator bacteria levels in coastal areas around the world, to estimate the quality of coastal waters, European Bathing Water Directive 2006/7/EC provides guidelines to assess levels of fecal bacteria, including *Escherichia coli* and intestinal enterococci. These microbiological criteria are based on studies that determine the risk of diseases caused by enteric bacteria related to human activities like swimming (Januario et al, 2019). One of the main impacts of urban sprawl in rapidly growing countries has been contamination of coastal environments by waterborne pathogens, posing a critical risk to ecosystem and human health (Zeki, 2020). Coastal water quality assessment is important to maintain a healthy environment for various uses including fisheries and recreation activities (Mehmuna et al, 2021). The use of indicator bacteria such as total coliforms, fecal coliforms and intestinal streptococcus are much common in routine analyses due to i) these bacteria detectable less time with more economical way, ii) share the same environment with pathogenic bacteria, iii) numerically higher than pathogenic bacteria (Droste, 1997; APHA 1998, Prescot et al, 1999, Bitton, 2005; Burak et al., 2009).

Various studies conducted in Turkish seas since 2000 have revealed the presence of indicator bacteria in coastal areas and fluctuations above the limit values, especially in the summer season. When compared the bacteriological studies conducted in the Sea of Marmara with our other marine areas, encountered coastal areas with fluctuations in pollution (Altuğ, 2016b). In the seas of Turkey, including the coastal areas; the changes saved in bacterial compositions by region in different studies formed the x-ray of the environmental effects that bacteria are exposed to. High levels of enteric bacteria in areas where domestic pollution pressures are intense belong to the Enterobacteriaceae family, which includes

the Gamma Proteobacteria group manifested by the presence of bacteria. This situation is observed as an anthropogenic pollution input in all coastal areas from the Eastern Mediterranean up to the East Black Sea (Altuğ et al., 2011, Çardak et al., 2015). Today, the necessity of studies related to bacterial community structure in marine areas has an increasing importance with the increase of human-induced pressure in coastal areas due to technology and population growth. The purpose of this study is to determine of the levels of indicator bacteria in the Kınalıada coastal water area and investigation bacterial pollution from coming of Sea of the Marmara.

Materials and Methods

Sampling

A total of ten stations were shown in Figure 1.
Stations were determined around the coastal area of Kınalıada, the Marmara Sea, which was chosen as the study area; between June 2018 and May 2019 taking into account environmental factors. Surface water sampling was carried out monthly from these stations between June and August, and seasonally in autumn, winter and spring seasons. The sea water samples were collected from the surface from the depth of 0-30 cm under aseptic conditions with sterile glass tubes and were analyzed within 4-6 hours after being transferred to the laboratory under the cold chain (APHA, 1998; EPA, 2006).

The sampling plan of the study was shown on Table 1. Location of the sampling stations was shown in Table 2. Sea water samples were taken into 500 ml sterile polyethylene bottles with caps and it was arrived to the Aquatic Microbial Ecology Laboratory of the Faculty of Aquatic Sciences, Istanbul University. Nutritional salts (ammonium, nitrite, nitrate total phosphorus) and chlorophyll-a analyzed using spectrophotometric method (APHA, 2012). The variable environmental parameters (temperature, salinity, dissolved oxygen, pH) were measured in-situ by using a multi-parameter probe (YSI Model 556).

Bacteriological Analyses

Dilutions of water samples were prepared to 10^{-8} in 0,9 ml amounts of sterile seawater (artificial seawater, Sigma) and were inoculated (0.1 ml) in triplicate on Marine Agar (Difco). Petri dishes were incubated at 22 ± 0.1 °C for 72 hours. The colonies that developed were counted, multiplied by the dilution factor and recorded as colony forming units (CFU/100 ml) / heterotrophic aerobic bacteria (HAB) level in 100 ml of seawater sample (Austin, 1988). The membrane filtration system was used for the intestinal streptococcus, total coliform and the fecal coliform analyses. As for the medium, m.FC-NKS (Sartorius) was used for fecal coliform, Endo-NKS (Sartorius) was used for the total coliform while Azide-NKS (Sartorius) nutrient pad system was used for intestinal streptococcus.

The samples incubated at 44.5 ± 0.1 ºC for 24 hours for fecal coliform and at 37 ± 0.1 ºC for 24 hrs for intestinal streptococcus and total coliform. In the post incubation phase, the blue colonies, grew at mFC NKS were considered as the fecal coliform suspects while the metallic green -dark red colonies, grew in Endo-NKS are marked for total coliform suspects and the brown-red colonies, grew in Azide-NKS were marked as intestinal streptococcus suspects and the indicator bacteria count for the suspected colonies of 100 ml was calculated by implementing the following formula; [CFU (Colony Formed Unit) /100 ml = (Number of colony x 100)/ filtered volume (ml)] (APHA, 2006).

The suspected blue colonies of fecal coliform, grew in mFC medium that were determined to be Gram negative rod bacteria were subjected to cytochrome – oxidize test and the ones that came up with negative results were marked as fecal coliform. The total cultivable heterotrophic aerobic bacteria count was determined by using the spread plate method (Austin, 1988).

Statistical Analyses

Bacteriological data obtained at designated stations variable environmental parameter levels, nutrient salts and Chlorophyll-*a* data were transferred to the SPSS 21 (Statistical Package for the Social Science) software package and the Kolmogrov-Smirnov (K-S) test program. According to seasons and stations, differences between the levels of indicator bacteria were compared using ANOVA (one-way analysis of variance). its non-parametric alternative, the Mann Whitney U test and the variance analysis test were separately applied to the extracted data. Spearman rank correlation analysis has been made to determine the relationships of the parameters with each other. Significance levels were taken as 0.01 and 0.05 in analyzes.

In order to determine the impact of the season and station factors on the changes in the pre-determined environmental parameters, one-way variance analysis was employed and to find out the interrelations of the parameters with each other, Spearman linear correlation analysis was used. Mann Whitney U test was used in a dual setting to determine the differences between the stations. (Sokal and Rohlf, 1998; Quinn and Keough, 2002).

Table 1. The Sampling Plan of the Study

Season	Sampling Type	Sampling Date
Summer	Monthly	June 2018/ July 2018/August 2018
Autumn	Seasonally	November 18
Winter	Seasonally	February 19
Spring	Seasonally	May 19

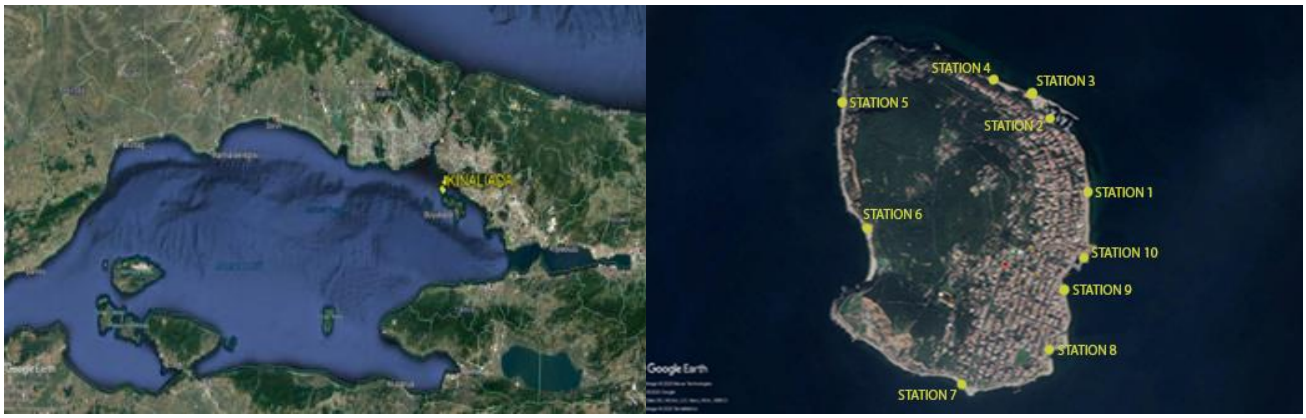

Fig. 1. Sampling Stations (Google Maps)

Table 2. Location of the Sampling Stations

Station No	Sampling Name	Latitude-Longitude
1	Public Beach 1	*40°91'27.39"N 29°05'28.87"E*
2	Water Club Port Inner	*40°91'40.42"N 29°05'05.23"E*
3	Water Club Pier	*40°91'45.53"N 29°05'07.27"E*
4	Public Beach 2	*40°91'40.99"N 29°04'80.34"E*
5	Reference Station	*40°91'02.39"N 29°04'01.16"E*
6	Special Beach 1	*40°90'64.43"N 29°04'43.97"E*
7	26 Number Beach	*40°90'34.52"N 29°05'32.91"E*
8	Special Beach 2	*40°90'62.18"N 29°05'65.74"E*
9	Kınalıada-Police Center	*40°90'80.91"N 29°05'61.45"E*
10	Marine Taxi Pier	*40°90'99.02"N 29°05'57.59"E*

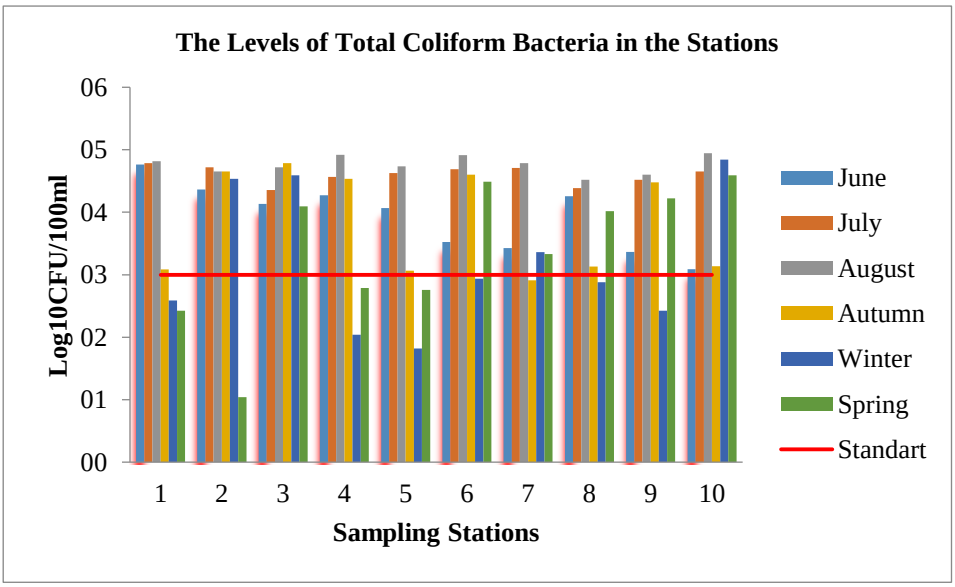

Fig. 2. Levels of total coliform bacteria(TC) in the stations.

Results

Fecal coliform, total coliform, intestinal streptococcus and total mesophilic heterotrophic aerobic bacteria (HAB) analyses were performed to the surface water samples, extracted between June 2018 and May 2019, from 10 stations in the areas, in the Kınalıada coastal area. For the Directive 2006/7/EC of the European Parliament, the standard values are 500 CFU/100 ml (2, 69 / 100 ml according to log10 value) for the total coliform count, 200 CFU/100 ml (2.0/100 ml according to log10 value) for fecal coliform and 100 CFU/100 ml (2.0/100 ml according to log10 value) for the intestinal streptococcus and the aforementioned standards are underlined as dark red in the Figure 2, 3 and 4 (European Parliament, 2006). The levels of total coliform bacteria in the stations were shown in Figure 2. The levels of fecal coliform bacteria in the stations were shown in Figure 3.

When all stations are compared, the lowest total coliform value was measured in Station 2 in May 2019 as 11 CFU/100 ml while the highest total coliform value was found out to be 81840 CFU/100 in Station 6 in August 2018.

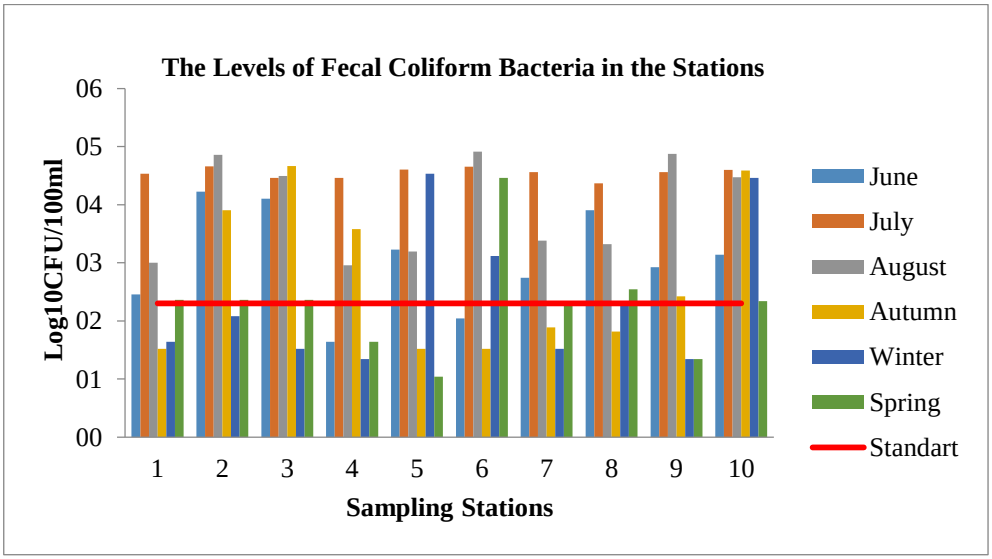

Fig. 3. Levels of fecal coliform bacteria(FC) in the stations.

When all stations are compared, the lowest fecal coliform value was measured in Station 5 in May 2019 as 11 CFU/100 ml while the highest fecal coliform value was found out to be 7448 CFU/100 in Station 9 in August 2018.

The levels of intestinal streptococci in the stations were shown in Figure 4. The levels of total mesophilic heterotrophic aerobic bacteria (HAB) in the stations were shown in Figure 5.

While the intestinal streptococci values were measured in the samples taken from a lot of stations in May 2019 as <10 CFU/100 ml the highest intestinal streptococci value was found to be 81840 CFU/100 in Station 10 in November 2018.

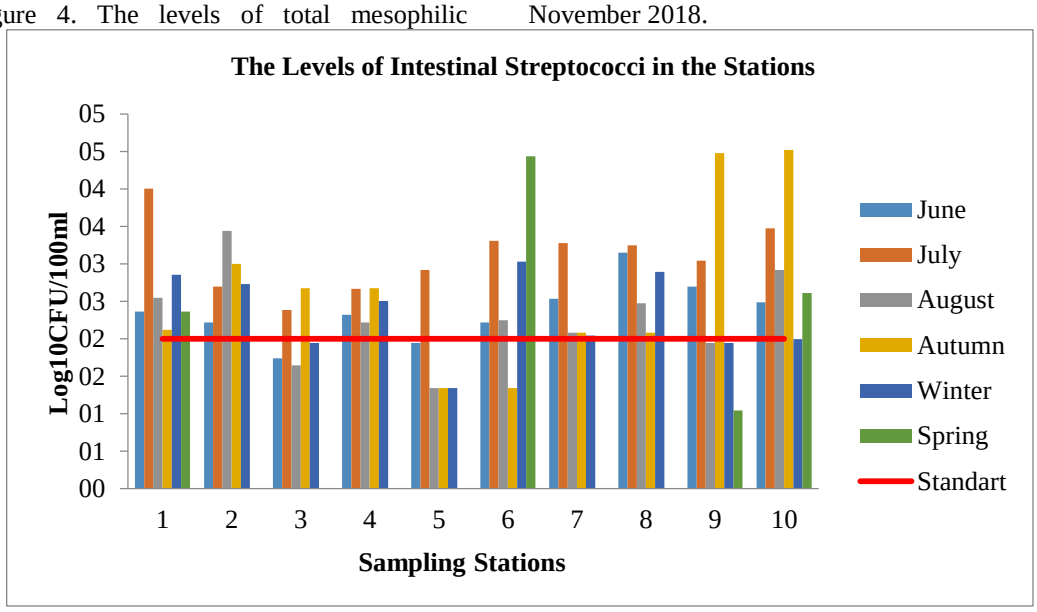

Fig. 4. Levels of intestinal streptococci (IS) in the stations.

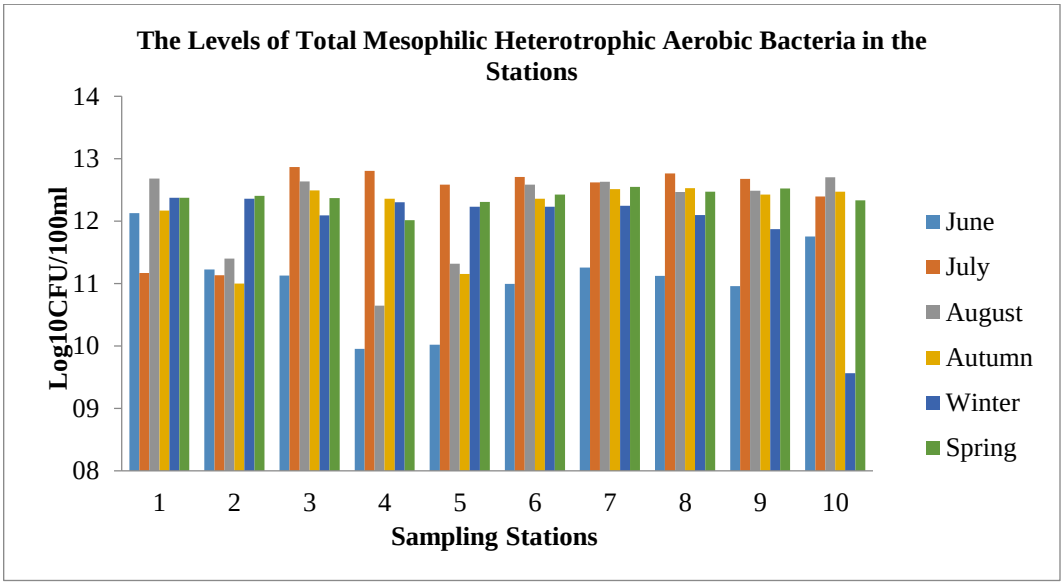

Fig. 5. The total mesophilic heterotrophic aerobic bacteria (HAB) in the stations.

Then all stations were compared, the lowest HAB was recorded in Station 10 in February 2019 as $36x10^8$ CFU/100 ml and the highest HAB value was found out to be $73660x10^8$ CFU/100 ml, measured in Station 3 in June 2018.

The levels of dissolved oxygen, temperature, salinity and pH values were shown in Table 3. The levels of Nutritional salts (nitrite, nitratei ammonium, total phosphorus) and Chlorophyll-*a* values were shown in Table 4. The correlation co-efficient for the comparison of the variable parameters with stations was shown in Table 5

Correlation co-efficient are analyzed for the comparison of the variable parameters with stations, a high level relevance between the ones marked with bold were detected (Table 5). The levels of total heterotrophic bacteria and indicator bacteria did not display a significant change related to the seasons and stations ($p > 0,01$).

While the values of temperature, pH, dissolved oxygen and salinity, which are environmental variable parameters, showed a significant difference between the seasons ($p<0.01$), they did not show a significant difference related to stations ($p>0,01$).

Nitrate, nitrite and ammonium nitrogen values showed a significant difference according to the seasons ($p<0.01$), However, there is no significant difference among the stations ($p>0.01$).

Phosphorus levels did not show a significant change according to the seasons and the stations ($p > 0.01$).
It was determined that chlorophyll-a levels displayed significant difference with respect to the seasons ($p<0.001$), but no significant difference between the stations ($p>0.001$).

Table 3. The levels of max–min and mean-SD values environmental variable parameters during the study (SD:Standard Deviation)

Seasons	T (◦C)		Salinity (‰)	Ph	DO (mg/l)
	Max-Min /	Mean ± SD	Max-Min / Mean ± SD ±SD	Max-Min / Mean	Max-Min / Mean ± SD
Summer (June 28)	23,32 - 21,44	/22,7 ± 0,65	22,84 -22,57/ 22,7 ±0,07	10,00 -7,87 /8,7 ± 0,7	7,96 - 4,13 /6,8 ± 1,2
Summer (July 24)	25,07 - 24,36	/ 25 ± 0,38	21,98 - 21,18/ 21,6 ± 0,2	8,94 - 7,25 /7,8 ± 0,5	7,44 - 1,66 /5,4 ± 1,4
Summer (August31)	25,69 - 22,56	/ 22,3 ± 0,67	23,37 - 22,8/ 23,2 ± 0,2	11,55 - 9,22/ 10,2 ± 0,8	7,80 - 4,44 / 5,7 ± 1,01
Autumn	17,51 - 16,66	/ 17 ± 0,31	24,91 - 23,12/ 24,6 ± 0,5	9,66 - 9,02 / 9,1 ± 0,1	19,98 - 2,46 /9,7 ± 5,2
Winter	8,72 - 6,89	/ 8 ± 0,52	29,07 - 21,68/ 27,1 ± 2,7	- -	10,92 - 6,98/ 8,1 ± 1,07
Spring	17,68 - 15,58	/ 16,6 ± 0,79	24,22 - 22,79/ 21,1 ± 0,4	- -	11,69 - 6,43/ 8,07 ± 1,5

Table 4. The levels of Nutritional salts max-min and mean-SD (ammonium, total phosphorus, nitrite, nitrate) and chlorophyll-a values during the study.

Season (µg/l)	N–NO2 Max-Min / Mean ± SD	N–NO3 Max-Min / Mean ± SD ± SD	N–NH4 Max-Min / Mean	P–PO3 Max-Min /Mean ± SD	Ch-a Max-Min /Mean ±SD
Summer (June 28)	0,18 - 0,02 / 0,045 ± 0,049	7,79 - 0,88/ 3,97 ± 3,12	4,80 - 0,48/ 1,6 ± 1,24	1,38 - 0,08/ 0,42±0,39	3,86 - 2,64/ 3,22 ± 0,40
Summer (July 24)	0,12 - 0,01 / 0,049 ± 0,034	8,9 - 1,02/ 4,43 ± 3,37	3,2 - 0,19/ 0,86 ± 0,92	0,87 -0,45/ 0,76 ± 0,12	8,18 - 3,59 /4,52 ±1,39
Summer(August 31)	0,24 - 0,01 / 0,045 ± 0,069	8,01 - 0,46 /3,55 ± 2,96	1,82- 0,71 / 1,12 ± 0,38	0,97 - 0,10/ 0,67 ± 0,33	4,70 - 4,05/ 4,39 ± 0,23
Autumn	0,08 -0,01 / 0,036 ± 0,022	1,18 - 0,51/ 0,8 ± 0,37	1,29 - 0,02/ 0,51 ±0,33	22,45 -0,00 /2,79 ±6,97	4,70 - 4,05 / 6,22 ± 2,01
Winter	0,04 - 0,00 / 0,019 ± 0,011	6,02 - 0,13/ 1,12 ±1,74	0,46 - 0,30 /0,37 ± 0,04	0,75 - 0,05 /0,23 ± 0,18	4,70 -4,05 / 0,07 ±0,06
Spring	0,22 - 0,21 / 0,211 ± 0,03	9,90 - 8,08 / 9,5 ± 0,52	1,02 - 0,34/ 4,46 ±12,4	2,93 - 0,03 / 0,8 ± 0,87	4,70 - 4,05 / 6,14 ± 3,14

Table 5. The correlation co-efficient for the comparison of the variable parameters with stations. (HAB: The total mesophilic heterotrophic aerobic bacteria, TC: Total Coliform, FC: Fecal Coliform, IS: Intestinal Streptococci, DO: Dissolved Oxygen)

			HAB	TC	FC	IS	°C	pH	DO	‰	NO3	NO2	NH4	PO4	Ch-a
Spearman's rho	HAB	Cor. Coe.	1,000												
		Sig. (2-tailed)	.												
		N	40												
	TC	Cor. Coe.	,035	1,000											
		Sig. (2-tailed)	,833	.											
		N	40	40											
	FC	Cor. Coe.	,232	**,498****	1,000										
		Sig. (2-tailed)	,150	**001**	.										
		N	40	**40**	40										
	IS	Cor. Coe.	,107	,364*	**,541***	1,000									
		Sig. (2-tailed)	,509	,023	**,000**	.									
		N	40	40	**40**	40									
	°C	Cor. Coe.	,355*	,371*	**,439****	,371*	1,000								
		Sig. (2-tailed)	,024	,020	**,005**	,019	.								
		N	40	40	**40**	40	40								
	pH	Cor. Coe.	,118	,354*	,301	**,457****	,446**	1,000							
		Sig. (2-tailed)	,467	,027	,059	**,003**	,004	.							
		N	40	40	40	**40**	40	40							
	DO	Cor. Coe.	-,331*	**-523****	**-496****	-,388*	**-,559****	**-,550****	1,000						
		Sig. (2-tailed)	,037	**,001**	**,001**	,013	**,000**	**,000**	.						
		N	40	**40**	**40**	40	**40**	**40**	40						
	‰	Cor. Coe.	-,338*	-,096	-,203	-,178	**-,670****	-,174	,401*	1,000					
		Sig. (2-tailed)	,033	,560	,210	,271	**,000**	,282	,010	.					
		N	40	40	40	40	**40**	40	40	40					
	NO3	Cor. Coe.	**,470****	,019	,155	-,148	,218	-,396*	-,201	**-,479****	1,000				
		Sig. (2-tailed)	**,002**	,908	,339	,361	,177	,011	,213	**,002**	.				
		N	**40**	40	40	40	40	40	40	**40**	40				
	NO2	Cor. Coe.	,343*	,061	-,065	-,319*	,155	-,344*	-,119	-,201	**,766****	1,000			
		Sig. (2-tailed)	,030	,710	,690	,045	,340	,030	,463	,213	**,000**	.			
		N	40	40	40	40	40	40	40	40	**40**	40			
	NH4	Cor. Coe.	,234	,371*	**,543****	**,448****	**,616****	,241	**-,525****	**-,551****	,368*	,254	1,000		
		Sig. (2-tailed)	,146	,020	**,000**	**,004**	**,000**	,135	**,001**	**,000**	,019	,113	.		
		N	40	40	**40**	**40**	**40**	40	**40**	**40**	40	40	40		
	PO4	Cor. Coe.	,308	,066	,074	,071	,307	-,014	-,036	-,248	,275	**,451****	,285	1,000	
		Sig. (2-tailed)	,053	,690	,650	,663	,054	,929	,826	,123	,086	**,003**	,075	.	
		N	40	40	40	40	40	40	40	40	40	**40**	40	40	
	Ch-a	Cor. Coe.	,326*	,028	,098	-,003	**,438****	,175	-,303	-,160	,278	,401*	,122	,381*	1,000
		Sig. (2-tailed)	,043	,869	,553	,986	**,005**	,286	,061	,332	,087	,011	,461	,017	.
		N	40	40	40	40	**40**	40	40	40	40	40	40	40	40

**. Correlation is significant at the 0.05 level (2-tailed).*

***. Correlation is significant at the 0.01 level (2-tailed).*

Cor. Coe. Correlation Coefficient

Discussion and Conclusion

Kınalıada, one of the Prince Islands, is located on the coast of the Sea of Marmara. The studies reported on bacterial levels around the Prince Islands of the Sea of Marmara are very limited.

It has been reported that total and fecal coliform concentrations are correlated with each other and the reasons for the spread of coliform bacteria to the region are related to deep water discharge and water flow around the Prince Islands. (Turkdogan- Aydınol et al., 2011).

Although the occasional decreases and fluctuations, the levels of indicator bacteria were reported above the national limit values in a monitoring study, conducted in the coastal areas of Istanbul and around the Prince Islands of the Sea of Marmara in the period between 2000 and 2016. (Altuğ et al 2016 b).

In this study, indicator bacteria and heterotrophic aerobic bacteria, isolated from the seawater samples, taken from the surface and their interactions with variable environmental parameters, nutrient salts and chlorophyll-a values were investigated.

The obtained data analyzed in terms of the national and international water quality standards. According to the National Primary Drinking Water Regulations published on December 31, 2004, the standard values that the sea water, used for recreational purposes should provide are as follow; 1000 CFU/100 ml (3,0/100 ml. acc. log10) for total coliform, 200 CFU/100 ml (2,3 / 100 ml. acc. log10) for fecal coliform and 100 CFU/100 ml (2,0 / 100 ml. acc. log10) for intestinal streptococcus (Gazette, 2004). Furthermore, the standard values for the Directive 2006/7/EC of the European Parliament are 500 CFU/100 ml (2,69 / 100 ml. acc. log10) for total coliform, 100 CFU/100 ml (2,0 / 100 ml. acc. log10) for fecal coliform and 100 CFU/100 ml (2,0 / 100 ml. acc. log10) for intestinal streptococci (European Parliament, 2006)

The annual mean values obtained in this study are 29,466,000 CFU/100 for total coliform, 23,258,000 CFU/100 ml for fecal coliform, 3,473,000 CFU/100 ml for intestinal streptococcus is above the national and international limit values. When the distribution of these data according to the stations is evaluated, it has been determined that the 1th station - public beach has the highest pollution rate. The first station is in the area where the settlement of the island is dense the presence of motor piers and fishing shelters in the vicinity thought to cause it

Studies in coastal areas all over the world are related to human activities in marine environments depending on pointed and non-pointed pollution sources; domestic, industrial and ship-borne wastes entering the environment by sea, bacteria are considered as an indicator of contamination and the presence of potentially pathogenic bacteria (Ashbolt, 2001).

When the bacteriological studies carried out in the coastal regions of the Turkish Seas were evaluated, it was determined that the indicator bacteria levels were considerably above the limit values, in July, August and September, in the Güllük Bay (Aegean Sea). Regarding bacteriological pollution, it has been determined that point and point source pollution affects the region (Kalkan and Altuğ, 2015).

In the studies regarding Sea of Marmara, the terrestrial originated bacterial pollution pressure was revealed especially in the coastal areas (Çevikol, 1982; Unat et al., 1986; Kaşgar, 1992; Kimiran, 1999; Aslan-Yılmaz, 2002; Sur et al., 2004; Çiftçi, 2008; Sivri, and Seker 2010; Zeki, 2012; Altuğ et al., 2010, 2013; Çardak and Altuğ 2014; Çardak et al., 2016; Gazioğlu, 2018; Çiftçi Türetken and Altuğ, 2016, Altuğ et al., 2016a, b).

Metabolically the amount of active bacteria is found that similarly high in stations where pollution is intense. In most stations where the FC/IS ratio is higher than 0.7, human-induced pollution is mentioned and the region is under pressure of human-induced pollution. Güllük Port and Sarıçay Stream has been found the biggest pollution factors in the study areas of the Aegean Sea (Altuğ et al., 2013).

Bacteriological pollution and marine areas are closely related to each other and water quality conservation is also decisive for human and ecosystem health.

In this study, according to the Water Pollution Control Regulation (ANON, 2004) when the nutrient salt values determined in the Kınalıada coastal area are examined that the region is classified between class I and class II. Increasing anthropogenic activity with regionally over population in summer months apart from pollution, adversely affects water quality in marine areas. In this study the finding above national limits in summer season supported this situation.

Nutrients in the Sea of Marmara was reported to be higher in winter than in spring and summer, although years were also pointed out differences between (ANON, 2018). In this study, the relatively high nutrient salt values detected in the summer months were found in the region shows the continuity of terrestrial source inputs.

In the Sea of Marmara surface waters within the scope of "Integrated Marine Pollution Monitoring Study" in which chlorophyll-a levels were compared between 2014 and 2017, the highest value (>4 µg/L) was detected in Bandırma and Izmit Bay in summer (ANON, 2018). In this study, the lowest chlorophyll-a level was in the 2nd and 4th stations in winter samples, the lowest chlorophyll-a was measured as 0.01 µg/l at the station 2 and maximum level was 13.22 µg/l at the 4th station. High chlorophyll-a concentration indicates a tendency towards eutrophication in the region.

The maximum chlorophyll-a value in the Sea of Marmara was determined as $41{,}6.10^{3}$µg/l (Dursun et al.,

2021). In this study O_2 value which was found as 19.98 mg/ with microalgae increase evaluated a point possible.

Statistical relationship and positive correlation between the temperature and the high bacteria levels have been evaluated as the indirect effects of the increase of human activities and population in summer season in the study region.

In this study, the first bacteriological data were provided in terms of levels of indicator bacteria and heterotrophic aerobic bacteria in the coastal area of Kınalıada. Despite some fluctuations throughout the year, indicator bacteria which are imply occurrence of the pathogenic bacteria and the continuity of the polluting sources indicates a significant potential threat for the region.

The obtained data in this study contributed the regional bacteriological knowledge for Kınalıada region of the Sea of Marmara. There is need long-term monitoring studies for the protection of the region and it is necessary to take urgent measures to control the pollution pressure caused by appears to be inevitable.

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