Original Article

Microbiological Water Quality Close To The Stormwater Outfalls In Recreational Beaches Of Kuwait Bay

Ohoud Bushaibah[1], Fatemah Dashti[2], Adel Al-Haddad[3]

[1] Senior Research Associate, Environmental Pollution and Climate Program, Environmental and Life Science Research Center, Kuwait Institute for Scientific Research,
[2] Research Associate, Water Resources Development and Management Program, Water Research Center, Kuwait Institute for Scientific Research,
[3] Research Scientist and Program Manager, Wastewater Treatment and Reclamation Technologies, Water Research Center, Kuwait Institute for Scientific Research
Email: [1]ashaiba@kisr.edu.kw,[2]fmdashti@kisr.edu.kw, [3]ahadad@kisr.edu.kw

***Corresponding Author:** Ohoud Bushaibah
Senior Research Associate, Environmental Pollution and Climate Program, Environmental and Life Science Research Center, Kuwait Institute for Scientific Research.
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Abstract

Kuwait Bay's southern shore is home to several facilities used for various purposes, impacting the beaches' ecosystems and coastal environment. Furthermore, the presence of numerous stormwater outfalls on Kuwait Bay's southern shores may be one of the sources of pollutants that are discharged from these outfalls. This research aims to evaluate the microbiological quality of seawater near 5 selected stormwater outfalls located on Kuwait Bay's recreational water by measuring the levels of microbial bacteria such as fecal coliform (FC), and Escherichia Coli. (E. Coli), and fecal streptococci (FS), and water quality parameters including temperature, pH, electrical conductivity (EC), and dissolved oxygen (DO). The analytical results were compared with Kuwait Environmental Public Authority (EPA) requirements for water discharge to Kuwait Bay to assess the suitability of the beaches for recreational activities. The field results revealed the presence of mildly alkaline seawater samples, a range of fresh to saline water types, and various DO levels from very low to acceptable levels. noteworthy, the microbial indicators were extremely high and far beyond EPA guidelines, demonstrating extensive microbiological pollution at these locations. The mean FC/FS ratios of C18 had the greatest mean FC/FS ratio (16.75), signifying human contamination. C3 and C5 indicated human waste in mixed pollution with averages of (3.45 and 2.34 respectively), whereas C8 and C10 showed human contamination with average values (of 5.98, and 4.21 respectively). It is suggested that the seawater quality close to wastewater outfalls be frequently evaluated and treated using efficient onsite treatment technologies to decrease the amount of polluted wastewater discharged directly to the beaches.

Index Terms— Water quality, Microbial, Fecal Coliform, E Coli, Fecal Streptococci.

INTRODUCTION

The significant nature of Kuwait Bay as a shallow semi-closed extension of the semi-closed Arabian Gulf is elevated by the fact that it extends to the northwest portion of The Arabian Gulf, which is conceived of as a semi-closed sea body extending from the Gulf of Oman [1]. Furthermore, several stormwater and wastewater outfalls are located along Kuwait's south coast, which may be connected to an increase in pollution risk from the discharge of residential, industrial, and medical untreated wastewater from many establishments located along Kuwait's Bay beaches. Previously, the coastal environment of Kuwait experienced severe pollution problems as a result of the discharge of untreated sewage into the sea due to sporadic disruptions of the sewage treatment plants, which may randomly occur on Kuwait's shores. The environmental quality of Kuwait Bay has deteriorated over the last few decades as a result of the continuous pumping of pollutants through coastal outfalls and the outlets of power and desalination facilities. Moreover, 25% of untreated wastewater is dumped into the ocean, increasing the amount of contamination in the seawater [2], [3]. Worth mentioning that there is a research study previously done in the last decade showed that the microbial indicators of total and fecal coliform were exceeding the acceptable limits of Kuwait EPA many times during the study of the influence of the discharge the wastewater into Kuwait beaches [4]. Despite significant upgrades to Kuwait's wastewater treatment system, which are anticipated to enhance the quality of sewage before it is discharged into the sea, the results for fecal sterol contamination of sediments demonstrate that sewage continues to contaminate a variety of areas [5].

Foundationally, the quality of water is determined by its physical, chemical, and biological parameters, Consequently, as a result, the water quality of natural water sources for various purposes should be determined in terms of the precise water-quality characteristics that have the greatest influence on the possible use of water [6], [7]. The microbial water quality of the recreational beaches is crucial to the safety of the Locals who visit these beaches. In terms of rest, relaxation, exercise, cultural

and religious traditions, and aesthetic enjoyment, using coastal recreational areas has major positive effects on health and well-being. Nevertheless, recreational water quality is extremely sensitive to municipal wastewater microbiological contamination, degrading water quality, and increasing human health hazards. Recreational water bodies are characterized and classified to determine their suitability for recreational use, based on susceptibility to fecal contamination, which the Microbial infections introduced by fecal pollution from humans and animals are the most prevalent hazards in recreational waters. [8], [9]. Therefore, pathogen levels in water resources are routinely assessed using indicator organisms such as fecal coliform, fecal streptococci, and Escherichia coli (E. coli) counts, which are used to assess the extent of sewage contamination on the coastal water. [8-11]. Recently a study has reported that the level of fecal coliform and E. coli in Doha Bay, which is part of Kuwait Bay's southwest, is devastating, with Bacteria levels exceeding all regulations and restrictions. This dispersion causes the degradation of fishery resources and marine life's overall health and ecological balance. Furthermore, for beachgoers, high quantities are risky and could cause several diseases [3]. As a result, it is vital to frequently monitor the quality of the seawater nearby the wastewater discharge outfalls, as the wastewater may contain pathogens, including bacteria that cause deoxygenated dead zones in the sea, accumulation of nitrous oxide, and emissions of methane; a powerful global warming gas [12]. To meet the requirements of recreational water quality as a healthy environment and safe entertaining place to practice recreational activities, however, intensive monitoring and investigation can play a significant role in addressing the contributing factors that cause such negative effects. Thus, this study aims to emphasize microbiological contamination by investigating microbiological indicators (fecal coliform, E. coli, and fecal streptococci) near selected wastewater outfalls in Kuwait's recreational water Bay.

MATERIALS AND METHODS

Kuwait Bay, a high - productivity ecosystem, provides a range of services such as supplying, regulating, supporting, and cultural support. Kuwaiti marine water, primarily Kuwait Bay, is teeming with a diverse variety of organisms that have provided almost half of the country's food requirements [1]. Wherefore, this study was conducted at selected stormwater outfalls located in recreational water on the south shores of Kuwait Bay, where the sites of targeted sample locations are close to a range of facilities that serve a variety of activities such as healthcare, commercial, domestic, and recreation purposes such as (swimming, boating, water skiing, and fishing). Table (I) lists the locations, coordinates, descriptions, and kinds of nearby amenities for the five outfalls. The sampling locations span from Platinum Health Club (C18) on the open side of Kuwait Bay to Sulaibikhat Traditional Cafe near the closed side of Kuwait Bay (C3). Therefore, identifying these locations will provide an in-depth assessment of the various wastewater discharge sources into Kuwait Bay and a comprehensive depiction of Kuwait's coastal water quality. In this research study, the water samples were analyzed for the physical parameters of temperature, and electrical conductivity (EC), and the chemical parameters for the hydrogen ion concentrations (pH) and dissolved oxygen (DO), while the microbiological parameters are the: Fecal coliforms (EC), Escherichia coli (E. coli), and Fecal Streptococci(FS). Additionally, The FC/FS ratio was used to estimate the source of fecal contamination [13], and it implies contamination from human sources (FC/FS > 4), and animal sources (FC/FS < 0.7). The range of (2.0 to 4.0) was regarded as human waste in mixed pollution, and the range of (0.7 to 2.0) was suggested as animal waste in mixed pollution. However, the FC/FS ratio value has lately been considered a regulatory tool rather than a diagnostic tool

Table I. Coordinates and Descriptions of the Samples Locations

Site Code	Coordinate		Activity Type
	Longitude	Latitude	
C3	47.863044	29.320015	Domestic and Recreation
C5	47.902617	29.334869	Healthcare and Recreation
C8	47.946706	29.357277	Commercial and Recreation
C10	47.957159	29.365538	Domestic and Recreation
C18	47.989117	29.391525	Recreation

in detecting contamination sources [14-16]. As a result, the FC/FS Ratio was utilized to determine the source of fecal contamination at the five locations selected.

This study, which lasted from January to May 2022, was based on the examination of 100 samples of mixed wastewater and seawater collected during low and high tides.
The samples were collected from five stormwater outfalls in Kuwait Bay's recreational water on the southern shoreline.

The water samples were analyzed onsite for the water physical and chemical quality parameters using portable field meters, afterward, each sample was collected using (500 ml) bottles, and the outfall location, the time, and the date of sampling were labeled. The collected samples were sorted, transferred, and stored in an icebox with ice bricks to keep the samples cold at 4 ℃ [17]. Furthermore, the water samples were analyzed at Kuwait Institute for Scientific Research (KISR) laboratories for the microbiological indicators (Fecal coliforms, Escherichia coli (E. coli), and Fecal Streptococci) by using the Membrane Filter Technique method to determine the presence of bacteria using 0.25 ml dilution [17]. The laboratory results were contrasted to KEPA permissible requirements [18], [19] to determine the microbiological contamination levels and identify the hotspots of the most polluted recreational water in Kuwait Bay coastal areas. The total dissolved solids (TDS) values of each water sampling location were derived using the ratio [17]:

Calculated TDS/EC= 0.75 (1)

The salinity expressed as TDS with EC values relationship was stated in the equation:

TDS= EC x F (2)

Where F is a constant value for the natural water type, which ranged between 0.55 and 0.8 in this study F is assumed to be 0.75 according to the high salinity of Kuwait Bay [1].

RESULT AND DISCUSSION

Water Quality

The water quality field measurements of the five selected sampling locations indicated the seawater temperatures at all locations were ambient and within EPA requirements Fig. (1), The temperature values range from (18.7°C – 31.3°C), where the highest mean of the temperature measurements of all the samples during the study periods from Jan. 2021 to May 2022 was 26.7°C for the sampling sites C5 and C8, whereas the lowest mean value of 24.45°C at the sampling
location C18. It's worth mentioning that, throughout the study time, the seawater temperatures at sampling locations C3 and C5 were the highest among the other sample locations. Significantly, the research was carried out over winter, spring, and summer, in which the changes in weather conditions influenced the temperatures of the seawater considering the very high temperature in Summer that represented the increase of the water temperature during the study. Furthermore, chemical and biological reaction rates increase with increasing temperature, and the reaction rates are usually assumed to double for an increase in temperature of 10 °C [6]. The pH mean values of all samples were somewhat alkaline, nevertheless, the mean pH values in all the sample locations were within the permissible pH values (6-9) of the KEPA requirements [18]. Moreover, the mean pH values for the water samples for the five locations were nearly comparable with a range from 6.96 (slightly acidic) at C18 to 8.03 (mild alkaline) at C8, while, the locations C3, C8, and C10 showed pH maximum values among other locations (Fig. 2). On the other hand, the averages of DO values of the samples' locations fluctuated from 1.825 mg/l at C5 to 4.9 mg/l at C18 (Fig. 3). During the research investigation, the DO mean values revealed that C3, C5, and C8 were below the minimum KEPA requirement of 4 mg/l [18], indicating that these locations had insufficient rates of DO, which are crucial for a healthy marine environment and necessitate urgent treatment. Nevertheless, the DO mean values of the sampling locations C10 and C18 were within the KEPA standards, the Do levels were relatively very low during the study, and this may be attributed to pollutant accumulation and the longest residence duration of contaminated water due to slow circulation of the water due to the nature of Kuwait Bay [20]. During the study period, the EC mean values for all collected samples, were within the range from 1234 µS/cm at C5 to 73660 µS/cm at C8 (Table II) and accordingly the calculated TDS ranges from 925.5 mg/l at C5 to 55245 mg/l at C8, TDS levels confirmed the presence of freshwater at C5 and saline water at the other locations (Fig. 4). Whereas the EC and TDS are linked to the salinity, the high weather temperatures, evaporation levels, and freshwater influx from the Shatt Al-Arab all affected the salinity of seawater in Kuwait.

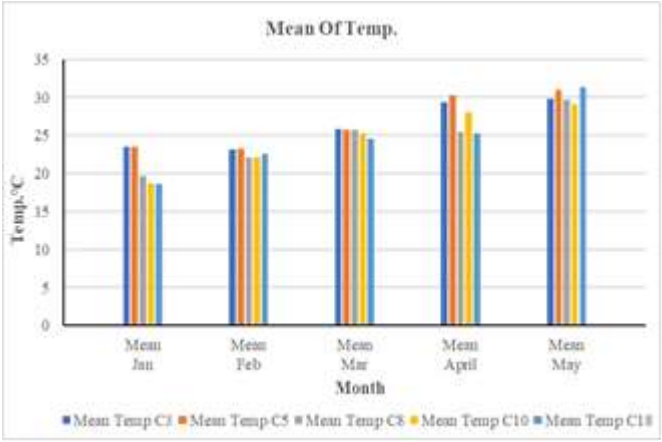

Fig. 1. The mean of the temperature values of the sampling locations.

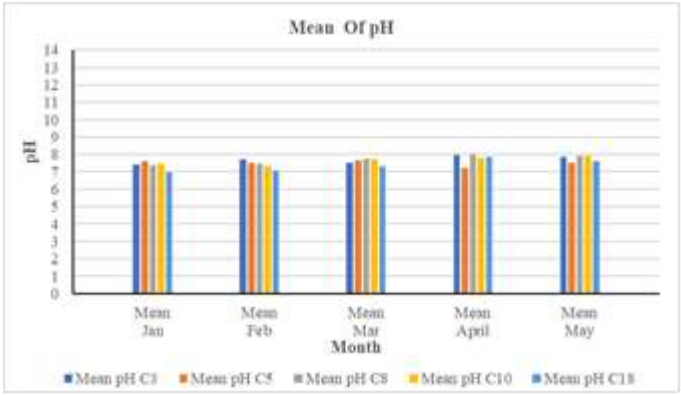

Fig. 2. The mean of the pH values of the sampling locations.

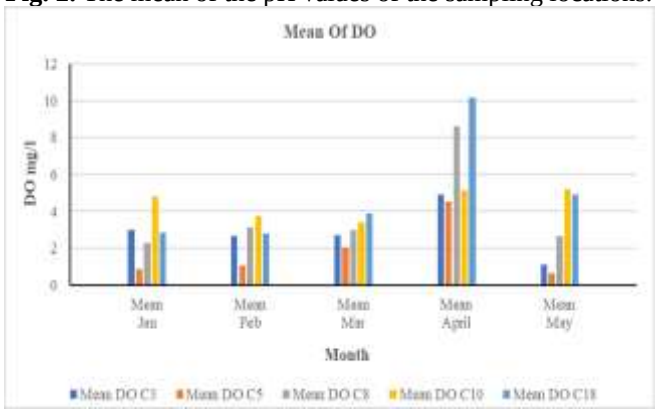

Fig. 3. The mean of the DO values of the sampling locations.

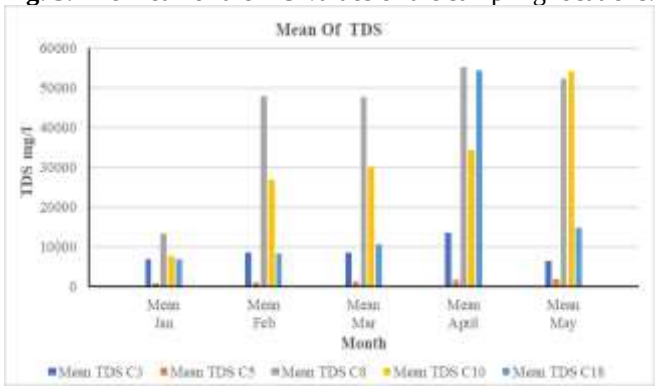

Fig. 4. The mean of the TDS values of the sampling locations.

However, the salinity fluctuates. during the seasons, it is at elevated levels in Summer and Fall and relatively low in Spring and Winter [1].

The EC measurement's mean values are presented in Table (II), and generally, the salinity of the water is categorized as follows: freshwater (less than 1000 mg/l-TDS), brackish water (between 1000 and 10,000 mg/l-TDS), saline water (between 10,000 and 100,000 mg/l-TDS), and brine water (greater than 100,000 mg/l-TDS) [7], [21]. Accordingly, the TDS values in fig (4) specified the presence of saline water types at 3 out of the 5 locations which are C8, C10, and C18, while, brackish

Table II: The EC Means Values of the Sampling Locations During the Study

Sampling Date	EC C3 (µS/cm)	EC C5 (µS/cm)	EC C8 (µS/cm)	EC C10 (µS/cm)	EC C18 (µS/cm)
Jan	9295	1234	1786.5	10390	9105
Feb	11445	1402	63925	35845	11100
Mar	11375	1605.5	63680	40155	14245
April	18150	2350	73660	45895	72485
May	8780	2614.5	69840	72315	19805

water types at C3 and C5 during the study period. While there are no specific guidelines set by KEPA concerning the EC or TDS parameters to compare with, but, water quality and the ecosystem environment are affected by the salinity of the seawater [1], [20]. These results revealed that the C5 is subjected to untreated wastewater flow, whereas monitoring is required for location C3 due low level of salinity indicators measurements. Since water quality can also be determined by the odor and color of seawater [6-7], it is important to note that during field trips, there were noticeable distasteful odors and variations in the shade and clarity of the effluent discharged especially in sites C3 and C5, which may imply the likelihood of contamination. Consequently, these findings underscore the need for consistent observing and support the purpose of assessing the water quality near stormwater outfalls as well as justifying the relevance of monitoring as an investigation's main objective.

Microbiological Results

The microbiological indicator laboratory results revealed that the average values of all the detected bacteria counts for all sites were substantially beyond the Kuwait EPA permissible limits. Figure 5 shows that all mean fecal coliform values at all sampling sites were higher than the permissible limits of KEPA (<500 CFU/100ml) for the discharging water in Kuwait Bay [19], with average values ranging from 12,000 CFU/100ml in C8 to the maximum number of bacteria of 4,315,000 CFU/100 ml at the same location (fig.5). Despite being located on one of Kuwait's most famous recreational beaches, which is frequented by many individuals for a variety of activities, there is a notable change in biological contamination at this site, which necessitated consistent intensive care and additional inspecting to determine the causes of the rising and dropping contamination levels in this attractive tourism coast. Although there is massive fecal contamination at all the sites, the laboratory results revealed that in general the sampling locations C18 and C10 were affected by less Fecal contamination than the other locations. Similarly, E. Coli measurements ranged from a high of 3990000 CFU/100ml at location C5 to a low of 6000 CFU/100ml at location C8, far beyond the acceptable limits of KEPA (<500 CFU/100ml) (fig.6). Locations C18 and C10 presented consistently lower E Coli contamination than the other sampling locations, whereas C5 had the highest microbiological contamination. In like manner, sampling location C8 showed the uppermost E Coli contamination in March and the lowermost pollution in April, indicating the necessity of additional monitoring at this location. The Fecal Streptococcus mean values ranged from 4000 CFU/100ml at location C10 to the maximum value above 3037500 CFU/100ml which was measured in sample location C5 (fig.7). Contrarily, sampling location C8 had the lowest level of FS contamination among the other sites in April but not the greatest in March, however, it is considered in the high level of the microbial contamination which indicating that microbiological pollution for that month came from a variety microbial source other than FS. Worth mentioning that the E. Coli and FS values are far above the KEPA acceptable limits of the water discharge into Kuwait Bay seawater which is (200 CFU/100ml) [19]. The analytical results of all microbial indicators revealed the necessity for extensive treatment and continuous periodic monitoring since these beaches are declared unsuitable for recreational activities and even pose a serious risk to aquatic species and human health. In general, the microbiological indicators' overall analysis findings showed significant bacterial

contamination in all of the sample sites, notably in C3 and C5, which had higher rates of microbial contamination than the other 3 sites.

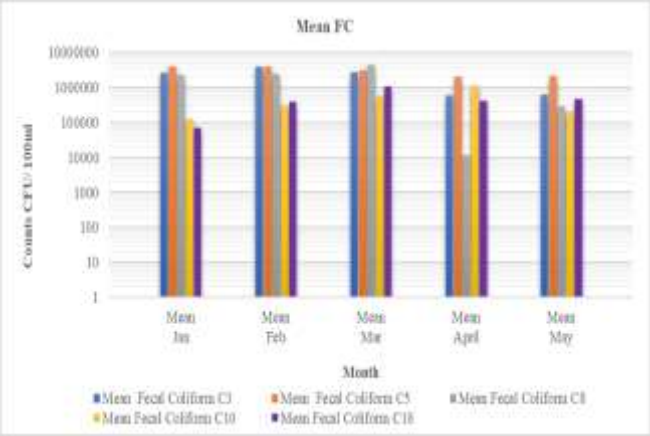

Fig. 5. The mean values of the microbial indicators of Fecal Coliform of the sampling locations

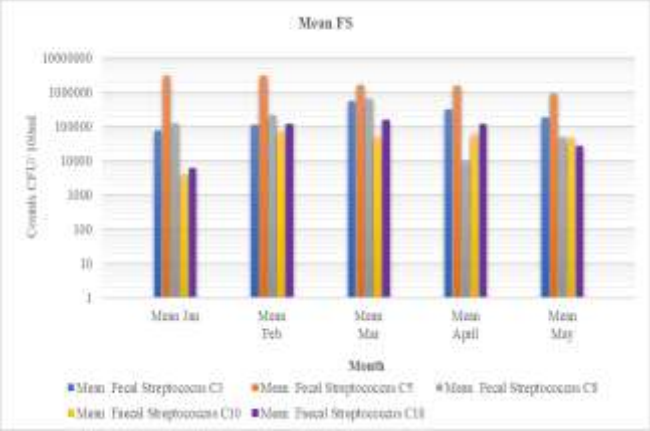

Fig. 6. The mean values of the microbial indicators E. Coli of the sampling locations.

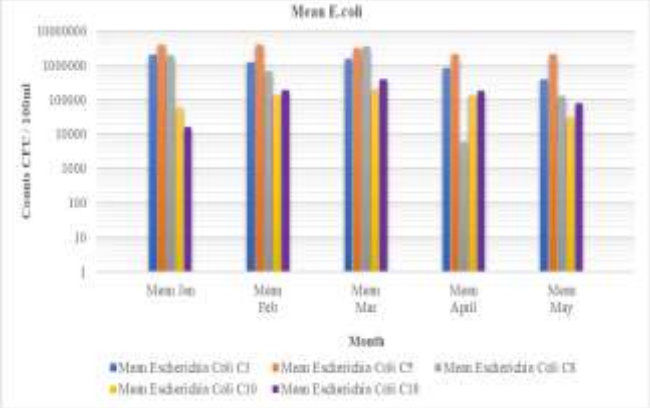

Fig. 7. The mean values of the microbial indicators Fecal Streptococcus of the sampling locations.

Remarkably, the sample analysis study indicates that C10 was the least microbial-polluted location during the study period except in April when sample location C8 was the least microbial contamination; yet, serious microbiological contamination persists at all locations. The general outcomes demonstrate severe microbiological pollution on Kuwait Bay's southern shoreline, particularly near the chosen wastewater outfalls, which was significantly beyond Kuwait EPA's permissible limits. Disinfection measures are necessary as a potential treatment in light of the classification of these five sample locations and the neighboring beaches as unsuitable for bathing and inappropriate for recreational activities.

FC/FS Ratio

The FC/FS ratio was intended to determine the source of fecal contamination, and the obtained values may indicate the human source, animal source, or combined human and animal sources in mixed pollution, depending on the findings of each selected sample location. Understanding the assumptions and limits associated with each fecal source monitoring technique and its intended use is crucial [13-14]. In this regard, FC/FS was evaluated in this research (fig. 8) to assess recreational water quality and measure users' safety. The mean of the FC/FS ratio for sites C3 ranged from 1.8, in April 2022 indicating that animal waste in mixed pollution to the highest ratio value of 34 revealing human waste in January and February 2022. Likewise, at site C8 the FC/FS ratio ranged similarly from animal waste in mixed pollution in April 2022 to human waste source in the rest study period. February and April 2022 the source of fecal contamination in C18 as presented in the FC/FS ratio with values of 3.3 indicated that human waste in mixed pollution whereas human waste in the rest period of the study. On the contrary, Sample location C5 demonstrated the animal waste in mixed pollution with ratio values ranging from (1.3-1.9) in all the study periods except May 2022 where the FC/FS ratio was 2.3 which indicated the human waste in mixed pollution [14]. In April the FC/FS ratio for C10 was indicated as the human waste source while other sampling sites were ranging from mixed to animal waste sources It is worth noting that site C5 is inhabited by a variety of bird species, including flamingos since is their primary migratory location in Kuwait, as well as an endemic for a herd of dogs, which may justify the source of pollution as animal waste in mixed pollution.

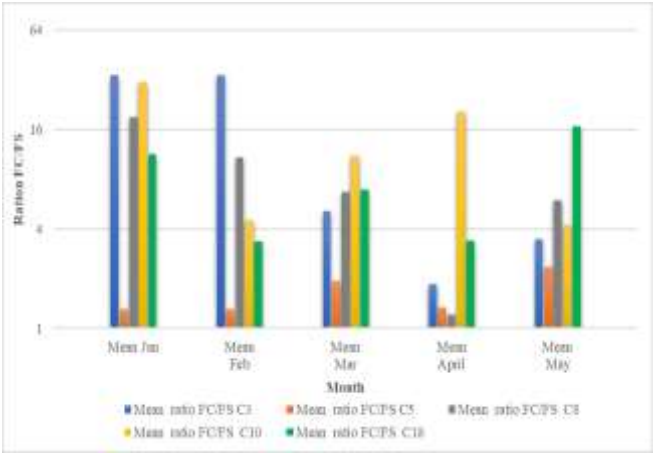

Fig. 8. The FC/FS Ratio values of the microbial indicators in the sampling locations

CONCLUSION

The assessment of the five selected sample locations suggested that C5 was seriously affected by severe microbial pollution and insufficient level of DO levels, whereas C10 represented the least contaminated outfall compared to other sites. Low levels of DO (dissolved oxygen) show a high oxygen demand and signify that the sample locations aren't in optimal health, by the study results. Hence, adopting efficient oxidizing technologies is essential for maintaining the ecosystem's balance in seawater. The existence of immensely pathogenic microorganisms such as fecal coliform, E Coli, and fecal streptococci implies that these coastal areas are subjected to major microbiological pollution, posing serious health risks to individuals who engage in recreational activities and adversely impacting the food supply chain of aquatic organisms as well as public health. Furthermore, the presence of substantial quantities of fecal bacteria might result in cloudy and stinky seawater. As a consequence, recreational activities could be extremely unwise nearby these discharge sewers, suggesting their relation to serious health hazards.

Since the estimation of the FC/FS ratio revealed a variety of animal and human waste sources in the sampling sites, it is suggested that additional studies be carried out to assess the validity of the findings as a tool for estimating the fecal contamination source and the convenience of this presumption in regards to the treatment techniques that will be used to eliminate microbiological pollution in Kuwait Bay's south coastlines. The study's findings indicate that in addition to proper onsite waste treatment, monitoring of the treatment processes, and the implementation of appropriate wastewater disposal, there is a critical need for ongoing monitoring to prevent the unintended discharge of polluted wastewater directly into the sea. Additionally, it is advised to characterize the features of the recreational water body, support risk categories, and carry out a critical assessment of the water's microbiological quality to control authorized leisure activities, it is also essential to keep track of monitor operations and maintain control measures. To ensure the effective implementation of these regulations and the fulfillment of the higher requirements of discharged wastewater quality, it is strongly recommended that effective environmental laws be enforced. The decision-makers must be aware of the wastewater dumping on Kuwait Bay's southern shore as the study's chosen outfalls are near the most popular beaches for swimming, fishing, and leisure activities.

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