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RESEARCH PAPER

Assessment and classification of water quality using different water quality indices in the coastal waters of Eastern Aegean Sea

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Abstract

The water quality monitoring in coastal areas of Aegean Sea interpreted through indices provides easy to understand and simple information for coastal managers and the general public. The Coastal Water Quality Index (CWQI) synthesizes the status of the eight water quality indicators such as chlorophyll *a*, total nitrogen, ammonium, nitrate+nitrite, total phosphorus, pH, dissolved oxygen; and fecal coliform into a single indicator of water quality. The CWQI compares measured variables to standard values. Seawater samples at 14 sampling points between 2014 and 2015 from Güllük Bay, Akköy and Ildır Bay of the Aegean Sea (eastern Mediterranean), have been analyzed seasonally in the current study. Investigation of environmental parameters demonstrated unsuitable water quality in some stations from Güllük Bay and Akköy. The anthropogenic inputs may be the likely reason for unsuitable water quality. However, generally good water quality was observed at Ildır stations indicating suitability of those areas for human activities like recreation. Furthermore, fecal contamination risk was detected at some stations in Akköy and Ildır.

Introduction

Various physical, chemical and biological processes mainly influence the coastal environment, as a complex system. Water quality affects both directly and indirectly the species abundance and diversity of marine living communities as well as recreational use of the coast. Excessive nutrient inputs, red tides and cyanobacteria (harmful algal bloom) are the main environmental problem affecting the coastal regions in the world (Anderson et al., 2002).

Decrease in water quality is primarily owing to the increased levels of several contaminants such as heavy metals, petroleum hydrocarbons, pesticides and nutrients (Shahidul & Tanaka, 2004) giving rise to turbidity (Orpin et al., 2004) and a considerable fall in dissolved oxygen concentrations (Sanchez et al., 2007). The primary productivity and sustainability of marine ecosystems mostly rely on the coastal water quality. It is a measure of the status of water concerning the needs of one or more biotic species and or to any human requirement or goal (Johnson et al., 1997). Thus, monitoring programs of marine environment play an important role in water quality management.

To maintain the sustainability of any aquaculture system at an optimal level, it is essential to monitor and verify specific water quality variables or indicators. Water quality variables such as dissolved oxygen, pH, ammonium, total nitrate+nitrite, chlorophyll-a, total phosphorous, fecal coliform (FC) and fecal streptococci (FS) are the health indicators of coastal regions. The widely used indicators are FCs of the contamination sewage and run off from agricultural lands. Furthermore, fecal coliforms (FC) are used as another fecal indicator, which are present in substantial quantities in animal and human intestines. Regular monitoring of FC is necessary to maintain sanitation standards in recreational activities. (Chigbu et al., 2004; Kim et al., 2005; Kacar, 2011).

Nevertheless, a coastal water quality index (CWQI) briefs large amounts of water quality data into simple terms (e.g., bad, good, excellent etc.) to provide regular information for managers and the public (Hulya, 2009). A coastal water quality index gives a single number that explains whole water quality at a particular area and period, depending on various water quality parameters. The coastal Water Quality Index (CWQI) can be used as a tool to compare the water quality of various sources for the general understanding on potential water issues of a specific area. These indices are among the most effective methods to communicate information regarding water quality trends for the purposes of water quality management (Jagadeeswari & Ramesh, 2012).

Investigations have been performed to evaluate the water quality of Eastern Aegean coasts (Kontas et al., 2004; Kucuksezgin et al., 2005; 2019; Yucel-Gier et al., 2007; 2010; 2018; Aydin-Onen et al., 2012; Kalkan & Altug, 2015). However, they have not enumerated the CWQI on this coast with seasonal variations and this study suggests an original technique by combining CWQI and eutrophication assessment using different indices for sustainable management of marine and coastal resources. The CWQI takes complex scientific data of measured variables and integrates into a single number based on the suggested level to obtain important information that is easily comprehensible by the administrator and coastal policy managers.

The study was conducted to determine the Coastal Water Quality Index (CWQI) for assessing the quality of coastal waters in western Turkey based on physical, biological, and chemical water quality variables. Recommended standards were used to monitor concentrations, spatial and temporal variability of chlorophyll, nutrients, physical parameters.

Chl-a was also examined to determine the trophic state of three different sampling regions using the Eutrophication Index (E.I.) and Chl-a biomass classification scheme. The study aimed to assess E.I. as a simple and reliable tool for better environmental management practices in the coastal bays. Additionally, the study examined the bacterial quality of these waters and develop gauge information that will help in future water management and environmental protection

Materials and Methods

Güllük Bay

Study area and sampling points in three different regions of east coast of Aegean Sea are showed in Figure 1. To summarize pollution source in Gulluk Bay, firstly, the increasing number of summer houses around the Bay of Güllük, along with the presence of Bodrum-Milas airport, the discharge of the domestic wastewater of the Milas settlement, the transport of waste waters through the Sarıçay Stream, as well as the discharge of olive processing facilities are all contributing factors to the pollution of Güllük Bay. Furthermore, dust clouds formed by trucks transporting mineral materials are also a significant source of pollution. Despite these challenges, Güllük port continues to export bauxite, feldspar minerals, marble and fish to various countries in Europe. The powders formed by the feldspar mine during the transportation of the mines by the trucks have negative effects on the flora and fauna around the Bay of Güllük. Lastly, in the summer months, recreational and boating activities also have negative impact on the coasts. Approximately 133 soil ponds (seabass and seabream production) are present in the vicinity of the Güllük Lagoon. Most of the fish farms that are in operation are using the water of Güllük Lagoon in their own enterprises and discharge the output waters of the enterprises to Güllük Lagoon (Özdemir et al., 2013). Güllük Bay has become one of the riskier areas for the occupation of the invasive species in the eastern Aegean coasts due to the increased ship traffic.

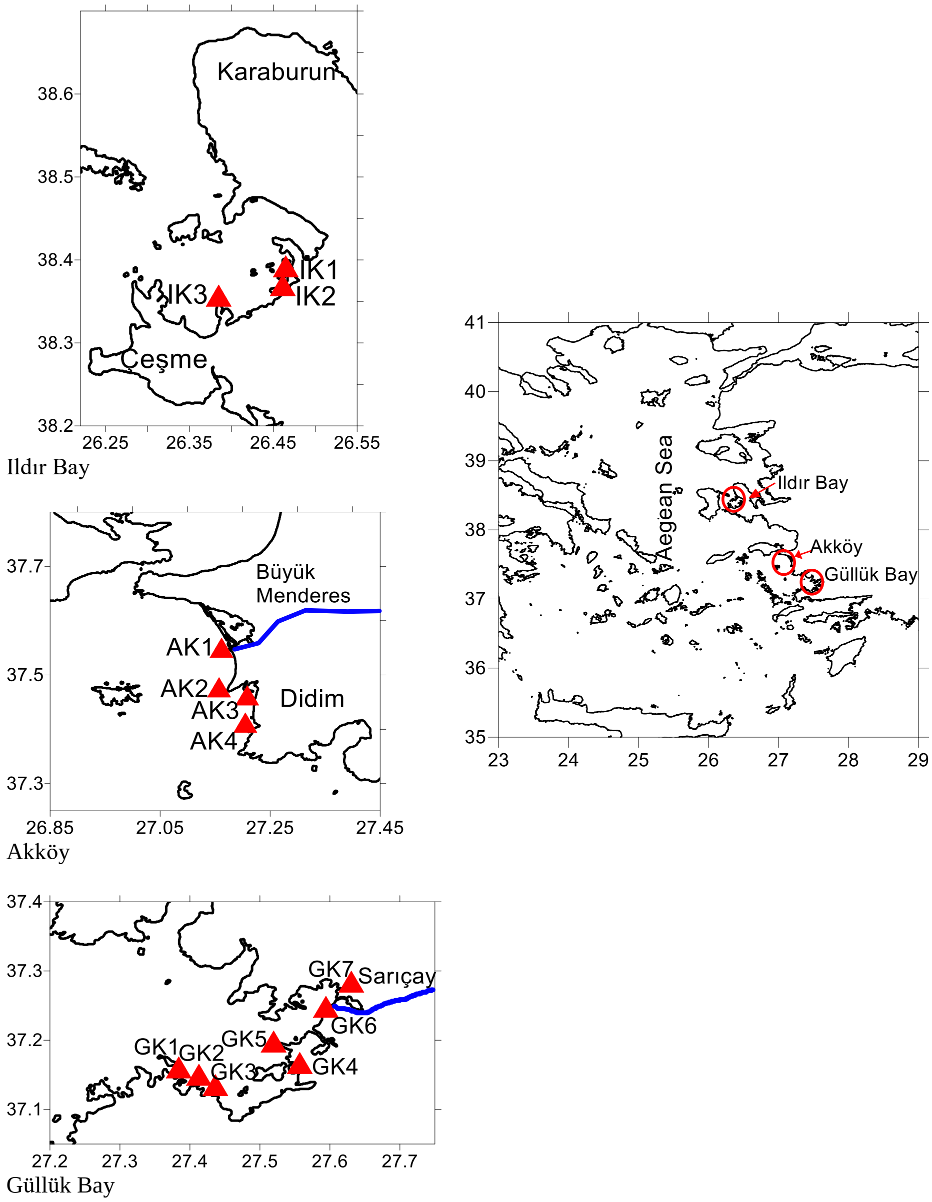

Figure 1. Map showing sampling stations in three different regions from eastern coast of Aegean Sea, Turkey

Akköy

Akköy has no dense settlements, no industrial facilities, but there is a residential area in Yalıköy. Didim is the closest settlement area to the fish farm in Akköy. The most important input including domestic, industrial and agricultural activities along the Akköy coasts is the Büyük Menderes River.

The Büyük Menderes River is the longest river that flows into the Aegean Sea, with a length of 548 km (Figure 1). In a study carried out on the Büyük Menderes River, it was determined that the FC was 50-2.2x10^4 cfu/100 ml and the FS ranged from 3-1.2x10^3 cfu/100 ml (IMST-165, 2009). The study's findings indicate that the discharge of Büyük Menderes River into the Aegean coast is contributing to an increase in fecal pollution. Domestic, agricultural and industrial wastewaters are the pollution sources. Among the rivers flowing into the Aegean Sea, the Büyük Menderes River has the lowest ammonium load. This result shows that industrial pollution is more effective than domestic borne pollution (IMST-165, 2009).

Ildır Bay

Ildır Bay located between Çeşme and Karaburun Peninsulas which is one of the most intensive aquaculture regions in the coast of Aegean Sea of Turkey (Figure 1), with some islands situated at the outer part of the bay (Bengil, 2011). The islands of Ildır Bay have been designated as an Important Nature Area. In the southern part of the bay, there are tourist facilities, large hotels, and summer houses. Ildır Village also has a dense non-residential area. Gerence and Ildır Bay are home to aquaculture facilities, and there is no industrial activity in the area. These facilities yield a total of 15,690 tons of aquaculture fish annually through 20 different facilities in Ildır Bay. (Bengil, 2011).

Sampling and Analytical Procedures for Physical and Chemical Variables

Figure 1 illustrates the research area and sampling sites located between the latitudes 38°21'–38°41' N and longitudes 26°30' - 27°08' E. In order to measure the physical properties of the water samples (e.g., temperature, pH, salinity), a mobile device (HACH HQ4OD) was utilized. Sample collection was conducted during the months (April–July-October-February) of 2014-2015 from three different regions of the eastern Aegean coast. Samples of surface water were obtained by Nansen bottle for chlorophyll-a (Chl-a), dissolved oxygen and nutrients at a depth of 0-0.5 m. 100 ml glass bottles were used in order to determine dissolved oxygen (DO) in the water samples; certain fixing chemicals were added and then DO was measured by Winkler titrimetric method (APHA-AWWA-WPCF, 1980). Entire samples were prefiltered through 210 µm nylon mesh put in a funnel in order to remove the larger particles (e.g., meso-zooplankton which would otherwise have created errors). Water samples (n=3) analyzed for nutrients and Chl-a were filtered instantly using Whatman GF/F filters and kept frozen. In order to extract Chl-a from water samples, 90% acetone solution was used and spectrophotometric method was performed for the determination of Chl-a (Stricland & Parsons, 1972). Analysis of dissolved inorganic nutrients (ammonium (NH_4), nitrate+nitrite (TNO_x), ortho and total phosphate ($o.PO_4$, TPO_4)) was conducted within 1 week using Skalar (two-channel) Autoanalyzer applying the standard colorimetric methods in accordance with Strickland & Parsons (1972). Analytical methods used for nutrients were checked using intercalibration seawater samples (from QUASIMEME, Plymouth Marine Laboratory, AQ1 nutrients in seawater, 2015.1 and 2015.2). The values obtained for the analyses of 10 replicates of this sample (certified; observed values in µM±standard deviation) were as follows: TNO_x-N

(2.41±0.17; 2.42±0.12), NH_4-N (0.99±0.11; 1.1±0.12), o.PO_4-P (0.32±0.04; 0.29±0.01), Total PO_4-P (0.44±0.05; 0.50±0.07).

Analysis of Fecal Indicator Bacteria

Fecal indicator bacteria (fecal coliforms, FC and streptococci, FS) were counted by standard methods (APHA, 1998). The membrane filter method was utilized for the counting of indicator bacteria. For analyses of FCs, the water samples were diluted and filtered. Membrane filters were put into 50 mm petri plates including m-FC broth and incubated for 24 h at 44.5°C. FS were found via the same method. Membrane filters were put into the petri plates including Azide Dextrose broth and incubated at 37.5°C for 24-48 h (APHA, 1998). The reference value for FSs and FCs cfu per 100 ml of seawater sample should not be more than 100 and 200, respectively in accordance with the Quality of Swimming Water Regulation (76/160/EU The Official Gazette, 2006) in Turkey.

Calculation of Coastal Water Quality Index (CWQI) of Coastal Waters of Eastern Aegean

In order to define whole status of water quality in an easy and comprehensible manner, the water quality index was used as an important tool (Mahuya et al., 2001; Gupta et al., 2003). To that end, eight major water quality indicators (e.g., DO, pH, NH_4, NO_3, TN, TP, Chl-a and fecal coliform) at three different regions of study area were chosen which are commonly utilized in seawater analysis. The CWQI was calculated by using weighted arithmetic water quality index method which was originally suggested by Horton (1965), created by Brown et al. (1972) and then by Cude (2001). Individual water quality parameters are multiplied by a weighting factor found for each variable and summed using the simple arithmetic mean formula in accordance with this method. The CWQI is calculated as per the quality standards and permissible limits for coastal waters recommended by the USEPA (1986), Jones et al. (2004), Stevenson et al. (1993), Anonymous (2003), COMAPS (2012), Dennison et al. (1993). Calculation of CWQI is carried out by the Weight Arithmetic Index method, using the equations as follows:

$$WQI_A = \sum_{i=1}^{n} w_i q_i / \sum_{i=1}^{n} w_i = \sum_{i=1}^{n} Sl_i / \sum_{i=1}^{n} w_i \quad (1.1)$$

Where n is the number of variables, w_i is the relative weight of the i^{th} variable and q_i is the water quality rating of the ith variable. The unit weight (w_i) of the several water quality variables is conversely proportional to the suggested standards for the related variables. The value of q_i computed using the equation given below according to Brown et al. (1972):

$$qi = 100\,[(Vi - Vid)/(Si - Vid)] \quad (1.2)$$

Where V_i is the detected value of the ith variable, Si is the standard allowable value of the ith variable and Vid is the ideal value of the ith variable in sea water. All the ideal values (Vid) are accepted as zero for sea water except dissolved oxygen and pH (Tripaty and Sahu 2005). The ideal value is 8.2 (the mean pH for sea water) for pH and a allowable value is 8.5 for contaminated water. Accordingly, the quality rating for pH is computed from the equation as follows:

$$qpH = 100\,[(VpH - 8.2)/(8.5 - 8.2)] \quad (1.3)$$

where VpH = measured value of pH.

The ideal value is 9.0 mg l^{-1} for dissolved oxygen and the standard permitted value for sea water is 5 mg l^{-1}. Thus, its quality rating is computed from the equation as follows:

$$qDO = 100\,[(VDO - 9.0) / (5.0 - 9.0)] \quad (1.4)$$

where VDO = measured value of dissolved oxygen.

Statistical Analysis

The statistical data analysis was performed using STATISTICA (v.8.0 software package). The distribution of data was controlled using Kolmogorov-Smirnov test and Levene's test was applied to control homogeneity of the variances. Spearman's Rank Order correlation test was applied to detect important correlations between variables.

Then, if required the transformation of data was carried out. One Way ANOVA was utilized to find out the impact of sampling season and stations on changes in different variables. Following ANOVA, statistically significant differences were explained using post-hoc Tukey's HSD test for unequal group size ($p<0.05$). In all tests, the significance level was taken as $p<0.05$. A principal component analysis (PCA), on the basis of Pearson's correlation matrix, was performed to investigate the relationship between the observed variables at the sampling stations and periods in the study area.

Assessment of Eutrophication

The eutrophication quality of the selected coastal areas of Turkey was assessed using different tools applied in the oligotrophic waters of the Eastern Mediterranean coastal areas: eutrophication index (E.I.) (Primpas et al., 2010); and Chl-a biomass classification scheme (Simboura et al., 2005; Pagou et al., 2002).

The E.I. was calculated according to the following equation (Primpas et al., 2010):

$$E.\ I. = 0.279*C_{PO4} + 0.261*C_{NO3} + 0.296*C_{NO2} + 0.275*C_{NH4} + 0.261*C_{Chl\text{-}a}$$

where C_{PO4} is the concentration of phosphate; C_{NO3} is the concentration of nitrate; C_{NO2} is the concentration of nitrite; C_{NH4} is the concentration of ammonium (nutrient concentrations for E.I. calculation in mmol m^{-3}); $C_{Chl\text{-}a}$ is the concentration of phytoplankton Chl-a (in mg m^{-3}).

Results and Discussion

Physicochemical Variables

The quality of coastal surface waters related to physicochemical variables, including dissolved oxygen, temperature, pH, and salinity (Kucuksezgin et al., 1995). This study assesses the spatial and temporal variation of nutrients concerning these physicochemical variables. Table 1a-c reports the range and average values of these variables in three sampling regions in the coastal area of the Eastern Aegean Sea.

In coastal regions, sea surface temperature (SST) may be affected by variability in air temperature. SST varied from 14.4°C in winter (GK2, GK3) to 29.0°C in summer (GK7), from 14.0°C in winter (AK4) to 30.9°C in summer (AK3), from 16.4°C in winter (IK3) to 26.4°C in summer (IK1) in Güllük Bay, Akköy, Ildır Bay, respectively. Besides, salinity varied between 13.6 psu in fall (GK6) and 39.9 psu in spring (GK1, GK4), between 1.7 psu in fall (AK1) and 40.6 psu in summer (AK3), between 31.9 psu in fall (IK1) and 39.9 psu in summer (IK1). Consequently, the annual means of sea surface salinity in Güllük, Akköy and Ildır regions were found to be 36.7, 32.9 and 37.6 psu, respectively. Due to the fact that freshwater inputs via rainfall, creeks and runoff in coastal zones, salinity decreased to lower values particularly in fall whereas the highest salinity levels were observed during the summer when higher temperatures increased levels of evaporation in the bays.

Dissolved oxygen concentration in surface water is impacted by temperature since the levels of DO increases in cold water than warm water. Consequently, the dissolved oxygen concentration is high when the water temperature is low in winter. In the present study, the maximum DO concentrations (8.89, 9.60, 8.27 mg l^{-1}) were measured in winter 2015 in GK7, AK1 and IK3, respectively. Whereas lowest oxygen concentration (3.33 mg l^{-1}) was determined in summer 2014 (AK1), relatively higher oxygen concentrations (6.03 and 6.18 mg l^{-1}) were observed in spring 2014 (GK4) and fall 2014 (IK3), respectively. Relying on the water temperature requirements for certain marine species at several life stages, the water quality criterion for DO values varied between 5.0 and 9.5 mg l^{-1}, i.e., a minimum dissolved oxygen level of 5-6 mg l^{-1} for warm water living organisms. Additionally, descriptor 5, oxygen deficiency is a sign of the negative effect of human-induced eutrophication as stated by the Marine Strategy Framework Directive (MSFD, 2010).

The pH values ranged between 7.71 in winter (GK6) and 8.25 in winter (GK2), 7.74 in summer (AK1) and 8.35 in summer (AK3), and 7.92 in spring (IK2) and 8.23 in summer (IK3). pH values indicated temporal variation throughout the sampling periods (Table 1a-c). The seasonal pH values detected in Güllük and Ildır stations were as follows: summer>winter>fall>spring, whereas the pH of seawater in Akköy was as follows: spring> summer> winter> fall.

In summer 2014, the lowest oxygen concentration (3.33 mg l^{-1}) with the lower pH value (7.74) represented the advanced stage of eutrophic condition in Büyük Mendere River Estuary (AK1). This finding showed that degradation of organic matter lowered pH and DO and increased the levels of inorganic nutrients. High amount of organic material loadings can be associated with domestic wastes.

Table 1a. Summary statistical results of sea water quality parameters during 2014-2015 in the coasts of Güllük Bay

Güllük Bay	**GK1**		**GK2**		**GK3**		**GK4**		**GK5**		**GK6**		**GK7**		**Annual Mean**
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	
Temperature (°C)	15.2-26.2	20.0	14.4-26.0	19.7	14.4-26.6	19.7	15.1-28.4	21.3	15.0-28.6	21.3	15.0-28.9	21.8	15.5-29.0	22.3	20.9
Salinity (psu)	38.7-39.9	39.3	37.7-39.7	39.1	39.0-39.6	39.3	39.2-39.9	39.5	39.2-39.8	39.5	13.6-23.9	17.2	38.5-38.9	38.7	36.1
pH	8.04-8.20	8.13	7.98-8.25	8.13	7.95-8.21	8.13	8.01-8.20	8.13	7.90-8.20	8.09	7.71-8.00	7.81	8.08-8.20	8.14	8.08
DO (mg l^{-1})	6.55-7.90	7.08	6.27-7.52	6.87	6.64-7.94	7.05	6.03-8.72	7.08	6.26-8.21	7.05	6.05-8.17	6.97	6.21-8.89	7.23	7.05
TPO_4 (µM)	0.16-0.24	0.19	0.07-0.29	0.16	0.09-0.33	0.16	0.10-0.19	0.13	0.15-0.30	0.22	0.99-3.06	1.82	0.36-0.42	0.39	0.44
TNO_x (µM)	0.84-5.21	2.53	0.40-1.74	0.98	0.63-3.86	1.54	0.36-1.85	1.16	0.79-1.29	1.13	16.2-51.5	39.0	2.38-2.97	2.76	7.01
NH_4 (µM)	0.52-2.54	1.22	0.10-1.94	0.73	0.54-2.14	1.15	0.43-3.50	1.75	0.61-38.1	10.5	0.48-12.0	6.46	0.55-2.75	1.77	3.36
TN (µM)	10.6-24.1	17.6	6.68-42.1	21.8	7.09-24.6	15.8	5.82-31.9	20.5	7.11-50.0	26.1	35.3-78.2	59.2	10.6-20.8	16.0	25.3
Chl-a (µg l^{-1})	0.22-1.93	1.08	0.32-1.10	0.62	0.34-0.90	0.54	0.46-1.36	0.85	0.46-1.84	1.15	1.36-11.7	4.81	1.34-1.70	1.48	1.50
FC (cfu/100 ml)	3-8	6	1-10	6	3-10	5	2-3	3	1-8	3	20-130	60	3-100	37	17
FS (cfu/100 ml)	1-8	4	1-10	4	1-8	4	1-7	3	1-3	2	5-20	12	3-78	30	8

Mean values (n = 4) are presented.

Table 1b. Summary of statistical results of sea water quality parameters during 2014-2015 in the coasts of Akköy

Akköy	**AK1**		**AK2**		**AK3**		**AK4**		**Annual Mean**
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	
Temperature (°C)	14.2-26.5	19.7	14.1-24.8	19.7	14.1-30.9	21.4	14.0-29.3	20.7	20.4
Salinity	1.7-38.9	13.55	38.9-39.5	39.2	38.7-40.6	39.6	38.9-39.6	39.2	32.9
pH	7.74-8.13	7.98	8.05-8.21	8.14	7.93-8.35	8.12	7.95-8.33	8.19	8.11
DO (mg l^{-1})	3.33-9.60	5.81	5.60-7.76	6.73	5.73-9.04	7.81	5.54-8.80	7.57	6.98
TPO_4 (µM)	3.11-11.6	7.86	0.19-0.33	0.29	0.28-0.47	0.39	0.19-4.24	1.24	2.45
TNO_x (µM)	14.0-198	86.0	0.57-2.92	1.25	2.04-16.0	5.82	0.09-35.3	9.33	25.6
NH_4 (µM)	12.3-54.8	28.1	0.67-3.73	1.61	1.29-9.26	4.69	0.90-2.01	1.52	8.98
TN (µM)	109-401	201	9.10-30.8	18.0	16.8-59.8	33.7	13.3-41.6	25.7	69.6
Chl-a (µg l^{-1})	1.76-9.76	4.96	0.33-1.83	1.24	0.66-3.04	1.57	0.11-1.12	0.78	2.14
FC (cfu/100 ml)	250-1300	825	3-120	45	100-250	155	1-100	49	268
FS (cfu/100 ml)	110-950	610	2-15	9	80-200	123	4-90	52	199

Mean values (n = 4) are presented.

Table 1c. Summary of statistical results of sea water quality parameters during 2014-2015 in the coasts of Ildır Bay

Ildır Bay	IK1		IK2		IK3		Annual
	Range	Mean	Range	Mean	Range	Mean	Mean
Temperature (°C)	16.4-26.4	20.9	16.8-26.2	20.9	16.4-24.5	20.5	20.8
Salinity	31.9-39.9	37.1	32.4-38.8	36.5	38.7-39.6	39.0	37.6
pH	8.04-8.20	8.11	7.92-8.19	8.06	7.98-8.23	8.12	8.10
DO (mg l^{-1})	6.26-8.16	7.45	6.24-8.17	7.34	6.18-8.27	7.25	7.35
TPO_4 (µM)	0.18-3.67	1.07	0.19-0.61	0.31	0.14-0.43	0.25	0.55
TNO_x (µM)	0.98-33.9	9.64	0.39-11.7	5.63	0.33-0.62	0.49	5.25
NH_4 (µM)	0.35-2.34	1.55	0.97-4.96	2.46	0.82-2.92	1.85	1.95
TN (µM)	6.31-83.8	33.1	13.1-42.4	29.0	5.03-19.6	14.7	25.6
Chl-a (µg l^{-1})	0.34-3.84	1.50	0.32-3.98	1.66	0.34-1.36	0.91	1.36
FC (cfu/100 ml)	15-30	23	200-750	415	1-3	1.9	146
FS (cfu/100 ml)	1-100	32	50-950	428	1-2	1	154

Mean values (n = 4) are presented.

Nutrients and Chlorophyll-a

Table 1a-c summarize the mean and range values of nutrient and Chl-a. In the Güllük Bay-Sarıçay, the highest (52µM) and the lowest (0.36 µM) concentrations of TNO_x were observed at GK6 and GK4 stations during 2014 fall and 2015 winter periods, with an annual average value of 5.95 µM, respectively. The most important stream reaching Güllük Bay is Sarıçay. The alluviums brought by Sarıçay filled an estuary that was flooded by the sea and formed a small plain with a length of 7-8 km. The estuary of Sarıçay may receive high nutrient loadings. Low primary production, maximum nutrient loads from riverine inputs, densely precipitation and also nitrogen fixation caused relatively higher TNO_x concentrations (Kucuksezgin et al., 2019). In Akköy region, TNO_x levels were found between 0.09 µM at AK4 and 198 µM at AK1 during summer and fall periods, with an annual mean value of 25.6 µM, respectively. Besides, AK1 station was situated in the mouth of Buyuk Menderes River. The amounts of TNO_x at Ildır Bay ranged from 0.33 µM (IK3) to 33.9 µM (IK1) during winter and fall sampling periods.

The minimum (0.10 µM) and maximum (38.1 µM) NH_4-N concentrations were measured during spring and fall periods with an annual mean value of 3.36 µM, respectively. Maximum value and minimum value of Güllük Bay were found at GK5 and GK2 stations, respectively. Moreover, NH_4-N concentrations varied from 0.67 µM at AK2 station to 55.0 µM at AK1 station during winter and spring periods, respectively. Furthermore, ammonium levels were 0.35-4.96 µM at IK1 (fall) and IK2 (summer), respectively.

The highest total nitrogen (TN) levels were measured at station GK6 (78 µM), AK1 (401 µM), IK1 (84 µM) during fall period in three different coastal regions. This can be attributed to rainfall in this sampling period. In general, inorganic nitrogen was predominant form of TN at stations GK6 (47-87 %) and AK1 (56-80 %) due to the river/stream inputs of NO_x whereas other stations contributed higher percentage of organic nitrogen (63-95%).

In terms of TPO_4-P concentrations, minimum level was observed at GK2 whereas maximum level was found at GK6 station located near the Sarıçay Stream in the Güllük Bay. TPO_4-P was found between 0.07 and 3.06 µM at Güllük Bay. In Akköy region sampling points, the lowest and highest values were observed in AK2 (0.19 µM) and AK1 (11.6 µM) situated in the estuary of the Büyük Menderes River with an annual mean value of 2.45 µM. While the lowest values were recorded in spring and winter periods, maximum concentrations were measured during fall and summer seasons at Güllük Gulf and Akköy. Concerning TPO_4-P levels in Ildır Bay, fall concentrations were higher than other sampling periods. Significant decrease in TPO_4-P concentrations were observed in IK3 during fall period as a result of increasing phosphate uptake by phytoplankton. Furthermore, TPO_4-P varied within a range of 0.14 µM at IK3 sampling point in fall to 3.67 µM at IK1 in fall. Consequently, the observed annual mean TPO_4-P concentrations were higher than coastal water quality values for coastal waters, a clear indication of the role of anthropogenic inputs along the coasts of the eastern Aegean.

Chlorophyll-a, which is one of the eutrophication indicators, is the most frequently used, simple and reliable indicator for phytoplankton biomass. In this study, minimum Chl-a levels in surface water samples from the study sites were found in winter due to low production whereas the highest Chl-a concentrations related to increased phytoplankton production were measured in summer for the entire sampling regions. Ildır Bay can be considered as mesotrophic condition as indicated by Chl-a (annual mean: 1.36 $\mu g\ l^{-1}$) concentrations according to Turkish legislation (The Official Gazette, 2012). Maximum Chl-a levels were found to be 9.8 $\mu g\ l^{-1}$ at AK1 station located at the estuary of Büyük Menderes River and to be 12.0 $\mu g\ l^{-1}$ at GK6 station near the mouth of Sarıçay Stream. These sampling stations are presented as eutrophic conditions depending on increasing nutrient input. When evaluated according to Chl-a content, Güllük Bay and Akköy have a similar trophic state with Ildır Bay except for AK1 and GK6 sampling points situated at the mouth of the streams.

According to Spearman Rank Order correlation test; temperature indicated positive correlations with total nitrogen ($r=0.38$, $p<0.05$) and Chl-a ($r=0.35$, $p<0.05$) whereas negative correlations were observed between dissolved oxygen and temperature ($r=-0.51$, $p<0.05$). No relationship was observed with temperature and salinity, pH, o-PO_4, TNO_x, NH_4, TPO_4. Salinity, pH and dissolved oxygen showed negative correlations with nutrients. This result showed that pH and DO decreased due to bacterial degradation of organic matter, while inorganic nutrients were released into the marine environment.

Microbiological Evaluation

Membrane filtration analysis indicated that fecal contamination risk was detected in two sampling stations in Akköy and one sampling station in Ildır Bay. The reference value for FSs and FCs cfu per 100 ml of seawater sample should not be more than 100 and 200, respectively in accordance with the Quality of Swimming Water Regulation (76/160/EU The Official Gazette, 2006) in Turkey. In addition, the highest FC ($1.3x10^3$ cfu/100 ml) and FS ($9.5x10^2$ cfu/100 ml) results were observed in the winter periods. Among the coastal stations in Akköy, especially in station AK1 located at the mouth of Büyük Menderes River, it was determined that there has been serious pollution in all period. Additionally, it was also found that there was a periodic fecal contamination in station AK3 and this station was located at fisher’s shelter. On the other hand, in the region of Ildır, there was no risk detected except for station IK2, which was close to the settlement area. Additionally, in the Güllük Bay, there was not observed a problem in respect to the microbial pollution. The agricultural fields, which are located in near the coastal areas and rivers, may affect the concentration of microbial pollution on seawater. Similarly, Crowther et al. (2002) reported that there was a correlation between fecal indicator concentration and agricultural activity. These results showed that there are inputs from domestic and agricultural pollution sources along the Güllük Bay coasts. Considering the findings of this study, it can be said that coast of the Aegean Sea should be monitored regularly in terms of sanitary standards.

Assessment of Coastal Water Eutrophication

The two different methods used for the eutrophication evaluation, the classes of eutrophication status, and the eutrophication range for the coastal areas of Güllük Bay, Akköy and Ildır Bay were reported in Table 2. The results showed that according to the E.I. 63% of the Akköy coast was characterized by bad eutrophication status. In addition, bad (31%) and poor (35%) status were observed in Güllük coast. Similarly, bad (42%) and poor (42%) status was identified in Ildır coasts (Table 3).

Table 2. Methodological tools and eutrophication range used for evaluation of the eutrophication status of the coastal regions of Güllük Bay, Akköy and Ildır Bay

Methods	Eutrophication Range	Eutrophication Status
Chl-a biomass classification[a,b]	<0.1	High
	0.1-0.4	Good
	0.4-0.6	Moderate
	0.6-2.21	Poor
	>2.21	Bad
Güllük Bay	0.22-11.71	Good-Bad
Akköy	0.11-9.76	Good-Bad
Ildır Bay	0.32-3.98	Good-Bad
E.I.[c]	<0.04	High
	0.04-0<0.38	Good
	0.38-0.85	Moderate
	0.85-1.51	Poor
	>1.51	Bad
Güllük Bay	0.37-11.96	Good-Bad
Akköy	0.56-61.12	Moderate-Bad
Ildır Bay	0.46-10.09	Moderate-Bad

[a]Simboura et al., 2005; [b]Pagou et al., 2002; [c]Primpas et al., 2010

Table 3. The eutrophication assessment of E.I. and Chl-a of Güllük Bay, Akköy and Ildır Bay

	E.I. (%)	Chl-a (%)
Güllük Bay	Bad (31) Poor (35) Mod. (31) Good (4)	Bad (4) Poor (62) Mod. (19) Good (15)
Akköy	Bad (63) Poor (19) Mod. (18)	Bad (25) Poor (56) Mod. (6) Good (13)
Ildır Bay	Bad (42) Poor (42) Mod. (16)	Bad (16) Poor (50) Mod. (9) Good (25)

The eutrophication assessment according to Chl-a levels, demonstrated that the sampling stations, Güllük, Akköy and Ildır are classified into poor status (62%, 56%, and 50%, respectively).

Table 4. Unit Index for coastal water quality variables

Variables	Standard Value	Unit Index (W_i)
pH	6.5-8.5[a]	0.0007
DO (mg l^{-1})	> 5[a, b]	0.0013
TP (mg l^{-1})	< 0.0371[c]	0.1698
NH_4 (mg l^{-1})	< 0.018[d, e]	0.3490
NO_x (mg l^{-1})	< 0.124[d], [e]	0.0507
TN (mg l^{-1})	< 0.650[c]	0.0097
Chl-a (mg l^{-1})	< 0.015[c], [f]	0.4188
FC (cfu/100 ml)	200-500[a], [d]	0.00003
		$\sum W_i$=1.00

[a]USEPA, 1986; [b]Jones et al., 2004; [c]Stevenson et al., 1993; [d]Anonymous, 2003; [e]COMAPS, 2012; [f]Dennison et al., 1993

Status of the Water Quality Index

The data regarding physicochemical parameters was collected during 2014 and 2015. Water quality index values indicated through the weighted arithmetic water quality index method were given in Table 4 and 5. Researches on water quality displayed considerable variations between the coastal environment exposed to pollution and the unpolluted locations. Statistical descriptions such as mean, maximum and minimum values of analytical results of physico-chemical parameters at different field station at eastern Aegean coast are given in Table 1a-c. During the study, the values of water quality parameters at the sampling areas (Güllük Bay, Akköy and Ildır Bay) are within the range of recommended standards (Table 4).

Table 5. Grades of Coastal Water Quality Index (CWQI) and status of Water Quality Rating

WQI	Category of Water Quality
< 50	Excellent
50-200	Good
100-200	Poor
200-300	Very Poor
> 300	Unsuitable

Table 6 demonstrates the coastal water quality index values of different sampling stations during sampling periods at the eastern Aegean coastline. The calculated values of CWQI for the studied variables in the present research were lower than 50 for the sampling stations of Güllük Bay which indicate excellent water quality, where minimal human intervention was observed. In sampling stations such as GK5 and GK6 recorded CWQI values in between 369-1270, indicating unsuitable quality of water. Human interventions like fishing, surfing and recreation activities are observed in these areas.

Table 6. Coastal Water Quality Index (CWQI) calculated in different sampling stations during sampling periods at the eastern Aegean coastline

Station	Period	q_{pH}	q_{DO}	q_{TP}	q_{NH4}	q_{NO3}	q_{TN}	$q_{Chl\text{-}a}$	q_{FCU}	**CWQI**	**Status**
Güllük Bay											
GK1	Spring	-53.3	54.8	14.0	79.1	149	6.41	12.9	2.50	41	Excellent
	Summer	-6.7	48.5	13.4	52.0	42.1	2.93	9.27	3.00	25	Excellent
	Autumn	-33.3	61.3	16.3	254	260	16.7	5.21	4.00	102	Poor
	Winter	0.0	27.5	19.7	104	55.1	4.61	1.47	1.50	41	Excellent
GK2	Spring	-73.3	50.5	5.69	10.0	26.9	1.16	7.33	5.00	9	Excellent
	Summer	-6.7	68.3	24.3	42.0	87.1	4.66	4.75	1.50	24	Excellent
	Autumn	-30.0	57.0	6.28	194	62.6	6.88	2.26	5.00	69	Good
	Winter	16.7	37.0	15.8	47.0	19.8	1.86	2.15	0.50	20	Excellent
GK3	Spring	-83.3	51.0	7.53	69.2	43.6	1.88	6.00	2.50	29	Excellent
	Summer	0.0	58.5	11.3	54.0	193	9.47	2.95	5.0	30	Excellent
	Autumn	-20.0	59.0	8.54	214	31.6	5.97	2.26	1.50	75	Good
	Winter	3.3	26.5	27.6	123	39.5	4.35	3.05	1.50	48	Excellent
GK4	Spring	-63.3	74.3	9.37	257	89.5	3.85	6.60	1.50	94	Good
	Summer	0.0	57.3	10.2	48.0	92.6	5.02	3.85	1.00	24	Excellent
	Autumn	-26.7	54.0	7.95	350	32.8	8.95	3.05	1.50	120	Poor
	Winter	-10.0	7.0	15.8	43.0	17.9	1.70	9.05	1.00	21	Excellent
GK5	Spring	-100.0	47.3	12.6	168	39.3	1.69	12.3	0.50	65	Good
	Summer	-16.7	68.5	12.3	61.0	64.5	4.09	7.69	0.25	29	Excellent
	Autumn	-26.7	59.5	24.7	3813	62.3	84.8	3.05	4.00	1270	Unsuitable
	Winter	0.0	19.8	23.7	142	60.8	5.68	7.58	1.00	57	Good
GK6	Summer	-66.7	57.5	82.9	48.0	811	36.0	78.1	65.0	100	Good
	Autumn	-163.3	73.8	256	1203	2575	137	9.05	10.0	568	Unsuitable
	Winter	-163.3	20.8	118	686	2460	121	9.05	15.0	369	Unsuitable
GK7	Summer	0.0	60.0	30.3	200	119	9.44	9.33	4.00	81	Good
	Autumn	-40.0	69.8	32.6	275	147	12.2	8.95	1.50	107	Poor
	Winter	-20.0	2.7	35.5	55.0	148	7.57	11.3	5.00	36	Excellent

Table 6. (continued)

Station	Period	q_{pH}	q_{DO}	q_{TP}	q_{NH4}	q_{NO3}	q_{TN}	q_{Chl-a}	q_{FCU}	**CWQI**	**Status**
Akköy											
AK1	Spring	-23.3	93.8	825	5480	700	148	35.1	425	1995	Unsuitable
	Summer	-153.3	141.8	969	2046	2757	163	65.1	125	993	Unsuitable
	Autumn	-96.7	98.3	578	2490	9875	479	20.5	450	1404	Unsuitable
	Winter	-26.7	-15.0	260	1230	3865	193	11.7	650	641	Unsuitable
AK2	Spring	-13.3	41.8	27.6	69.2	28.5	2.72	10.3	2.50	33	Excellent
	Summer	3.3	85.0	27.6	136	146	9.22	12.2	25.0	62	Good
	Autumn	-50.0	69.0	27.6	373	31.6	9.40	8.26	1.50	133	Poor
	Winter	-16.7	31.0	15.8	67.0	44.4	3.36	2.21	60.0	28	Excellent
AK3	Spring	0.0	35.0	23.4	129	102	7.17	12.5	125	56	Good
	Summer	50.0	3.50	36.3	194	155	10.8	20.3	60.0	86	Good
	Autumn	-73.3	81.8	32.6	926	106	24.5	4.75	50.0	319	Unsuitable
	Winter	-90.0	-1.0	39.4	626	801	47.9	4.42	75.0	254	Very poor
AK4	Spring	23.3	32.8	15.9	178	68.6	6.79	7.13	0.25	68	Good
	Summer	43.3	5.00	24.8	138	4.45	3.16	7.48	22.5	53	Good
	Autumn	-83.3	86.5	19.3	201	26.1	5.45	5.32	25.0	73	Good
	Winter	6.7	19.0	355	90.0	1766	78.0	0.74	50.0	173	Poor
Ildır Bay											
IK1	Spring	-53.3	36.5	17.8	198	75.2	7.50	9.33	15.0	76	Good
	Summer	0.0	68.5	14.9	234	49.0	7.15	25.6	10.0	93	Good
	Autumn	-50.0	29.3	307	35.0	1696	73.8	2.95	7.50	144	Poor
	Winter	-16.7	21.0	19.7	152	107	7.89	2.26	12.5	60	Good
IK2	Spring	-93.3	32.3	20.3	237	286	17.4	10.1	125	100	Good
	Summer	-33.3	69.0	17.0	496	235	20.8	26.5	230	189	Poor
	Autumn	-56.7	43.8	51.1	152	584	34.9	5.42	375	89	Good
	Winter	-3.3	20.8	15.8	97.0	19.6	2.93	2.15	100	37	Excellent
IK3	Spring	-73.3	46.8	35.7	168	31.2	4.96	4.73	0.25	65	Good
	Summer	10.0	39.5	17.2	292	20.0	7.15	9.05	1.50	104	Poor
	Autumn	-36.7	70.5	11.7	199	30.2	5.58	8.13	1.00	73	Good
	Winter	-6.7	18.3	19.7	82.0	16.3	2.47	2.26	1.00	32	Excellent

The present study revealed that the coastal waters were subjected to considerable seasonal changes based on the data analysis (ANOVA). In particular, at all sampling stations from Güllük Bay relatively high values were observed in fall period of 2014-2015 compared to other seasons, this can be the result of rainfall and human activities, which carried waste-laden run-off from land to sea.

The computed CWQI values are between 28 and 1995 in Akköy; and between 32 and 189 in Ildır. In addition, the water quality of Akköy is in the “excellent” to “unsuitable” range for all periods mostly due to input of domestic wastes and/or agricultural activities discharge from Büyük Menderes River. The CWQI values for sampling stations (AK1 in all periods and AK3 in fall) were enumerated above 300, because of high amounts of pollutants discharges such as riverine inputs. The data points from location AK2 in the spring and winter periods are categorized as excellent water; the data points from locations AK2 (summer), AK3 (spring-summer) and AK4 (spring-summer-autumn) are categorized as good water, while the data point of AK2 (fall) is categorized as poor water in the dry period, and as good water in the wet period; the data point from location AK3 is categorized as very poor water in the winter period and the data point from locations AK1 (all periods) and AK3 (fall) is classified as unsuitable for coastal water quality.

The calculated CWQI are 32 and 189 for the Ildır station. The Water Quality Status is “poor” for IK1 (fall), IK2 (summer) and IK3 (summer) sampling stations (Table 6). The values indicate that the status of these areas is not suitable for human uses without treatment process during these periods, based on the poor class range (100-200). In general, the results at sampling sites for mentioned waters showed that the values of some variables such as NO_x and NH_4 are beyond permissible limits prescribed by USEPA, COMAPS and other authors for coastal water quality standards (Table 4). These variables have the greatest effect on the WQI scores. As clearly seen in Table 6, NO_x and NH_4 are the two determining parameters that have the maximum effect in the calculation of WQI.

The findings from this study demonstrated that CWQI score varied from 9 to 1270 indicating unsuitable to excellent water quality at Güllük Bay and from 28 to 1995 suggesting unsuitable to excellent water quality at Akköy at the same time, whereas it ranged from 32 to 189 at Ildır Bay (Table 6). These results clearly exhibited that some stations at Güllük Bay and Akköy were polluted due to land-based discharge from pollution sources and agricultural runoff, whereas Ildır revealed healthy environment owing to minimal anthropogenic inputs.

All of the individual water quality variables displayed higher rankings at the mouth of the streams (AK1 and GK6 stations), therefore the bad ranking of water quality obtained through CWQI may be attributed to higher concentration of these variables at Akköy and Güllük Bay stations. Maximum levels of TNO_x at GK6 (51.5 µM) and AK1 (198 µM) was detected in the present study as a result of organic pollutants and anthropogenic inputs, including domestic waste-water. The recorded concentration of NH_4 at AK1 (54.8 µM) and AK3 (9.26 µM) was higher compared to Ildır Bay stations. Similarly, ammonia (38.1; 12.0 µM) was high at GK5 and GK6, respectively. This can be ascribed to more discharge points around these stations (Fig. 1). The highest measured concentration of TPO_4 (3.06 µM) at GK6 and (11.6 µM) at AK1 was in agreement (0.19-7.14 µM) with the study performed by Kucuksezgin et al. (2019) at the coastal zones of Izmir Bay, Eastern Aegean. Higher Chl-a concentrations (12.0 µg l^{-1}; 9.76 µg l^{-1}) were recorded at GK6 and AK1, respectively.

The physicochemical parameters were well within the allowable standard at all sampling stations. Fecal coliform counts indicated a significant increase in the estuarine or coastal environment as a result of domestic sewage release (Kelsey et al., 2004). In the present study, the highest fecal coliform counts (250 to 1300 cfu/100 ml) were recorded at AK1. Additionally, FC varied from 200 to 750 cfu/100 ml at IK2, which indicates higher values than permissible limits prescribed by USEPA.

The most striking result is that ammonium and nitrate among the other variables have the highest sub-index values, whereas both variables have not the maximum unit weights. This observation is mainly because of these parameters determined were at very high levels in water samples.

Data Analysis

Significant correlations were found between TNO_x and o-PO_4 (r=0.70, p<0.05), TNO_x and TPO_4 (r=0.59, p<0.05), TNO_x and TN (r=0.67, p<0.05), TNO_x and FC (r=0.59, p<0.05). There was a high correlation between o-PO_4 and TPO_4 (r=0.80, p<0.05), whereas positive relationships were found among NH_4 and o-PO_4 (r=0.26, p<0.05), NH_4 and TNO_x (r=0.33, p<0.05), NH_4 and TN (r=0.44, p<0.05), NH_4 and TPO_4 (r=0.34, p<0.05), NH_4 and Chl-a (0.28, p<0.05), NH_4 and FC (r=0.32, p<0.05). A Strong and positive correlation was observed between FC and FS (r=0.83, p<0.05). Positive correlations were also found among Chl-a, FC, FS and other all variables in the sampling sites.

One-way ANOVA indicated significant seasonal variations between different sampling periods for pH, temperature, total dissolved nitrogen, Chl-a and dissolved oxygen. Non-significant statistically difference was observed for salinity, dissolve nutrients (o-PO_4, TPO_4, TNO_x, NH_4), fecal coliform and fecal sreptococci. According to Post hoc Tukey’s HSD test, dissolved oxygen levels in winter were different from the other sampling seasons. The concentrations of Chl-a in winter differed statistically from the levels in spring and summer due to primary production. Additionally, Chl-a levels were different in summer from the values in fall period. The highest total dissolved nitrogen results were found in fall season due to rainfall and anthropogenic inputs. DO concentrations in fall were significantly different from winter period in accordance with Post hoc Tukey’s HSD test.

ANOVA results demonstrated significant spatial variability between different sampling points for all variables except temperature, pH and dissolved oxygen during all periods. Salinity, o-PO_4, TNO_x, NH_4, TN, TPO_4 values in AK1, located in the estuary of Büyük Menderes River, were statistically different from other sampling sites except GK6 (situated near the Sarıçay Stream in the Güllük Bay) in accordance with Post hoc Tukey’s HSD. Significant differences were observed for oPO_4, TNO_x, TPO_4 between stations GK6 and GK2, GK3, GK4, GK5, IK3 during different seasons. Chl-a concentrations in AK1 significantly differed from GK3 station due to riverine input (Post hoc Tukey’s HSD test). When taking into consideration fecal coliform and fecal streptococci results, sampling points AK1 and AK3 were statistically different from all stations excluding GK6, AK3, IK2 and GK6, GK7, AK1, AK2, AK4, IK1, IK2, respectively. The highest fecal streptococci and fecal coliform results were found in AK1 and IK2 due to anthropogenic activities during all sampling seasons.

The PCA was carried out in the study areas; a correlation matrix contained 11 variables, nutrients, physico chemical characteristics and 14 sampling points. The total variance of the four principal components is shown in Table 7. According to this, the first four principal components were examined in correlation matrix for variables. The first four principal components characterized 82.65 % of the total variability for sampling points in the study areas with the values for component 1, component 2, component 3, component 4 of 51.0%, 65.8%, 76.0%, 82.7%, respectively.

Table 7. Loadings of the variables for the first four principal components

Variables	PC1	PC2	PC3	PC4
T	-0.039675	-0.748889	-0.502727	0.331703
S	0.922892	0.065503	-0.180668	-0.018946
pH	0.516558	0.121026	-0.761645	-0.198027
DO	0.507823	0.658244	-0.017680	-0.106235
Chl-a	-0.502435	-0.448365	0.140282	-0.153183
FC	-0.635395	0.466056	-0.318390	0.026409
NH_4	-0.759588	0.029200	-0.200346	-0.374687
TNO_x	-0.773720	0.357819	-0.001540	0.477639
TN	-0.869133	0.240305	-0.197577	0.305069
o-PO_4	-0.901060	-0.105004	-0.042974	-0.285939
TPO_4	-0.909848	0.003103	-0.058876	-0.240865
Eigen Value	5.604928	1.628967	1.071333	0.786423
T.V(%) *	50.95	14.81	9.74	7.15
C.V (%) **	50.95	65.76	75.50	82.65

* Total variance. ** Cumulative variance.

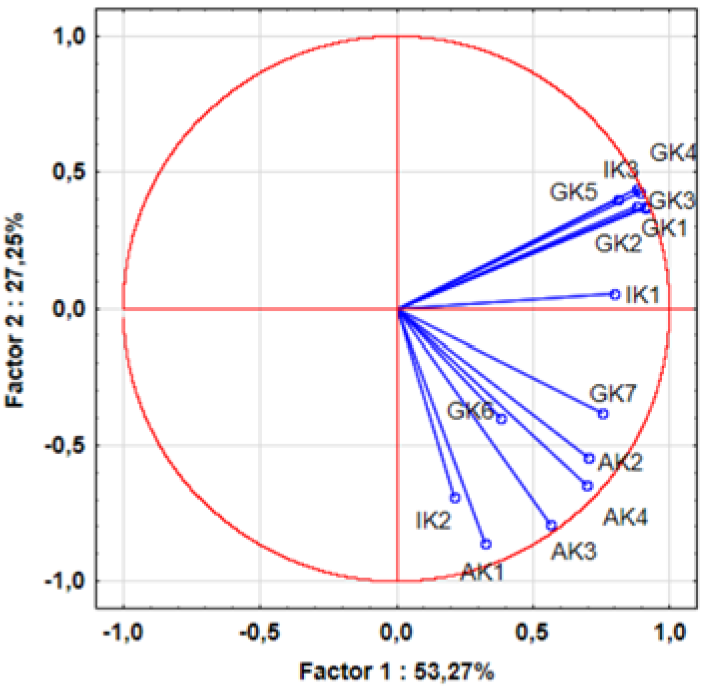

Figure 2. Result of PCA by correlation circles for factors 1, 2 for sampling points

Sampling points GK1, GK2, GK3, GK4, GK5, GK7, AK2, AK4, IK1, IK3 showed high scores on the positive part of first component. Sites AK1 and AK3 were differentiated from the other stations in the negative part of the component 2. These two points are situated in the estuary of the Büyük Menderes River in Akköy region. Sampling stations GK6 and IK2 were related to PC 3 and PC 4 on the positive part, respectively. The first point is located near the mouth of Sarıçay Stream in the Güllük Bay and the last station is situated near the summer houses and hotels in the Ildir Bay. Furthermore, PCA analysis supported the results of one-way ANOVA. Figure 2 shows loading plots of sampling points from PCA analysis.

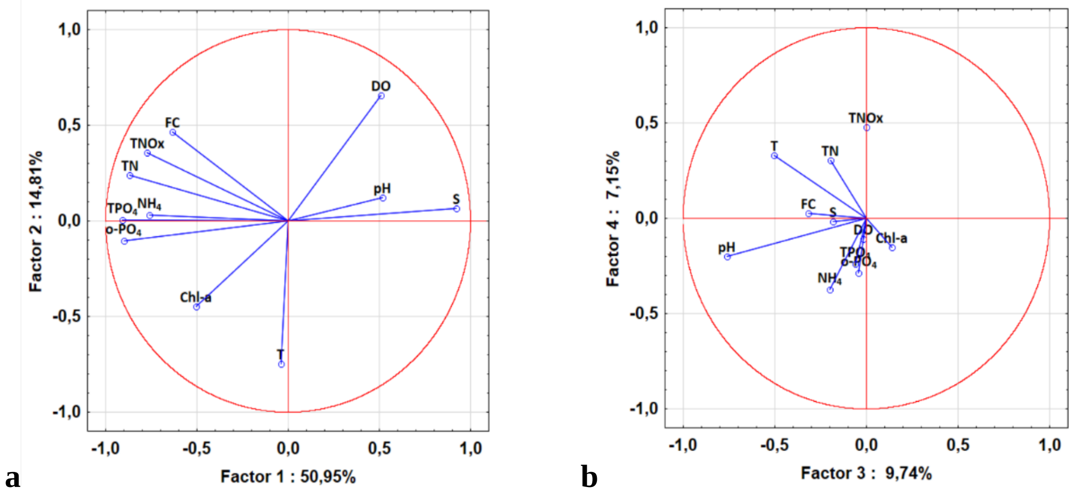

Figure 3. Output of PCA by correlation circles for factors 1, 2 (a) and 3, 4 (b) for all variables

In the PCA, components 1, 2, 3 and 4 indicated 82.7% of the total variability for physico chemical variables, nutrients, Chl-a and fecal coliform (Fig. 3a and 3b). Based on these four factors, the subsequent analysis is performed. According to the statistical correlation coefficients, we can categorize them into 'strong' (>0.75), 'moderate' (0.75–0.50), or 'weak' (0.50–0.30) for the absolute values.

The variables o-PO_4, TPO_4, NH_4, TNO_x and TN were associated with the strong negative scores ($|r| > 0.50$) of component 1, indicating a possible relationship between the application of agricultural fertilisers and manure, the discharge of wastewater and airborne emissions from shipping and combustion processes. The highest correlation coefficient for PC1, $|r| > 0.75$, were explained to be o-PO_4, and TPO_4. Salinity had a strong positive correlation ($r > 0.92$) on the component 1. Temperature and dissolved oxygen were related to strong negative ($r = -0.75$) and moderate positive ($r = 0.66$) scores on factor 2, respectively. pH displayed ($r = -0.76$) strong correlation with component 3. The variables other than pH and temeperature demonstrated weak correlation on component 3, whereas in PC4, all variables had a week correlation ($|r| < 0.50$). In addition, PC4 was represented by 7.15% of the total variance. Figure 3 displays loading and score plots of all parameters.

Conclusions

On the basis of the determined variables in this investigation, higher CWQI scores were perceived in the stations close to the river mouths. The calculated CWQI values of Akköy are under unsuitable range (641-1995), which shows the possible vulnerability of water quality at AK1 station situated in the mouth of Büyük Menderes River. Further, GK6 station at the mouth of the stream exhibited degraded water quality owing to land-based discharge from pollution sources and agricultural runoff in Güllük Bay. On the other hand, less exploitation of coastal resources due to minimal anthropogenic activity suggested good water quality index at Ildır Bay. Differences in water quality between regions reflect variation in nutrient concentrations. During the study, whole samples have TPO_4, TNO_X and NH_4 values exceeding the permissible limits as prescribed by USEPA and COMAPS standards. Whereas we noticed parameters such as salinity, temperature, dissolved oxygen and pH values are within coastal water standards.

It is concluded that the CWQI classification function is one of the best tools to enumerate the pollution potential in comprehensive manner and also used for categorization of the quality of coastal waters in Aegean Sea, Eastern Mediterranean. This is essential for comparing the water quality of different regions and in monitoring the seasonal differences in water quality. Thus, the current study may provide a good reference for coastal water quality evaluation in the Eastern Mediterranean coast of Turkey.

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Ethical approval

The author declares that this study complies with research and publication ethics

Data availability statement

The authors declare that data are available from authors upon reasonable request.

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Author contribution

Lütfi Tolga Gönül: Writing original draft, Conceptualization, Data curation, Formal analysis

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