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Wastewater Effluent from Outfalls in Kuwait Bay: A Threat to Recreational Water Quality

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Abstract

The implications of wastewater discharge into marine ecosystems are gravely concerning due to their ability to trigger a chain reaction of contaminants that pose severe risks to both humans and aquatic life. Kuwait Bay is no exception, with numerous wastewater outfalls posing a threat to the marine environment on its southern coasts. This study sought to extensively evaluate the recreational water quality adjacent to wastewater outfalls at five specified sites and compare the results according to the KEPA's (Kuwait's Environmental Public Authority) guidelines. Field measurements and laboratory analyses were conducted to gauge various parameters associated with water quality, such as nutrients, heavy metals, fecal bacterial indicators (FBI), and pharmaceutical compounds. The results of field measurements indicated that two locations had insufficient DO levels with values < 4 mg/l below KEPA standards and brackish to saline water concerning Electrical conductivity (EC) measurements. However, the heavy metal results demonstrated mercury (Hg) pollution at all locations, whereas the nutrient data revealed significant PO4-P concentrations. Furthermore, EPA requirements were considerably exceeded for bacterial indicator counts (fecal coliforms, E. coli, and fecal streptococci), suggesting serious biological pollution at these locations and elevated concentrations of paracetamol and ranitidine have been detected in pharmaceutical compound analysis, particularly in location OC5. The study's findings emphasized the significance of periodic surveillance to ensure the ongoing improvement of water quality and public health in Kuwait's coastal zones and highlighted the dire need to address the extensive contamination by implementing measures to mitigate the dump of unprocessed wastewater into the sea.

Keywords: *water quality, heavy metals, microbial nutrients, pharmaceuticals, and public health.*

1. Introduction

Kuwait Bay is a unique ecosystem rich in diverse marine species that are recognized as the primary source of the country's food requirements (Al-Yamani et al., 2004; Al-Abdulghani et al., 2013). Significant anthropogenic pressures from several local and regional causes, such as desalination and power plants, as well as numerous emergency and stormwater outfalls, recreational activities, and development along the shore through reclamation and dredging. They are the main causes of pollution in Kuwait Bay because they pour untreated effluent into the southern beaches (Al-Abdulghani et al., 2013; Al-

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Mutairi et al., 2014a). In addition, a massive amount of raw sewage was discharged several times in the past; which led to the disruption of seawater quality and ecosystem stability and adverse health and environmental effects (Bushaibah et al., 2023a). Moreover, Infiltrations of stormwater flow into a separate network from the wastewater network and are dumped into the sea untreated (Aleisa, 2019). Even though Kuwait's wastewater treatment system is undergoing significant changes that should improve the quality of sewage before it is released into the sea, significant sewage pollution continues to occur in a variety of sites on occasion as a substantial amount of raw sewage was discharged previously, caused disruption of seawater quality and ecosystem stability, as well as detrimental health and environmental repercussions (Al-Yamani et al., 2004; Al-Abdulghani et al., 2013; Al-Mutairi et al., 2014b).

Kuwait's wastewater treatment system has been undergoing a profound modification that should positively affect the sewage's quality before being released into the sea. Nevertheless, substantial sewage pollution continues to occur in a variety of locations (Lyons et al., 2015). According to simulation research done by Aleisa (Aleisa, 2019; Aleisa et al., 2015), 25% of untreated wastewater is released into the sea, and the number of pollutants discharged into the sea would grow again if the Ministry of Public Works (MPW) expansion projects for Wastewater Treatment Plants (WWTP) do not begin on schedule. This wastewater is rich in pathogens that contribute to nitrous oxide accumulation, methane emissions, and deoxygenated dead zones in the ocean. These pathogens include bacteria, parasites, and viruses (Bushaibah et al., 2023a; Aleisa, 2019; Corcoran,2010). Despite warning signs, several locals and people continue to engage in their hobbies there, putting themselves and their children at risk of contracting numerous diseases from the microbially contaminated beaches of the prohibited zones. Microbial water quality and bacteria counts of fecal coliforms, fecal streptococci, and Escherichia coli (E. coli) have been used to evaluate the level of microbial contamination on Kuwait’s coast. Monitoring the levels of indicator organisms, such as fecal coliforms and E. coli, is a common approach for quantifying potential pathogen loads in ambient water bodies (Pandey et al., 2014; Holcomb and Stewart,2020; Soto-Varela et al., 2021; Malakoff, 2002; Pandey et al., 2012; Pandey and Soupir,2013; Edge et al., 2021). Furthermore, previous studies of the earlier phase of this research showed that there was grave microbial contamination of fecal coliforms, E. Coli, and fecal streptococci (F.S) exceeded the acceptable guidelines of the Kuwait Environmental Public Authority (KEPA) in the areas studied on the southern beaches of Kuwait Bay (Bushaibah et al., 2023a; Bushaibah at al., 2023b). Additionally, Previous studies have shown that direct discharge of stormwater runoff into coastal waters through storm drain systems can cause pathogen contamination, even where separate storm and sanitary sewer systems are in place (Weiskel et al., 1996).

Nonetheless, the accumulation of pollutants and the prolonged residence period of the polluted water mass due to the inverse circulation in the estuary in the interior of Kuwait Bay led to a drop in the dissolved oxygen content (Al-Abdulghani et al., 2013; Li et al., 201; Al-Rashidi et al., 2009). Diverse marine microorganisms, including pathogenic bacteria, have been detected in household and industrial wastewater sources, and the variations in these bacteria are affected by a variety of variables, including the number of heavy metals, nutrients, antibiotics, and detergents that might be disposed of in wastewater, which will be disposed into seawater, which is critical to consider when evaluating the direct and indirect negative impacts on human health (Malik and Ahmad, 2002; Soo et al., 2016; Devlin et al., 2020; Glibert et al., 2002; Heil et al., 2001). As a consequence, it's essential to periodically monitor the seawater quality in the area of wastewater effluents to gauge the potential level of stress on the marine ecosystem (Pemberthy et al., 2020; Rueda-Márquez et al., 2021; Weber et al., 2014; Gevao et al., 2014). Also, to reduce the negative effects that may result in an imbalance in the marine ecosystem, it is crucial to address the main environment and sources of pollutants and establish suitable clean-up techniques. A study conducted at the Kuwait Institute for

Scientific Research (KISR) revealed that there is a persistent discharge of untreated and/or partially treated wastewater to the marine environment via the WWTPs and suggested that there is a possible local source or chronic input of untreated and/or partially treated water to the significant levels of endocrine-disrupting compounds (EDCs) detected in Kuwait Bay (Aleisa, 2019; Al-Jandal et al., 2018; Saeed et al., 2017). In the context of these findings, and to improve the quality and suitability of Kuwait Bay's beaches for recreation, this study aims to monitor and evaluate the safety of recreational seawater quality close to wastewater outfalls.

2. Materials and method

2.1 Study Area

The southern section of Kuwait Bay faces significant stress near the shoreline as a consequence of excessive pollution generated by anthropogenic activities (Al-Yamani et al., 2004). Additionally, the southern seashore served as the location of the most popular leisure places. Thus, the sample locations were chosen after numerous field excursions, including a screening visit in November 2021 to analyze the microbial, nutrient, and heavy metal contamination of beaches near selected wastewater outfalls. A total of 65 samples were collected from November 2021 to June 2022 and directly from the wastewater outfall discharge in locations OC18, OC10, OC8, OC5, and OC3, as represented in the locations map in Figure 1 and the coordinates of the five sample locations and their position descriptions are listed in Table 1 (Bushaibah et al., 2023a). These specifically selected sites were selected based on their proximity to infrastructure supporting medical, industrial, residential, and recreational activities, intending to offer an extensive evaluation of varied wastewater sources along with the current state of recreational waters in Kuwait Bay. The samples were collected using a Teflon bailer, and the on-site measurements of the water quality parameters of Temperature, pH, dissolved oxygen (DO), and Electrical Conductivity (EC) were conducted by using portable field meters. On the other hand, 3 liters from each site were collected, sorted, and transferred in an icebox to cool the samples at 4 °C (Rueda-Márquez et al., 2021) (27) for laboratory analysis of heavy metals, nutrients, microbial, and pharmaceutical analysis.

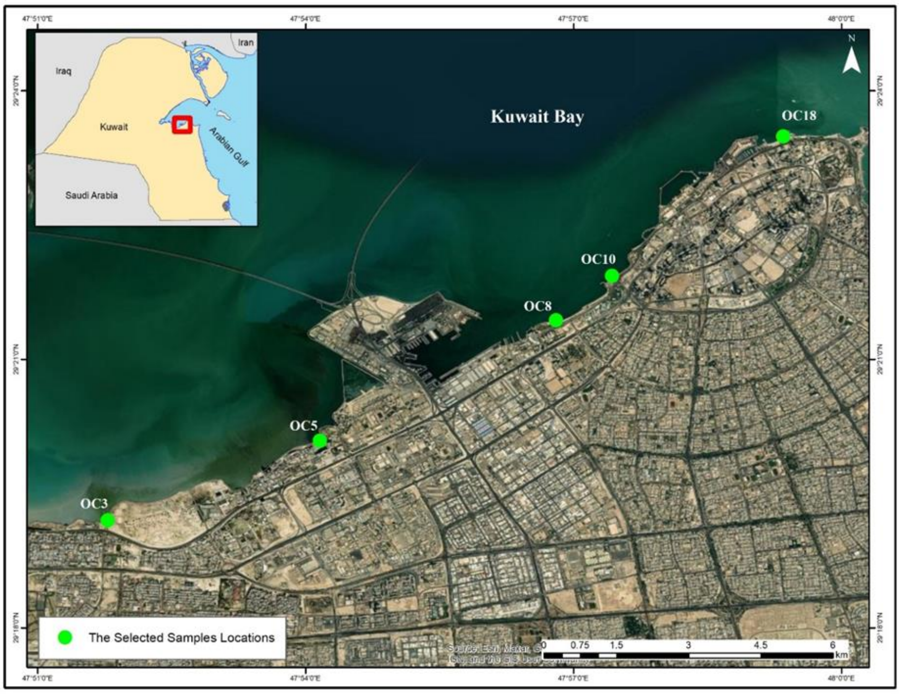

Figure 1. The sampling site’s locations in the south coast of Kuwait Bay.

Table 1. The Sampling Locations Coordinates and Descriptions.

Site code	Coordinate		(Type of close-by Activity)
	Longitude	Latitude	
OC3	47.863044	29.320015	Residential and Leisure
OC5	47.902617	29.334869	Medical
OC8	47.946706	29.357277	Industrial and leisure
OC10	47.957159	29.365538	Residential and Leisure
OC18	47.989117	29.391525	Leisure

The collected samples were analyzed for the following chemicals: total dissolved solids (TDS), nutrients (Ammonia (NH_3-N), total Kjeldahl nitrogen (TKN), total nitrogen (TN), and phosphate (PO_4-P)), heavy metals parameters including arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni), mercury (Hg), iron (Fe), copper (Cu), manganese (Mn), zinc (Zn), lead (Pb) and silver (Ag), and bacterial (fecal coliforms, Escherichia coli (E. coli), and fecal streptococci) parameters. All water parameters were analyzed according to the standard methods for the examination of water and wastewater (APHA, 2017). In this study, five pharmaceutical compounds including Metronidazole, Trimethoprim, Sulphamethoxazole, Paracetamol, and Ranitidine were analyzed in 15 samples in January, February, and April as an assessment of the pharmaceutical's existence and concentration in the sampling locations.

The TDS values of each water sampling location were calculated using the following ratio (APHA, 2017):

$$\text{Calculated TDS/ EC (Conductivity)} = 0.75 \quad (1)$$

F= 0.75 is a constant value for the natural water type, ranging between 0.55 and 0.8 (APHA, 2017). Generally, the salinity of the water is usually related to the TDS (APHA, 2017; Walton, 1989). Todd (Todd and Mays, 2004) classified the salinity of the water into 4 water categories: freshwater, 0–1000 mg/l-TDS, brackish water, 1000–10,000 mg/l-TDS, saline water, 10,000–100,000 mg/l-TDS, and brine water of more than 100,000 mg/l-TDS.

The analysis of the water samples was carried out for the nutrient parameters NH_3-N, nitrate (NO_3), and nitrite (NO_2) using the Met Rohm Ion Chromatograph (IC), ASTM D6919-17, SM4110 B Moreover, the TKN is determined using the following formula (APHA, 2017):

$$TKN = TN - ((NO_3\text{-}N) + NO_2\text{-}N) \quad (2)$$

The TN and PO_4-P were analyzed using the Hach DR 6000 Spectrophotometer, Hach Method 10072 (APHA, 2017). Furthermore, the nutrient parameter (PO_4-P) was analyzed in two steps: the first step is the conversion of organic phosphate to orthophosphate (Hach Method 8190), while the second step is the conversion of orthophosphate to total phosphate (Hach Method 8114). Heavy metal analysis was carried out using inductively coupled plasma using the Optical Emission Spectrometer (ICP-OES) and analyzed according to the method SM 3120 B (APHA, 2017). Moreover, the 0.25 ml of samples concentration was diluted and analyzed employing membrane filter methods for determining the microbiological indicator counts of fecal coliforms, Escherichia coli (E. coli), and F.S, with sample collection and analysis performed according to conventional laboratory protocols (APHA, 2017). The pharmaceutical parameters were analyzed using the DIN 38407 F47, HPLC-MS/MS method using high-performance liquid chromatography and mass spectrometric detection (HPLC-MS/MS or -HRMS) after direct injection (APHA, 2017; Beatriz et al., 2020). The research results were derived from the analysis of 55 samples and compared with the KEPA standards (KEPA, 2017a, KEPA, 2017b), to confirm the suitability of the selected locations as the research study area. There are no maximum limits set by KEPA for pharmaceutical compounds to compare with; however, the pharmaceuticals will be compared with recent references. The high spot areas of contamination, and the degree of stability of the other selected coastal areas. Data description and comparison were identified in detail to support the negative and positive impacts of sewage discharge into the sea and the suitability of the bathing water near the outfalls of sewage along Kuwait's beaches. The water quality parameters for the field and laboratory results for each sampling location (OC3, OC5, OC8, OC10, and OC18) are discussed separately. In addition, the comparison of the water quality parameters for all sites will be evaluated using statistical analysis.

3. Results and Discussion

Water Quality Field Analysis Results. The statistical results of the water quality parameters results are represented in Table (2), The temperature of all sample locations throughout the research period varied from 29.7 ° C to 15.7 ° C, indicating that all locations were at acceptable temperature ranges and met KEPA regulations and similar to the historical recorded temperature (Al-Abdulghani et al., 2013; Al-Rashidi et al., 2009). Throughout the investigation, the peak means temperatures were 26 °C for the sample locations OC3 and OC5, while the lowest overall values were 23 °C for OC18, OC10, and OC18. Despite the low-temperature variance, the OC3 and OC5 locations had the highest temperatures of any other sample location. It's noteworthy to mention that, according to previous studies (Al-Yamani et al., 2004; Al-Rashidi et al., 2009; Anderlini et al ., 1982), Kuwait Bay's northern and southern regions have different water temperatures. An increase in seawater temperature may be the result of anthropogenic activity in the southern half of the bay. Notably, the research was conducted in the colder and milder seasons of winter, spring, and the early summer, offering how variations in weather patterns and air temperature impacted seawater temperatures and demonstrating the unnecessity of water treatment concerning the water temperature. Similarly, the mean pH values at all sample locations were within the permitted pH (6-9) of the KEPA standards, even though the mean pH values of all samples were rather alkaline (KEPA, 2017a) (Figure 2a). The mean pH values for the water samples for the five locations were nearly comparable with a range from 7.3 at OC18 to 7.7 at OC10; the locations OC3, OC8, and OC10 showed pH maximum values among other locations; however, all pH mean values were within the KEPA guidelines. Nevertheless, the DO means values of all samples ranged from 1.9 mg/l at OC5 to 4.7 mg/l at OC18 (Figure 2b), which demonstrated that OC3 and OC5 were below the KEPA acceptable limit of > 4 mg/l (KEPA, 2017a) throughout the investigation period. These results indicate that these two locations had insufficient DO levels, which is required for a healthy marine environment; therefore, water treatment is needed for these locations. Notably, field measurements on April 22 revealed high DO values at all the sampling locations exceeding 8 mg/l, and combined with the fact that DO levels varied from 2-4 mg/l lower than the acceptable limit for the rest of the study period, suggests that the sudden elevation observed in April was not a typical occurrence during this study. A point source of pollution, such as a spill or discharge, might have caused the abrupt increase in DO levels especially since the samples were collected close to the wastewater outfalls. However, according to (Al-Yamani et al. 2004; Al-Mutairi et al., 2014), high dissolved oxygen levels are often linked to peak primary production rates. In consequence, increasing DO levels can harm aquatic creatures, especially fish and other animals that have acclimated to lower DO levels. Additionally, abrupt variations in DO levels can stress aquatic species, affecting their behaviors including eating, swimming, and migration (Corcoran,2010). Nevertheless, the

DO mean values of other sample locations were within the KEPA standards, and the DO levels were relatively low during the study. limited dissolved oxygen levels have previously been observed and connected with organic matter breakdown or limited water column mixing, particularly during hot and quiet summer months (Al-Yamani et al., 2004; Al-Mutairi et al., 2014). The average EC values for the samples collected fell between 1790 S/cm at OC5 to 65070 S/cm at OC8 (KEPA, 2017a), and accordingly, TDS ranges from 1280 mg/l at OC5 to 45000 mg/l at OC8 (Figure 2c), which indicated the presence of freshwater type at OC5 and saline water type in the rest locations. These findings illustrated that OC5 suffers from untreated wastewater discharge, while monitoring is needed for location OC3, as it indicates lower salinity. Further, the low EC values measured in a body of water could indicate contamination and inappropriate water quality of the water discharged from this outfall (Environmental, 2014). Noticeably, during the field visits to the OC5 sampling location, the water discharged went through physical changes affecting the healthy seawater characteristics; Furthermore, birds and puppies were observed exploiting the water to survive. Conductivity and TDS are related to salinity; in addition, high temperature, evaporation levels, and freshwater influx from the Shatt Al-Arab all have an impact on the salinity of seawater in Kuwait Bay, furthermore, Kuwait Bay's salinity varies from around 37 PSU (practical salinity unit) and 50 PSU. Seasonally, salinity varies; it is higher in summer and fall and lower in the spring and winter. Worth to mention that, the salinity of Kuwaiti waterways changes according to the amount of freshwater input via Shat Al-Arab and raising evaporation rates during summer's scorching temperatures (Al-Rashidi et al., 2009) (20). The southern coast of Kuwait Bay was originally claimed to have the greatest salinity, whereas the north shore of Kuwait Bay had the lowest salinity (Al-Yamani et al., 2004).

Table 2. Statistical Summary of water quality parameters and nutrients results.

Parameters		**Temp (C°)**	**pH**	**EC (mS/cm)**	**DO (mg/l)**	**NH_3-N (mg/l)**	**TKN (mg/l)**	**TN (mg/l)**	**PO_4-P (mg/l)**	**Cd (mg/l)**	**Hg (mg/l)**	**Fe (mg/l)**	**Cu (mg/l)**	**Pb (mg/l)**
KEPA Standards		**Δ5**	**6_9**	**_**	**>4**	**1.0**	**5.0**	**30.0**	**0.50**	**0.01**	**0.001**	**2.0**	**0.20**	**0.10**
OC3	Max	34.50	8.12	20.390	8.73	12.34	16.75	28.00	8.10	0.036	0.566	0.814	0.229	0.119
	Mean	27.69	7.75	11.788	2.67	8.80	12.49	16.41	4.71	0.010	0.076	0.396	0.048	0.017
	Min	23.00	7.24	7.190	1.00	0.86	4.18	11.21	1.80	0	0	0.142	0.014	0
	STD	3.90	0.29	3.575	1.96	3.06	3.78	4.64	2.28	0.013	0.153	0.189	0.056	0.032
OC5	Max	35.20	7.93	3.110	8.69	33.50	36.18	39.00	13.60	0.037	0.996	0.943	0.352	0.150
	Mean	28.12	7.56	2.023	1.60	20.89	28.27	31.74	10.21	0.010	0.139	0.565	0.096	0.017
	Min	22.30	7.18	1.198	0.38	15.11	19.72	21.17	7.50	0	0	0.157	0.021	0
	STD	4.30	0.20	0.743	2.20	4.80	4.91	5.76	2.38	0.013	0.319	0.210	0.096	0.045
OC8	Max	34.00	8.08	96.930	9.59	5.11	34.30	35.00	5.80	0.027	0.559	2.276	0.330	0.040
	Mean	25.76	7.74	56.636	3.60	2.11	5.69	7.77	2.94	0.005	0.122	0.724	0.082	0.004
	Min	17.90	7.25	9.590	1.10	0.38	0.45	0.66	0.40	0	0	0.141	0.023	0
	STD	4.94	0.27	22.825	2.45	1.78	9.04	9.61	1.56	0.010	0.222	0.754	0.094	0.011
OC10	Max	34.50	8.04	73.870	9.04	1.95	5.88	14.00	5.20	0.062	0.416	0.730	0.087	0.139
	Mean	25.98	7.69	44.953	4.39	0.77	1.84	5.15	1.82	0.013	0.086	0.330	0.028	0.016
	Min	16.10	7.12	8.930	1.27	0.13	0.26	0.39	0.40	0	0	0.084	0.002	0
	STD	5.37	0.28	21.264	1.85	0.53	1.46	4.32	1.67	0.021	0.155	0.201	0.023	0.040
OC18	Max	35.80	7.90	73.260	10.36	2.16	29.71	30.00	5.60	0.029	0.472	0.877	0.090	0.047
	Mean	26.10	7.42	23.104	4.46	0.91	3.45	3.83	1.74	0.007	0.076	0.222	0.028	0.011
	Min	15.70	6.91	8.350	2.57	0.26	0.38	0.47	0.10	0	0	0	0	0
	STD	5.74	0.35	22.546	2.67	0.61	7.92	7.91	1.96	0.011	0.144	0.230	0.025	0.017

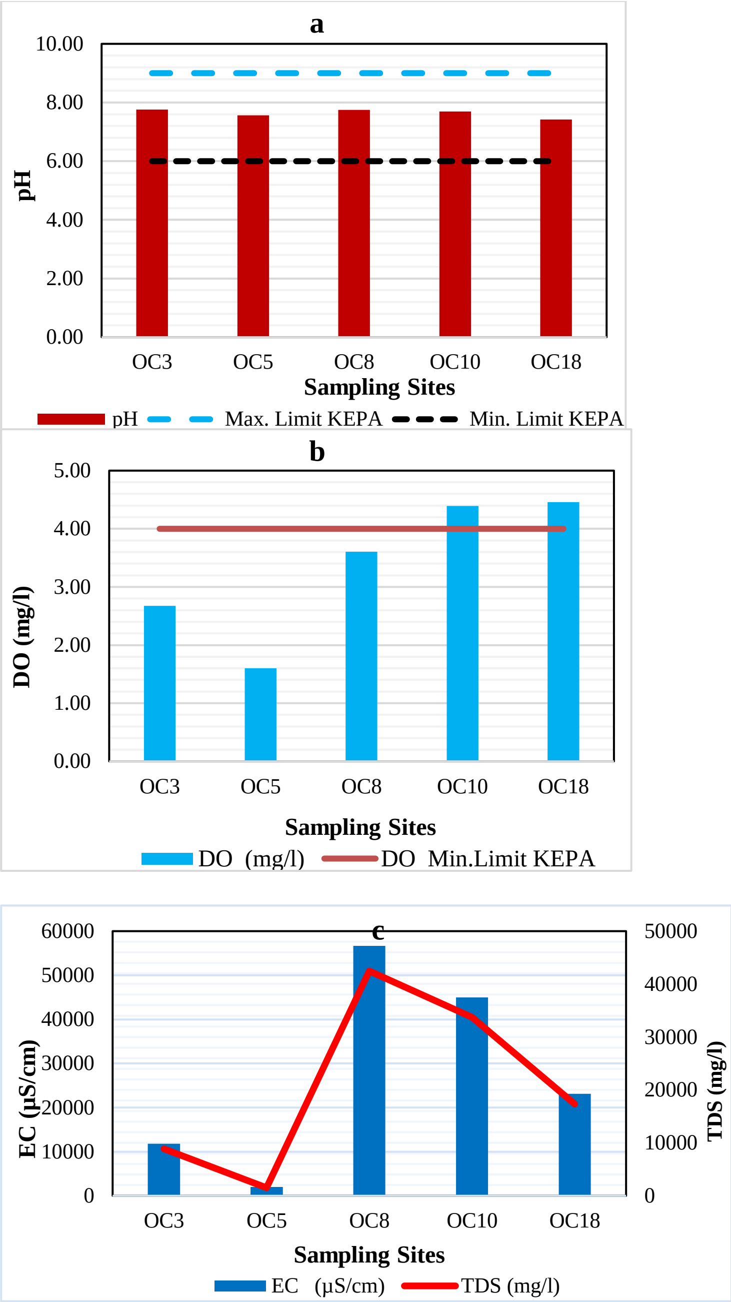

Figure 2. Water quality mean values for all the locations (a. pH, b. DO, c. EC, and TDS).

<u>Nutrients Analysis Results.</u> The NH_3-N average values during the study were beyond KEPA standards particularly, at locations OC3 and OC5, and ranged from 0.95 mg/l at location OC10 to 21.3 mg/l at location OC5 which exceeded the KEPA standards of (1 mg/l) (KEPA, 2017a) (Figure 3). For the TKN, the maximum mean values were at the location OC5 with a value of 29 mg/l and the minimum value was at the location OC10 with a value of 2.3 mg/l, TKN values were above the acceptable limits of KEPA of (5 mg/l) at locations OC3, OC5, and OC8 and within the acceptable limit at locations OC10 and OC18. In addition, Except for the sample location OC5, where the average was slightly over the limit with a concentration of 33.5 mg/l, the TN mean values for the collected samples during the study period were within the range of the KEPA guidelines (> 30 mg/l), whereas the minimum TN mean value was at location OC18 with a value of 4.2 mg/l. On the contrary, the mean values of PO_4-P were over the maximum limit of KEPA (0.5 mg/l) at all locations, with the highest mean value at OC5 being 9.7 mg/l and the lowest being 1.5 mg/l at OC18 (Table 2). Consequently, Excess phosphate

accumulation may trigger eutrophication-related impacts such as undesirable algal blooms, negative alterations in species diversity, bottom-layer anoxia, fish massive fatality, and seabed organisms (Al-Abdulghani et al., 2013; Bushaibah et al., 2023; Bushaibah et al., 2023; Aleisa, 2019; Heil et al., 2001; Shtereva et al., 2015). Therefore, an adequate phosphate removal approach should remove significant phosphate pollution. Kuwait Bay has historically been plagued by an overabundance of nutrients, and the primary contributors to the substantial amount of nutrients encountered in Kuwait's waters include Shatt Al-Arab, discharged sewage, land run-off, and possibly dust deposited by dust storms. Additionally, seawater near shore and in Kuwait Bay contains more nutrients compared to those offshore (Al-Yamani et al., 2004; Al-Abdulghani et al., 2013). Moreover, nutrient-rich water bodies promote aquatic plant development while degrading water quality by hastening the formation of algae clumps, generating a foul stench, and discoloring the water (Glibert et al., 2002), which was observed during the sampling in sites OC3, OC5 (Bushaibah et al.; 2023a; Bushaibah et al.; 2023bibah), where these adverse situations challenging the utilizing of these beaches for recreational activities. Then, the organic waste is subsequently digested by microbial growth, which develops effectively and consumes the dissolved oxygen in the water body while the bacterial decomposition of the organic load depletes oxygen in the water which will lead the aquatic organisms cannot survive and will perish in an oxygen-depleted environment (Al-Abdulghani et al., 2013; Aleisa, 2019; Singh, 2013). 5). As a consequence, in light of the nutrient analysis results, it is beneficial that active monitoring and appropriate intervention are vital for preventing superfluous nutrients from being dumped into Kuwait Bay.

<u>Heavy Metals Analysis Results.</u> The mean values of the results revealed that the heavy metals were typically in relatively low concentrations and within the KEPA guidelines (Bushaibah et al.; 2023a), except for Cd and Hg, which were found to be over the KEPA criteria at all sample locations. This study plots the results of the five highest heavy metal mean values for all sampling locations (Figure 4). The maximum Cd mean value was 0.02 mg/l at locations OC3 and OC18 exceeding the KEPA permissible limit of (0.01 mg/l) (KEPA, 2017a) as demonstrated in (Table 2), whereas the maximum mean value of Hg was 0.023 mg/l at location OC8 which was also greater than the KEPA standards for Hg (0.001mg/l) (KEPA, 2017a). Nevertheless, because Hg and Cd harm marine life, the Pb, Cu, and Fe levels should be closely monitored during the research period. A specific factor that could be implicated in the variation of Cd and Hg levels was industrial discharges. Hg and Cd are the two metals whose ingestion rates into coastal waters have mostly increased above natural rates (Daskalakis and Thomas, 1995). Furthermore, Nriagu observed that Cd and Hg are more likely to be present as contaminants based on ratios of total industrial discharges to natural weathering (Nriagu, 1990). Generally, Pb, Hg, Cd, and Cr are frequently detected in Kuwait Bay coastal and marine areas, and although heavy metals, like Fe and Ni, are vital micronutrients for the survival of animals and plants, Pb and Cd have slight functional significance (Okereafor et al., 2020). What’s more, heavy metals can accumulate in considerable quantities in some environmental situations, inflicting environmental damage.

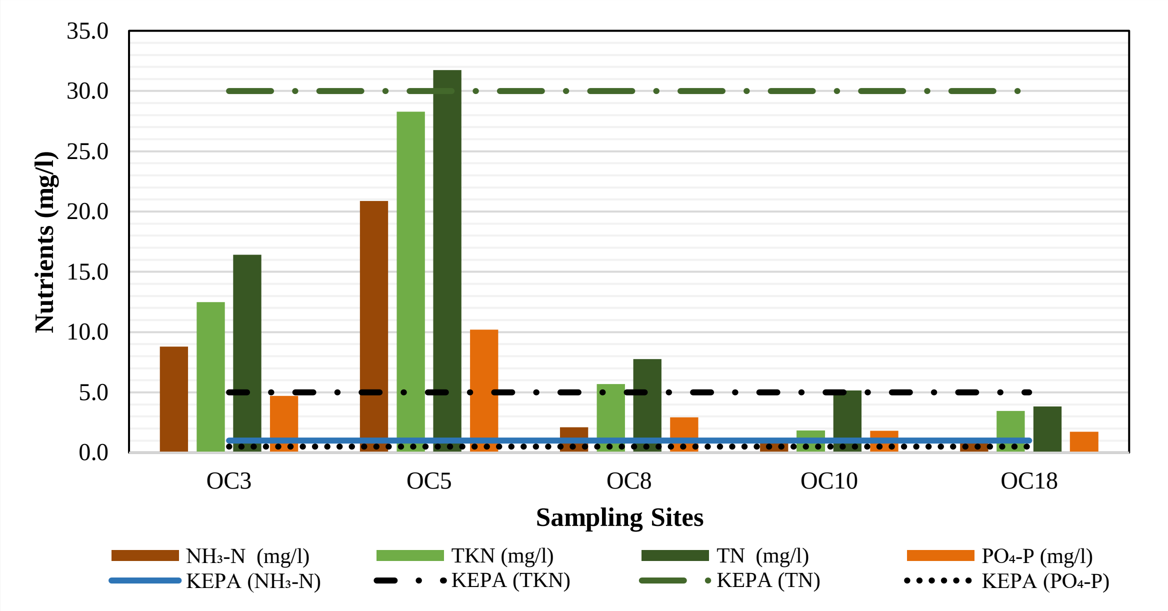

Figure 3. The nutrients' mean values for the sampling locations.

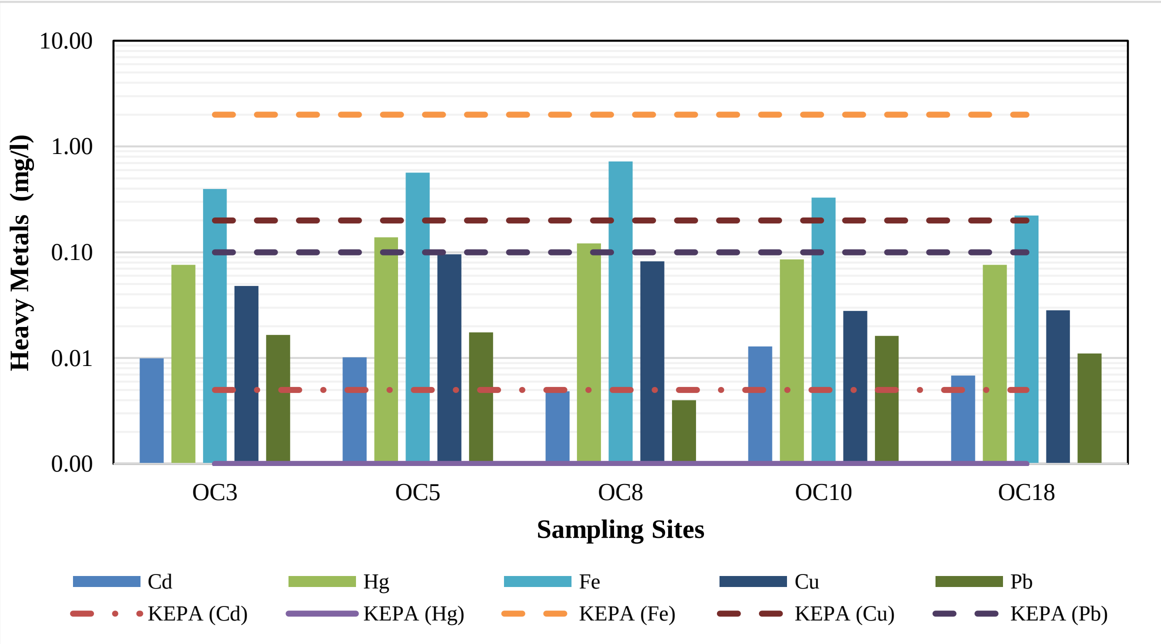

Figure 4. The heavy metals mean values for the sampling locations.

Contamination with heavy metals is cautious and frequently extremely poisonous to biota, and they have been identified as a prominent group of detrimental pollutants because of their high toxicity and persistence in all aquatic systems. The five metals with the highest potential impact are Cd, Cu, Hg, and Zn, which enter the environment in large quantities as a result of industrial and agricultural activities via stormwater and wastewater discharges (Al Naggar et al., 2018).

The Bacteria Indicators Analysis Results The excessive counts detected of all bacteria indicators that were considerably above the KEPA standard in the study shore outfalls that flow into Kuwait Bay were indicative of the existence of serious microbiological pollution, according to the results of all sample locations (Figure 5). The maximum mean value of fecal coliform measured exceeded the maximum permissible level (500 CFU/100 ml) (KEPA, 2017b), and mainly spanned from 40000 cfu/100 ml at OC10 to approximate counts of 3000000 cfu/100 ml at OC5 (Table 3). Likewise, E. coli concentrations varied from 8000 CFU/100 mL at the OC10 site to 2973000 CFU/100 ml at the OC5The averages of FS varied similarly, with the lowest value at the OC10 site of 4000 cfu/100 ml and the highest value of 1480000 cfu/100 ml. Elevated levels of fecal bacteria indicators, exceeding 2 million cfu/100ml, on some recreational beaches, can damage aquatic organisms and individuals participating in recreational activities. The high levels of these indicators at recreational beaches are a result of several causes. The quality of the water can also be harmed by contamination of beach sands, anthropogenic effects, and non-point source pollution (Powers et al., 2020). Considering that Kuwait Bay is semi-closed, urban runoff and confined beaches along urban coasts are frequent hotspots for contamination of fecal indicator bacteria (FBI) (Rippy et al., 2014; Noble et al., 2006). As these beaches are deemed inappropriate for leisure activities and subject aquatic species in addition to human health to very detrimental adverse impacts, these findings suggested the necessity for intensive treatment and attentive surveillance. The net result of the microbial indicators showed high contamination in all sample locations, however, OC3 and OC5 were the most microbial contamination locations among other locations while the results of the sample analysis demonstrated that OC10 was the least polluted site by microbial (Pandey and Soupir,2013; Al-Rashidi et al., 2009). To maintain the quality of the coastal waters and the health of beachgoers, it is vital to comprehend the quantities distribution, and sources of fecal bacteria indicators on beaches sand, and water.

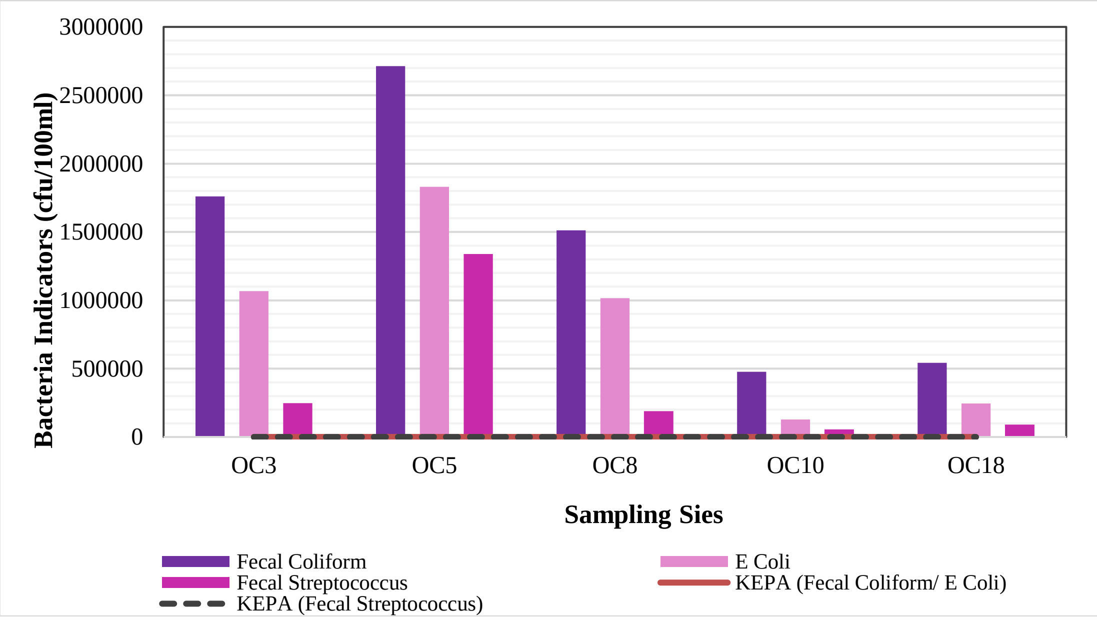

Figure 5. The mean values of the bacteria indicators for the sampling locations.

In addition, various climatological zones and anthropogenic factors should be considered in enhanced monitoring approaches (Powers et al., 2020; Halliday et al., 2011; Feng et al., 2016). These five sample locations might be categorized as undesirable beaches for swimming or other recreational activities since there is substantial microbiological contamination at all locations, making disinfection procedures as a remedy equally crucial.

<u>The Pharmaceuticals Analysis Results.</u> The results of the measured pharmaceutical compound mean values for all sampling locations showed that paracetamol had the highest concentration of pharmaceutical compounds in all five locations (Figure 6). The maximum mean value of paracetamol was at location OC5 with a value of 180 µg/l and the minimum mean value was at location OC18 with a value of 0.021 µg/l (Table 3). Ranitidine and Metronidazole were relatively high at locations OC3, OC5, and OC8, whereas they were in lower concentrations in OC10 and OC18. Most pharmaceutical compounds contamination was at the location OC5, located near a medical facility,

followed by OC5 and then OC3. Furthermore, the OC10 location has significant contamination of Paracetamol and Ranitidine more than other pharmaceutical compounds, while all pharmaceutical compounds were in relatively low concentrations at the OC18 location. Although pharmaceutical compounds were detected at <0.01 µg/l as an ND value during the study period, these values were considerably high concerning results of paracetamol compound concentrations in the published research which was measured in nano gram/l (Gevao et al., 2014; Al-Jandal et al., 2018; Saeed et al., 2017; Mydlarczyk et al., 2021). In general, pharmaceutical contaminants in varying quantities were a concern at all sampling locations; this was particularly true of the paracetamol component. Since it had been previously detected in Kuwait with a quantity calculated to be 2.086 µg/l in Waste Water Treatment Plant WWTP influent samples and 0.0521 µg/l in WWTP effluent in 2011 (Alajmi, 2014) while it was found in the current study in a significantly greater level in the mixed wastewater with seawater samples, it is necessary to be continuously monitored, controlled and appropriately treated. Further, sub-therapeutic amounts of pharmaceuticals in water, especially over an extended period, may have unpredictable consequences that warrant more research. Additionally, it has been demonstrated that drugs like Ranitidine, which are not detectable in water or sand, were detected in marine creatures (Gaw et al., 2014; Webb et al., 2003). As a result, the pharmaceuticals discharged into coastal

Table 3. Statistical summary microbial indicators, and pharmaceuticals compounds.

Parameters		F.C (cfu/100ml)	E Coli (cfu/100ml)	F.S (cfu/100ml)	Metronidazole (µg/l)	Trimethoprim (µg/l)	Sulfamrthoxazole (µg/l)	Paracetamol (µg/l)	Ranitidine (µg/l)
KEPA Standards		**500**	**500**	**200**					
OC3	Max	4.56E+06	3.92E+06	9.50E+05	0.14	0.04	0.06	12.00	0.09
	Mean	1.76E+06	1.07E+06	2.49E+05	0.05	0.02	0.04	7.04	0.06
	Min	0.00E+00	0.00E+00	4.00E+03	ND	ND	0.02	0.02	0.03
	STD	1.73E+06	1.14E+06	2.48E+05	0.06	0.01	0.02	5.10	0.02
OC5	Max	4.62E+06	4.21E+06	2.75E+06	0.03	0.06	0.27	280.00	0.47
	Mean	2.71E+06	1.83E+06	1.34E+06	0.01	0.04	0.15	144.00	0.25
	Min	9.91E+05	7.60E+05	2.45E+05	ND	0.02	0.03	73.00	0.11
	STD	1.09E+06	1.09E+06	6.76E+05	0.01	0.02	0.10	96.20	0.16
OC8	Max	5.42E+06	4.91E+06	7.50E+05	ND	ND	ND	0.09	0.03
	Mean	1.51E+06	1.01E+06	1.90E+05	ND	ND	ND	0.05	0.01
	Min	0.00E+00	0.00E+00	0.00E+00	ND	ND	ND	0.02	ND
	STD	1.77E+06	1.59E+06	2.34E+05	ND	ND	ND	0.03	0.02
OC10	Max	1.32E+06	4.50E+05	2.10E+05	0.16	0.03	0.09	89.00	0.24
	Mean	4.78E+05	1.27E+05	5.52E+04	0.05	0.01	0.03	29.68	0.08
	Min	4.00E+04	8.00E+03	4.00E+03	ND	ND	ND	ND	ND
	STD	3.85E+05	1.27E+05	5.36E+04	0.08	0.01	0.04	41.94	0.11
OC18	Max	1.25E+06	7.00E+05	2.44E+05	ND	ND	ND	0.07	ND
	Mean	5.44E+05	2.44E+05	9.04E+04	ND	ND	ND	0.03	ND
	Min	1.60E+04	8.00E+03	4.00E+03	ND	ND	ND	0.00	ND
	STD	3.85E+05	2.42E+05	8.42E+04	ND	ND	ND	0.03	ND

F.C (fecal coliform), F.S (fecal streptococci), ND=0

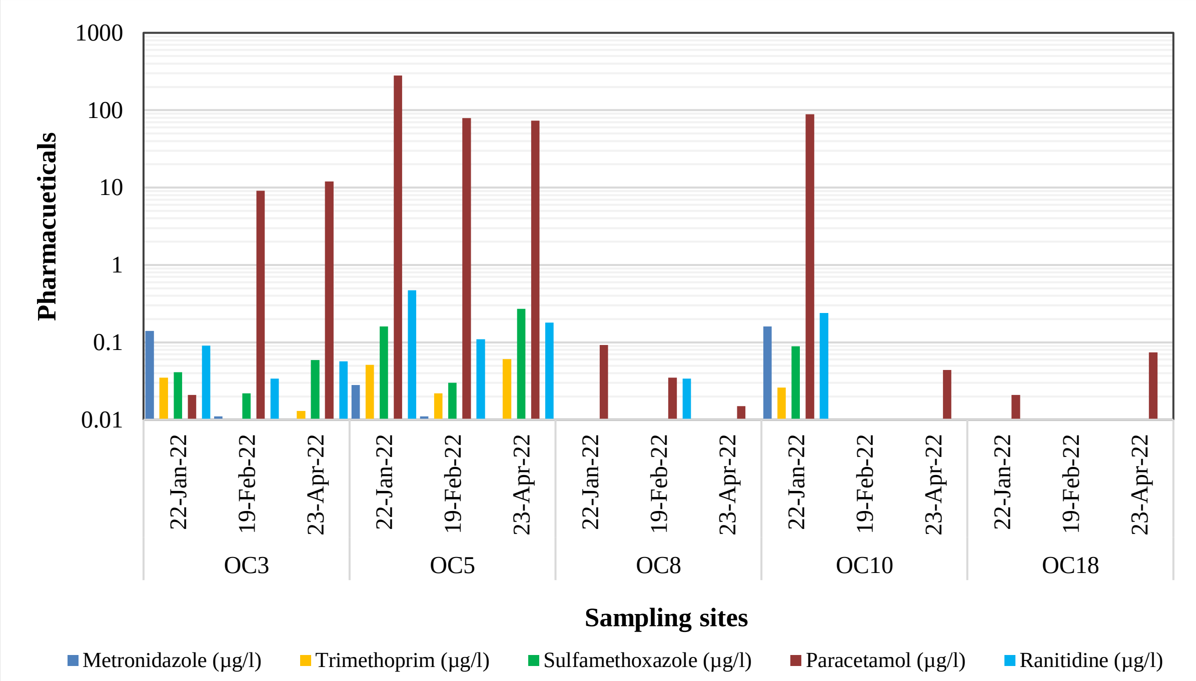

Figure 6. The mean values of the pharmaceutical compounds for the sampling locations.

ecosystems are high enough to have biological effects and might contribute to the stress currently experienced by marine ecosystems due to overfishing, eutrophication, and climate change (Gaw et al., 2014; Crain et al., 2009; Bottoni et al., 2010).

Correlation between the water quality parameters: The correlations between multiple water quality indicators chemicals, nutrients, heavy metals, microbiological, and pharmaceutical pollutants were examined in this study using a Pearson correlation matrix. In many different domains, the correlation coefficient may be used to make predictions or guide decision-making since it is an effective tool for assessing the link between two or multiple variables. The correlation coefficient measures the strength and direction (growing or decreasing, depending on the sign) of a linear connection between variables X and Y (Pearson et al., 1987). Pearson correlation coefficients (r) were obtained, and the significance of the correlations was determined using p-values (Table 4). Values closer to 1 indicate a high positive correlation, values closer to -1 suggest a strong negative correlation and values closer to 0 indicate no connection. The statistically significant was evaluated in two levels, as a p-value ($p < 0.05$) and ($p<0.01$). The correlation matrix findings revealed no significant relationships between temperature and dissolved oxygen (DO) during the study (Pearson et al., 1987), but significant positive relationships between temperature and pH ($r = 0.601$, p 0.05), electrical conductivity (EC), and DO ($r = 0.591$, p 0.05), pH and EC ($r = 0.591$, $p<0.05$). These relationships imply that as the temperature rises, so will the pH, and higher DO concentrations are associated with higher EC values. Because increased salinity, as shown by higher EC values, affects the solubility of oxygen in the water. However, higher EC values are frequently related to lower DO concentrations, which were normally associated negatively (Walton, 1989; Kefford, 1998), emphasizing the need to further investigate and monitor salinity as a factor impacting oxygen availability in coastal habitats. Notably, EC has a significant negative relationship with the nutrients NH_3-N, TKN ($r>0.5$ and p 0.05), TN ($r> 0.6$, $p<0.01$), and Trimethoprim ($r> 0.5$, $p< 0.05$), suggesting that higher temperatures encourage specific chemical and biological processes that influence these parameters. In a comparable vein significant negative associations between NH_3-N and DO ($r = -0.834$, $p< 0.01$), TKN and DO ($r = -0.879$, $p <0.01$), total nitrogen (TN) and DO ($r = -0.827$, p 0.01), and phosphate (PO_4-P) and DO ($r = -0.847$, $p <0.01$) were detected. Low levels of dissolved oxygen enhance the release of nutrients from the sediments, which influences the solubility and availability of nutrients and, consequently, the productivity of aquatic ecosystems (Abdelmongy and El-Moselhy, 2015). These findings demonstrate that increased nitrogenous compound and phosphate concentrations might lead to lower dissolved oxygen levels, which may harm aquatic life and overall water quality since high nutrient concentrations may trigger toxic algal blooms and oxygen depletion. Do also had negative relationships with fecal coliform, E. coli, and F.S. (r=-0.607, p<0.05), (r=-0.644, and r=-0.756 with p<0.01), supporting the fact of significant negative correlations between fecal coliform counts and DO (Pearson et al., 1987) and highlighting the significance of good wastewater management measures. Further, the matrix indicated a substantial negative connection between DO and Trimethoprim (Trim), Paracetamol (Para), and Ranitidine (Rani) (r>0.05, p0.05).

The results matrix analysis showed significant positive correlations between TN, PO4-P, and TKN (r = 0.925, 0.929, and 0.957, respectively) and p <0.01, highlighting their interdependence and showing that the inorganic nitrogen most likely came from sources that were related (McClelland and Valiela, 1985). In addition, the substantial correlation between NH_3-N and TKN (r = 0.980, p <0.01) implies that ammonia-nitrogen is a significant contribution to the total nitrogen level in the water samples investigated. These findings underscore the value of addressing organic nitrogen as a primary contributor to total nitrogen levels and the potential influence of organic nitrogen sources on beach water quality. Nutrients and microbiological indicators, in particular, can deleteriously influence aquatic ecosystems when present in excessive quantities. The matrix further showed a substantial positive association between NH_3-N and FC (r=0.585, p<0.05) as well as greater significant positive correlations with E. coli and fecal streptococci (F.S) (r = 0.606, and 0.771, p<0.01). Comparably (TKN) was significantly positively connected with FC (r = 0.631, p<0.05), E Coli, and F.S (r = 0.692, 0.852, p<0.01), whereas TN was significantly positively correlated with FC (r = 0.543, p<0.05), E Coli (r =0.604, p<0.050), and F.S (r =0.771, P<0.05 and 0.01). Furthermore, at 0.01 level of the significant correlation, (PO_4-P) demonstrated the most significant positive correlation with F.C, E Coli, and F.S. (r = 0.760, 0.807, and 0.854, respectively). Results were consistent with previous studies that found a significant relationship between fecal bacteria indicators and greater phosphorus and nitrogen levels in surface waters, as well as evidence that the positive impacts of nutrient addition to E. coli varied depending on nutrient levels (Wanjugi et al., 2016; Surbeck et al., 2010; Shelton et al., 2014; Korajkic et al., 2019). Moreover, these findings convey that the presence of these pollutants in the water may be contributing to the company of fecal bacteria indicators and that fluctuations in nutrient levels may be utilized to predict changes in microbial indicator levels, which could help identify potential environmental impacts and develop mitigation strategies to protect sensitive aquatic ecosystems. Trimethoprim, Sulfamethoxazole, Paracetamol, and Ranitidine all had significant moderate to strong positive correlations with nutrients and microbial indicators (r>0.5) and both had significant correlation p-values of 0.05 and 0.01, claiming that pharmaceutical contamination, most likely from wastewater, contributes to elevated nutrients and microbial growth, which can affect recreational suitability. The presence of antibiotics notably Trimethoprim and Sulfamethoxazole in saltwater has been related to antibiotic-resistant bacteria in coastal waterways. Researchers have shown that bacteria, notably E. coli, that are resistant to antibiotics (Al-Sarawi et al., 2022), such as Trimethoprim and Sulfamethoxazole, can survive in coastal waters where wastewater outfalls are present (Al-Mossawi et al., 10982; Ozgumus et al., 2007; Hernandez et al., 2019). It's important to note that these results support a previous study that was carried out in nearby Kuwait Bay areas where E. coli from recreational beaches (KPC, Sulaibikhat Sports Club, and Jabber City) proved to be resistant to the tested antibiotics. That study suggested that sewage discharge may be the cause of the resistance (Al-Sarawi et al., 2022; Hernandez et al., 2019). Antibiotic-resistant bacteria in coastal waters may profoundly impact human and environmental health. These microbes have the capacity to spread and cause diseases that are resistant to antibiotic therapy, making it more difficult to treat bacterial infections in both humans and animals (Crain et al., 2009; Bottoni et al., 2010; Al-Sarawi et al., 2022; Al-Mossawi et al., 1982).

Table 4. The Pearson correlation matrix between the water quality field measurements, nutrients, heavy metals, and bacteria indicators.

	Temp.	*pH*	*EC*	*DO*	*NH₃-N*	*TKN*	*TN*	*PO₄-P*	*Cd*	*Hg*	*Fe*	*Cu*	*Pb*	*F.C*	*E Coli*	*F.S*	*Metr*	*Trime*	*Sulf*	*Para*
Temp.	1.000																			
pH	**0.601***	1.000																		
EC	0.285	**0.591***	1.000																	
DO	-0.008	0.318	**0.707****	1.000																
NH_3-N	0.271	-0.089	**-0.579***	**-0.834****	1.000															
TKN	0.248	-0.114	**-0.589***	**-0.879****	**0.980****	1.000														
TN	0.106	-0.235	**-0.654****	**-0.827****	**0.925****	**0.957****	1.000													
PO_4-P	0.292	-0.031	-0.478	**-0.847****	**0.885****	**0.929****	**0.861****	1.000												
Cd	0.352	0.098	-0.036	-0.207	**0.552***	0.455	0.453	0.307	1.000											
Hg	-0.427	-0.257	-0.259	-0.331	0.376	0.343	0.456	0.169	0.271	1.000										
Fe	0.400	0.185	-0.018	-0.324	0.333	0.398	0.389	**0.533***	0.329	-0.198	1.000									
Cu	0.089	0.188	-0.140	-0.171	0.355	0.384	**0.524***	0.401	0.375	0.275	**0.667****	1.000								
Pb	-0.218	-0.049	-0.308	0.049	0.010	-0.013	0.129	-0.075	0.009	0.157	0.179	0.431	1.000							
F.C	0.118	0.219	-0.284	**-0.607***	**0.585***	**0.631***	**0.543***	**0.760****	-0.013	0.118	0.477	0.322	0.230	1.000						
E Coli	0.149	0.121	-0.350	**-0.644****	**0.606****	**0.692****	**0.604***	**0.807****	-0.037	-0.038	**0.546***	0.319	0.084	**0.925****	1.000					
F.S	0.144	-0.044	-0.381	**-0.756****	**0.771****	**0.852****	**0.771****	**0.854****	0.193	0.179	0.384	0.242	-0.254	**0.693****	**0.849****	1.000				
Metr	-0.377	-0.315	-0.321	0.117	0.037	0.042	0.283	-0.132	0.216	0.420	-0.087	0.437	**0.634***	-0.175	-0.164	-0.123	1.000			
Trime	0.226	-0.270	**-0.552***	**-0.593***	**0.861****	**0.829****	**0.874****	**0.701****	**0.678****	0.378	0.265	0.436	0.104	0.250	0.307	**0.540****	0.389	1.000		
Sulf	0.331	-0.181	-0.471	-0.508	**0.787****	**0.722****	**0.719****	**0.689****	**0.637****	0.201	0.230	0.332	-0.028	0.220	0.239	0.417	0.167	**0.920****	1.000	
Para	-0.065	-0.092	-0.422	**-0.569***	**0.791****	**0.744****	**0.710****	**0.619***	**0.514***	**0.608***	-0.031	0.216	-0.111	0.430	0.429	**0.682****	0.190	**0.711****	**0.638***	1.00
Rani	-0.070	-0.146	-0.468	**-0.521***	**0.781****	**0.730****	**0.751****	**0.591***	**0.566***	**0.648****	-0.026	0.322	0.045	0.352	0.336	**0.577***	0.394	**0.812****	**0.725****	**0.964***

F.C (fecal Coliform), F.S ((fecal Streptococci), Metr. (Metronidazole), Trime. (Trimethoprim), Sulf. (Sulfamethoxazole), Para. (Paracetamol), Rani. (Ranitidine)

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level

Strong positive correlations were identified between copper (Cu) and lead (Pb) (r = 0.667, p< 0.01) and iron (Fe) and PO4-P (r = 0.533, p <0.05) among the heavy metals. Certain correlations imply that the presence of certain heavy metals may be impacted by comparable sources or mechanisms. The matrix also shows that Fe and Cu have a significant positive relationship (r=0.667, p0.01), demonstrating that the correlation was likely caused by anthropogenic activities such as industrial discharge from similar sources and emphasizing the potential influence of one parameter on the concentration of another (Reddy et al., 2005). The matrix revealed a moderately positive association (r = 0.549, p <0.05) between E. coli and Fe concentrations in seawater samples collected near the outfalls during the investigation. Furthermore, Cd had an appropriately significant positive association with the pharmaceuticals Trimethoprim and Sulfamethoxazole (r=0.678,0.637, p <0.01), as well as with Paracetamol and Ranitidine (r=0.514, 0.566) with p<0.05. Similarly, Hg had a significant positive association with Paracetamol (r=0.608, p<0.05) and Ranitidine (r=0.648, p<0.01). In the context of microbiological contaminants, fecal coliform (F.C) and Escherichia coli (E Coli) were significantly related with a positive association (r = 0.925, p <0.01), and FC with F.S (r = 0.693, p<0.01), whereas E Coli and F.S were equivalent strong connection ($r=0.849$, $p<0.01$). This result is predicted since E Coli and F.S. are members of the fecal coliform group, and both are markers of fecal contamination and the potential presence of harmful organisms in the water. The significant positive connection between these markers indicates that they are most likely impacted by comparable pollution sources, such as untreated sewage or animal feces (Kefford, 1998; Noble et al., 2003). This research emphasizes the need to track microbial bacteria to determine the health hazards associated with fecal contamination on beach habitats, which harms beachgoer safety. Additionally, it seems that fecal coliform (FC), E. coli, and fecal streptococci (F.S) are strong to moderately positively associated with NH3-N, TKN, TN, and PO4-P concentrations (Surbeck et al., 2010; Shelton et al., 2014; Korajkic et al., 2019), notably the F.S, which displayed association among the bacteria indicators.

The correlation coefficients indicate significant relationships between various parameters and pharmaceuticals, providing insights into water quality issues and highlighting interesting associations, such as Metronidazole, which showed a significant correlation with Pb ($r= 0.634$, $p <0.01$) but failed to correlate with other parameters. Trimethoprim and Sulfamethoxazole, Paracetamol, and Ranitidine, on the other hand, showed a significant strength to moderate positive correlation with nutrients NH3-N, TKN, and TN ($r = 0.71$- 0.861, $p <0.01$), whereas a moderately significant positive correlation with Trimethoprim had a negative connection with EC ($r=0.552$, $p< 0.05$) and, together with paracetamol and ranitidine, had a moderately significant negative association with DO ($r > 0.5$, $p <0.05$). Among the pharmaceutical contaminants, strong positive correlations were observed between trimethoprim (Trim) and sulfamethoxazole (Sulf) ($r = 0.920$, $p < 0.01$), and between paracetamol (Para) and ranitidine (Rani) ($r = 0.964$, $p < 0.01$), while trimethoprim (Trim) and sulfamethoxazole (Sulf) correlate positively with Paracetamol and Ranitidine($r>0.638$, $p< 0.01$). These associations show that these pharmaceutical substances frequently co-occur in anthropogenically influenced water bodies, and they imply that pharmaceutical pollution, probably via wastewater, is causing higher nutrients and microbial development that may affect the suitability of the local region for recreational activities (Gaw et al., 2014; Al-Sarawi et al., 2022). The findings suggest that physicochemical characteristics and microbiological indicators may alter when pharmaceuticals are present in water samples. These results underline the need to maintain an eye on the existence and disposition of pharmaceuticals in water resources and any possible effects they may have on the aquatic ecosystem and general public health.

4. Conclusion

Wastewater from residential, medical, industrial, and commercial sources contributes significantly to the effluents released into Kuwait Bay seawater, which negatively impacts the seawater quality at the beaches used for recreation. Accordingly, microbial contamination, low Do levels, nutrient load building, and changes in physical and chemical properties will result in a stressful marine environment and the unanticipated growth of waterborne diseases. The study's results revealed that sample location OC5, which is close to medical activities, was extremely nutritionally, chemically, and microbially polluted, whereas OC10 was the least contaminated among other locations. Further, the research findings also revealed that there is an elevated demand for oxygen in the OC3 and OC5 sample locations, in addition to, the intensive existence of pathogens such as fecal coliforms, E coli, and fecal streptococci, as well as harmful chemicals of heavy metals and pharmaceuticals, implying that these beaches were vulnerable serious contamination. Besides this, seawater polluted with abundant fecal bacteria and nutrients could be cloudy and stinky, presenting serious health concerns to individuals who engage in recreational activities and causing adverse effects on aquatic species and human health; thus, effective disinfection methods are recommended to get rid of this serious contamination. The study's findings advocate for the use of effective onsite treatment procedures, as well as consistent audits and monitoring of environmental law implementation, in a bid to enhance the efficacy of discharged wastewater, inhibit the uncontrolled discharge of effluents into the sea, and improve the ecosystem's balance in seawater. The complex relationships between various water quality parameters and their implications for aquatic ecosystem health imply that efforts to reduce nutrient inputs and control pollution sources may aid in improving water quality and protecting aquatic organisms from the harmful effects of contaminants. The synergistic and antagonistic interactions of these characteristics and their effects on the composition and operation of aquatic ecosystems deserve more investigation. In general, Pearson correlations shed light on the links between several water quality indicators in the investigated locations. It is crucial to highlight, however, that correlation does not always imply causation, and further study is required to confirm the causative links between these factors and to evaluate the generalizability of these findings to other populations and regions.

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Author contribution

Ohoud Bushaibah conceived and designed the study supervised the sampling and data analysis, conducted the data interpretation, and wrote the manuscript. Dr. Adel Al-Haddad supervised the study, advised on sampling analysis, and revised the manuscript. Fatemah Dashti contributed to sampling collection, prepared the graphs, and performed data analysis. All authors read and approved the final version of the manuscript.

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Data availability

The research data sets developed and analyzed in the current study can be accessed upon adequate request from the corresponding author.

Declarations

Ethics approval

The current study did not involve live animals. It adheres to ethical norms, and no ethical approval was necessary.

Consent to participate

Not applicable

Competing interests

The authors declare that no potential conflicts of interest appear to have impacted the work presented in this study.

“All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors”

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