Preliminary Assessment of Wastewater Quality near Emergency Outfalls in Kuwait Bay

O. Bushaibah*, A. Al-Haddad, M. Khajah, F. Dashti, and E. Ibrahim

Abstract—**Twenty-two wastewater discharging emergency outfalls located within Kuwait Bay have the ability to pollute marine life. The quality of wastewater discharged to the sea has a direct and significant impact on the ecosystem including marine organisms, and an indirect effect on human health. The current study aims to evaluate the quality of wastewater discharged at selected sites of Kuwait Bay and to compare the obtained results with the standards of the Environmental Public Authority (EPA) for discharging treated wastewater to Kuwait Bay. Five locations were selected near emergency outfalls, and onsite field measurements for water quality were carried out, including temperature, pH, Electrical Conductivity (EC), and Dissolved Oxygen (DO). Furthermore, 15 mixed water samples (wastewater and seawater) were collected throughout November 2021 and January 2022 during low and high tides and within 1 m away from wastewater discharging outfalls. These samples were analyzed for nutrients, heavy metals, and bacteria parameters. The field results indicated the presence of slight alkalinity (pH 7.01–8.0), freshwater to saline water type (EC, 1.27 ms/cm–65.07ms/cm), oxidized environment (DO, 0.91 mg/l–5.28 mg/l). The laboratory results of water samples revealed that the concentrations of nutrients (total nitrogen, 2.0–35 mg/l) and all targeted heavy metals were detected in mixed samples for all sites in concentrations of microgram per liter and within EPA acceptable limits. On the other hand, phosphate concentration (4.2–13.6 mg/l) and the counts of microbial indicators (Fecal coliform, E. coli, and Fecal Streptococci) were high and above EPA standards, which shows the grave biological pollution that occurred at these sites. The variation in the contamination levels at the selected locations indicates the need for periodic monitoring of the quality of mixed water near wastewater emergency outlets and searching for the appropriate solutions to reduce the contaminated wastewater discharged directly into the beaches.**

Index Terms—**Environmental, heavy metals, microbial, nutrient, water samples.**

I. Introduction

Kuwait's marine environment is a distinct ecosystem with a diverse range of habitats and wildlife. It has high productivity that provides support to the functions of the aquatic organisms of this unique environmental system. Kuwaiti seawaters, mostly the Kuwait Bay, are rich in a variety of species that have supplied around 40% to 50% of the country's food demand [1]. The impacts of pollutants on Kuwait Bay's coastal environment may be noteworthy due to its nature as a semi-closed water body with shallow depth, limited circulation, high salinity, and temperature. The marine environment on the Kuwait coast has been previously facing serious pollution issues due to the redundant temporary disruption of the sewage treatment plants, which has led to the occasional discharge of untreated sewage into the sea. These issues may continue to occur on Kuwait's shores, which require continuous monitoring of seawater quality along the coastal line of Kuwait. Kuwait Bay is being polluted by a variety of sources, both local and regional, and the most significant influencing factors are desalination and power plants, as well as sewage outlets located along Kuwait Bay's southern coast. In August 2009, the Mishrif sewage pumping station broke down due to overload, and a massive amount of raw sewage was discharged into seawater and Kuwait Bay via the emergency outfalls, which had caused a major pollution disaster to Kuwait's marine environment [2]. Such an issue may additionally disrupt seawater quality and ecosystem stability and lead to adverse health and environmental effects, which can be categorized as serious or dangerous. Intensive monitoring and investigation can play an essential role in addressing the contributing factors that purpose such undesirable consequences to meet the necessities of a healthy seawater environment.

Significant improvements are underway to Kuwait's wastewater treatment system, which are expected to eventually improve the quality of sewage discharged into the sea. However, the data presented for fecal sterol contamination of sediments indicate that there are several areas that still receiving large quantities of sewage contamination [3]. On the other hand, there are more than 22 emergency outfalls on Kuwait's Bay's southern coast, which face an increased risk of pollution from the discharge of untreated wastewater. Domestic, industrial, and medical effluents from a number of facilities along Kuwait's bay beaches put additional strain on this semi-closed marine environment. Such an issue may additionally disrupt seawater quality and ecosystem stability and lead to adverse health and environmental effects, which can be categorized as serious or dangerous. Intensive monitoring and investigation can play an essential role in addressing the factors that contribute to such undesirable consequences, to meet the necessities of a healthy seawater environment.

A simulation study conducted by Aleisa *et al.* [4] shows that a total of 25% of untreated wastewater is discharged into the sea and the amount of contaminants discharged into the sea will rise again if the expansion projects of the Ministry of Public Works (MPW) for Wastewater Treatment Plants (WWTPs) did not commence on time. This wastewater contains a range of pathogens, including bacteria, parasites, and viruses, which cause deoxygenated dead zones in the sea; accumulation of nitrous oxide; and emissions of methane, a powerful global warming gas [5], [6]. Several citizens and residents continue to practice their hobbies in those

Manuscript received May 15, 2022; revised June 2, 2022; accepted June 15, 2022.

O. Bushaibah, A. Al-Haddad, M. Khajah, F. Dashti, and E. Ibrahim are with Kuwait Institute for Scientific Research (KISR), Kuwait.

*Correspondence: ashaiba@kisr.edu.kw

doi: 10.18178/ijesd.2023.14.1.1415

contaminated beaches despite the warning signs, which exposes their health and their children's health to develop various diseases because of the microbial polluted beaches of the restricted areas. Kuwait EPA has several monitoring stations along the Kuwait coast, which measure bacteriological contamination of the coastal water of Kuwait every month. Microbial water quality and bacteria counts of fecal coliform, fecal streptococci, and Escherichia coli (E. coli) have been used to evaluate the level of sewage contamination on the Kuwaiti coasts. Indicator organisms are commonly used to assess the levels of pathogens in water resources [7]-[9]. Moreover, a previous study has showed that the microbial indicators of total and fecal coliform were exceeding the acceptable EPA limits in different months of different years of the studied areas in Kuwait's beaches [10]. These findings support the necessity to regularly monitor the microbiological quality of coastal water on a regular basis in order to maintain a healthy and safe environment for aquatic animals and humans to live in or engage in recreational activities.

The crucial objective of this study is to show preliminary results of the assessment of the quality of the wastewater discharge through the emergency outfalls located on the southern coast of Kuwait Bay. This study provided an important opportunity to advance the understanding of the recent status of the southern beaches of Kuwait Bay, which is stressed with many facilities and considered as the busiest part of Kuwait's coasts. The findings and results of this study should contribute to the public and decision-makers and highlight the most polluted area among the five selected outfalls.

The microbial indicators will be the key factors to determine microbiological pollution near the sewage outfalls if any. However, a considerable major study has been published that discusses that the lower concentration of dissolved oxygen at the inner part of the Kuwait Bay might be attributable to the accumulation of pollutants and longest residence time of polluted water mass from the referred inverse-estuarine circulation [11]. The discharged wastewater may also carry out nutrients and heavy metals, which represent significant factors in investigating direct and indirect adverse effects on human health and the marine environment. Domestic and industrial sewage may also contain a variety of marine microorganisms including pathogenic bacteria species. differences in these bacteria depend mostly on many factors including the number of different antibiotics, heavy metals, and detergents, which may be disposed of sewage and from sewage to seawater and additionally, to the environmental factors and nutritional status. With increasing industrialization, pollution by heavy metals has posed a serious problem in water bodies because they exert harmful effects on aquatic organisms [12]-[14]. As a result, seawater quality near wastewater emergency outfalls must be monitored frequently to determine the degree of stress that may occur in the marine environment. Moreover, addressing the primary sources of pollutants and developing appropriate treatments are strongly needed to mitigate the negative consequences that may result in an imbalance in the marine ecosystem. Assessing the water quality periodically is a significant necessity to keep the Kuwait Bay coast suitable for recreational activities as well as maintain the ecosystem balance at its optimal health level.

II. Study Area

To conduct this study, five sample locations were chosen on the southern coastline of Kuwait Bay, considering the importance and sensitivity of these parts. The research results were derived from the analysis of 15 samples collected during the periods from November 2021 to January 2022 from the 5 sample locations. The selected sample locations are located on the coastline of the south of Kuwait Bay distributed from the outer area of Kuwait Bay at Platinum Health Club (OC18) to the near inner part of the bay at Sulaibikhat Traditional Café (OC3) Fig. 1. The codes for the five example locations, as well as their positions and descriptions, are illustrated in Table I. These areas are close to a variety of amenities that cater to various activities such as medical, industrial, residential, and recreational. The selection of these specific areas will provide a broad evaluation of the many sources of wastewater discharge into Kuwait Bay, as well as a comprehensive picture of the present quality of Kuwait's coastal water.

Fig. 1. The map of the five selected locations at the south of Kuwait Bay.

TABLE I: The Coordinates and Descriptions of the Sample Locations

Site Code	Coordinate		Site Descriptions	Remark (Activity)
	Longitude	Latitude		
OC3	47.863044	29.320015	Close to Sulaibikhat Traditional Cafe	Residential and leisure
OC5	47.902617	29.334869	Opposite Sheikh Jaber Al-Sabah Molecular Center	Medical
OC8	47.946706	29.357277	Close to Shuwaikh Beach Park	Industrial and leisure
OC10	47.957159	29.365538	Opposite the church	Residential and leisure
OC18	47.989117	29.391525	Close to Platinum Health Club	Leisure

III. Material and Methods

Three field trips were conducted during the periods from November 21 to January 2022, during low and high tides and within 1 m away from the five selected wastewater emergency outfalls. Samples of wastewater mixed with seawater were taken near these five emergency outfalls OC18, OC10, OC8, OC5, and OC3 (Fig. 1) on Kuwait Bay's beach. Three liters from each site were collected and analyzed onsite and in the laboratories of the Kuwait Institute for Scientific Research (KISR). The samples were analyzed onsite for the water quality parameters: temperature, pH, Dissolved Oxygen (DO), and Electrical Conductivity (EC). Each sample was collected using 500-ml bottles and labeled according to the outfall location, the time, and the date of sampling; then the samples were transported to KISR's laboratories in iceboxes. In the laboratories, the samples were analyzed for the parameters of nutrients, heavy metals, and microbial bacteria.

The nutrient parameters, Ammonia (NH_3-N), and Total Kjeldahl Nitrogen (TKN) were analyzed using Ion Chromatograph (IC) system. TKN is the concentration of ammonia and organic nitrogen and is determined using the calculation method:

$$TKN = TN - (NO_3\text{-N}) + NO_2\text{-N}) \qquad (1)$$

The Total Nitrogen (TN) and phosphate (PO4-P) were analyzed by using a spectrophotometer (Hach DR 6000). Furthermore, the samples were analyzed for the heavy metals including arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni), mercury (Hg), iron (Fe), copper (Cu), manganese (Mn), zinc (Zn), lead (Pb) by using inductively coupled plasma – optical emission spectrometer (ICP-OES). The microbial indicators fecal coliforms, Escherichia coli (E. coli), and Fecal Streptococci were analyzed by the membrane filter technique method to determine the presence of a member of bacteria using 0.25 ml dilution. Sample collection and analyses were conducted according to standard methods [15]. The laboratory results were compared with KEPA acceptance limits [16], [17] to highlight the hotspot coastal areas that reflect the most contaminated area on Kuwait beaches, and to assess the current quality of the wastewater discharge from the emergency outlets.

IV. Results and Discussion

The preliminary field results indicated that the temperatures at all the locations were ambient and within EPA requirements, with a range of 28 ℃ – 15 ℃, with the highest mean value of 25.2 ℃ at sample locations OC3 and OC5, and the lowest mean value of 20 ℃ at location OC10. Throughout the duration of the study, the temperatures at sample locations OC3 and OC5 were the highest of all the sample locations. The research was carried out over the fall and winter months, resulting in changes in weather conditions that influenced the temperature of the seawater. The EC values for the samples collected during the study period were within the range of 1.79 ms/cm – 65.07 ms/cm, which indicated an oxidized environment. The collected samples revealed the presence of saline to freshwater types, with a minimum EC of 1.27 ms/cm measured in both samples collected on Jan. 22 from sample location OC5, implying the type as freshwater [18]. However, the maximum EC value of 65 ms/cm was on Nov. 21 at the sample Location OC8, which indicated saline water type. The EC mean values were the highest at the locations OC8 and OC10, while the minimum mean value was at OC5. Moreover, mean values at sample locations OC5 and OC18 were close to 9.8 ms/cm representing a mix of freshwater with seawater. There is a significant link between conductivity and salinity; conductivity is used in algorithms that estimate salinity and Total Dissolved Solids (TDS), both of which affect water quality and aquatic life. On the other hand, salinity is important because it changes the solubility of DO—the higher the salinity level, the lower the DO concentration. A sudden increase or decrease in conductivity in a body of water might indicate contamination; for example, the added chloride, phosphate, and nitrate in wastewater discharge may increase conductivity. While the addition of other organic compounds would lower conductivity, the increased dissolved particles would have a detrimental influence on water quality in both circumstances [18].

The results of sample analysis also showed the presence of slight alkalinity to high acidity of pH values. The acceptable range is between pH 6.0 and 9.0 [16], according to EPA's maximum value for the water discharge into Kuwait Bay seawater. The pH measurements for the samples taken from the locations OC3, OC10, and OC5 showed pH values that are neutral and within the EPA standards during the study period (Fig. 2). However, the third sample obtained on January 8th from the sample location OC18 was strongly acidic, and the sample results obtained in November from OC8 were somewhat alkaline. However, overall, the mean pH values in all the sample locations were within the permissible pH (6.0-9.0) of the EPA requirements [16]. Fig. 3 illustrates that the DO range for all the locations was below the minimum acceptable limit, which is 4 mg/l [16], excluding samples from OC8 taken in November, which was exceeding the minimum EPA standard.

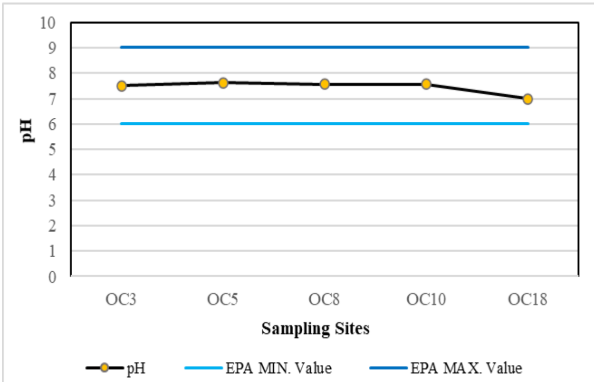

Fig. 2. The mean of the pH values for the five samples locations.

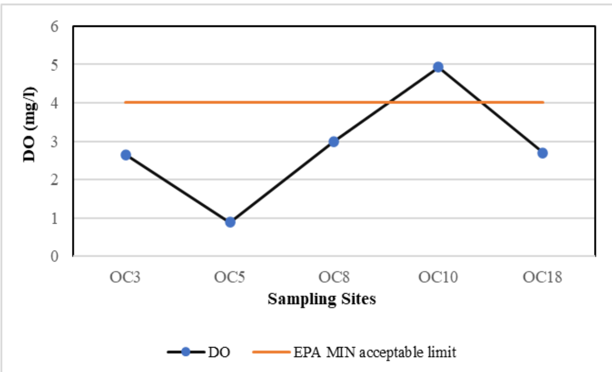

Fig. 3. The mean of the DO values for the five samples locations.

The laboratory results of the nutrients for the water samples revealed that the concentrations of the nutrients are varied, and for some of the parameters, the results were largely above the EPA standards for the water discharge in Kuwait Bay. Mean values of Total Nitrogen (TN) for all the samples during the study period were within the range of the acceptable limits, which is less than 30 mg/l, as shown, except for the sample location OC5 where the mean value was slightly above the limit with a concentration of 35 mg/l (Fig. 4). Nevertheless, P-PO_4 mean values were above the EPA maximum limits (0.5 mg/l) at all the locations due to the increased input of nutrients to the sea. The excessive phosphate may lead to undesirable effects related to eutrophication, harmful algal blooms, undesirable changes in species composition, bottom layer anoxia, mass mortality of fish and benthic organisms, and more [19]. The high values of phosphate need to be urgently treated using an effective phosphate removal technique.

Similarly, TKN values were also higher than the EPA standards for the water discharge to Kuwait bay (5 mg/l) at all the locations during the study period. The mean values of the analysis results of ammonia (NH_3-N) show variation during the research study, as demonstrated in Fig. 4. They were above the maximum limit at all locations except OC10, where the value was within the EPA standards (1 mg/l). In a nutshell, sample analysis results of OC5 showed that this location was the most polluted site with excessive nutrients, while the results from OC10 showed the fewest nutrient levels among the five sample locations. On the contrary, the analysis results of the heavy metals indicate that the mean values were in low concentrations and within the EPA standards, except Cd and Hg mean values, which were fluctuating between not detectable to above EPA standards. This suggests that Hg and Cd need more heavy metal concentrations in the seawater near the outfalls; hence, there is insufficient evidence to make a statement.

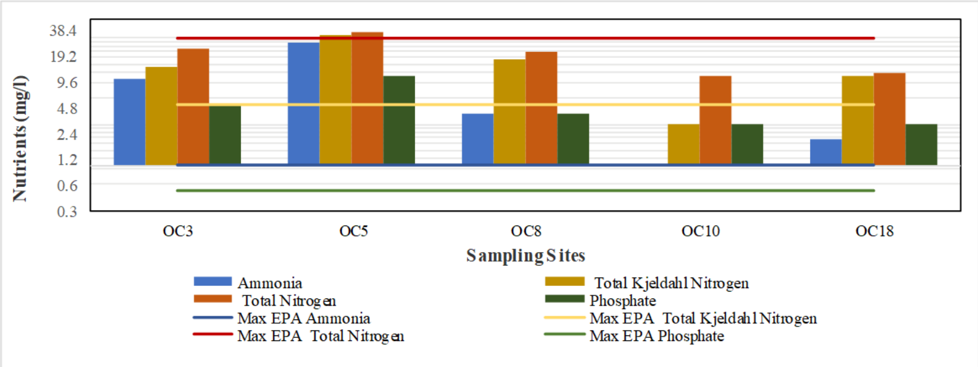

Fig. 4. The mean values of the nutrients ammonia, total Kjeldahl nitrogen, total nitrogen, and phosphate for the five sample locations.

The results of microbial indicators analysis of the fecal coliform, E. coli, and fecal streptococci occurrence are shown in Fig. 5, which illustrates that there is significant microbial pollution in the southern part of Kuwait Bay. Near these sewer outfalls, the values were very high and above the EPA maximum acceptable limits in most of the samples' locations. This shows the need for serious treatment and cautious observation as these beaches are considered unsuitable for recreational activities along with exposing aquatic organisms as well as human beings to highly adverse effects. Fecal coliform values were above the maximum limit (> 500 CFU/100 mL) in all the locations and generally ranged from hundreds of thousands in the location of OC10 to above three million counts in OC5. Similarly, E. Coli ranged from 60,000 in OC10 to above 2 million counts in OC5 as well. Mean values of fecal streptococci of the 15 samples exceeded the maximum EPA limits (> 200 CFU/100 mL) in all locations [17]. The mean values of fecal streptococci exceeded 20,000 counts in the OC10 location, and similar to the other microbial bacteria, the maximum value of the fecal streptococci was in the location OC5. The net results of the microbial indicators showed high contaminations in all sample locations. Fecal streptococci values from the results of OC5 and OC18 were approximately the same as the counts of the fecal coliform and E. Coli and slightly less than those in OC10. Whereas, in OC3 and OC8, the fecal streptococci were significantly lesser than the other two microbial indicators but still considered extremely high.

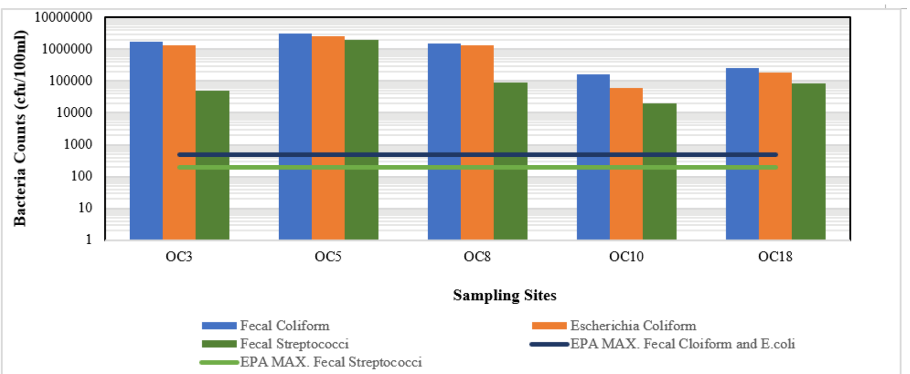

Fig. 5. The mean values of the microbial indicators fecal coliform, E.coli, and fecal streptococci for the five sample locations.

During the field visits for sampling, there were virtual notes documented in Fig. 6 for the sample location OC5 as there were noticeable unpleasant odors. Additionally, the conspicuous pollution, as the color and clarity of the discharging water were not at the optimum level, pointed to the importance of such a study; likewise, for the sample location OC3 (Fig. 7), as the water discharged was suffering from a physical change affecting the healthy sweater characteristics.

Fig. 6. The contaminated wastewater discharging from OC5 sample locations.

Fig. 7. The discharged wastewater from the sample location OC3.

Undoubtedly, the pollution of discharged wastewater through emergency outfalls puts not only aquatic life and living organisms under stress, but also the ecological balance in the ocean at risk. Furthermore, in the areas OC3 and OC5, birds and other animals such as dogs were seen using the water for their survival. These findings broaden the negative consequences to include the lives of both animals and humans. The contamination of the wastewater discharged from these emergency outfalls affects people who spend their leisure time at the beaches near these outfalls. Fig. 8 depicts white-colored effluent dumped from the OC8 outfall located near beaches where many residents enjoy swimming and other leisure activities. Moreover, when individuals stroll or swim in front of the outfalls, as seen in location OC10 (Fig. 9), they expose their health to the dangers of the unknown wastewater spilled from the outfalls. These observations bolstered the research study and emphasized the necessity to investigate the quality of wastewater discharged into the sea via emergency outfalls, to enhance seawater quality and provide healthy and safe beaches.

Fig. 8. The discharged wastewater from the sample location OC8.

Fig. 9. People in front of the sample location OC10.

V. Conclusion and Recommendation

Domestic and industrial wastewaters are substantial sources of effluents discharged regularly into receiving water bodies worldwide, due to growing industrialization and increasing population density. The degradation of receiving water bodies is caused by the quality of wastewater effluents, which has negative consequences. As a result of this degradation, many waterborne diseases spread, and DO levels dropped. Because the study's selected outfalls are located near the beaches most popular for swimming, fishing, and other recreational activities, decision-makers must pay special attention to wastewater discharged along Kuwait Bay's southern shore. The evaluation of the five sample locations indicated that sample location OC5 (Fig. 6) was considerably contaminated with excessive nutrients and microbiological pollution, whereas OC10 was the least contaminated outfall. Analogously, the presence of highly pathogenic microorganisms such as fecal coliform, E Coli, and fecal streptococci suggests that these beaches are subjected to severe microbial pollution, posing serious health risks to those who engage in recreational activities; the presence of these organisms also negatively impact the aquatic species and human health. Furthermore, the presence of high quantities of fecal bacteria might result in murky and stinky water. The low levels of DO indicate that there is a high oxygen demand and that the affected sample locations are not in optimal health. Furthermore, elevated P-PO4 and TKN levels have negative consequences for seawater quality, such as changes in aquatic life, As a result, effective removal methods are required to maintain the balance of the ecosystem in the seawater. The study's results demonstrate that there is a great need for frequent monitoring, as well as appropriate onsite waste treatment and disposal, based on the appropriate measures for preventing the discharge of polluted wastewater indiscriminately into the sea. To ensure the successful execution of these guidelines to achieve the requirements of higher quality of discharged wastewater, it is highly suggested that effective environmental legislation be enforced.

Conflict of Interest

The authors declare no conflict of interest.

Authors Contribution

O. Bushaibah conducted the study, wrote the research paper, and guided the research study team. A. Al-Haddad supervised the research team and participated in the writing of the paper. F. Dashti supervised the collection and analysis of data. E. Ibrahim collected the samples and conducted the field measurement, and M. Khajah participated in the evaluation of the results.

Acknowledgment

This study was an initial part of a research study that was funded by the Kuwait Institute for Scientific Research (KISR). The authors would like to sincerely thank KISR for its support.

References

[1] F. Y. Al-Yamani, J. Bishop, E. Ramadhan, M. Al-Husaini, and A. Al-Ghadban, *Oceanographic Atlas of Kuwait's Waters*, Kuwait: Kuwait Institute for Scientific Research, 2004.

[2] N. Al-Mutairi, A. Abahussain, and A. Al-Battay, "Environmental assessment of water quality in Kuwait Bay," *International Journal of Environmental Science and Development*, vol. 5, no. 6, pp. 527-532, 2014.

[3] B. P. Lyons, M. J. Devlin, S. A. Abdul Hamid, A. F. Al-Otiabi, M. Al-Enezi, M. S. Massoud, A. S. Al-Zaidan, *et al.*, "Microbial water quality and sedimentary fecal sterols as markers of sewage contamination in Kuwait," *Marine Pollution Bulletin*, vol. 100, no. 2, pp. 689-698, 2015.

[4] E. E Aleisa, A. Al-Jadi, and S. Al-Sabah, "A simulation-based assessment of a prospective sewer master plan," *World Journal of Modelling and Simulation*, vol. 11, no. 4, pp. 272-228, 2015.

[5] E. Corcoran, C. Nellemann, E. Baker, R. Bos, D. Osborn, and H. Savelli, *Sick Water? The Central Role of Wastewater Management in Sustainable Development: A Rapid Response Assessment*, United Nations Environment Program, Earthprint.

[6] E. Aleisa and K. AlShayji, "Analysis on reclamation and reuse of wastewater in Kuwait," *Journal of Eng. Research*, vol. 7, no. 1, pp. 1-13, 2017.

[7] P. K Pandey, P. H. Kass, and M. L. Soupir, "Contamination of water resources by pathogenic bacteria," *AMB Expr.*, vol. 4, no. 51, pp. 1-16, 2014.

[8] D. A. Holcomb and J. R. Stewart, "Microbial indicators of fecal pollution: Recent progress and challenges in assessing water quality," *Current Environmental Health Reports*, vol. 7, pp. 311-324, 2020.

[9] Z. E. Soto-Varela, D. Rosado-Porto, H. J. Bolívar-Anillo, C. P. González, B. G. Pantoja, D. E. Alvarado *et al.*, "Preliminary microbiological coastal water quality determination along the Department of Atlántico (Colombia): Relationships with beach characteristics," *Journal of Marine Science and Engineering*, vol. 9, no. 2, p. 122, 2021.

[10] A. Bu-Shaiba, "Efficiency of a sewage treatment plant as manifested by a reduction in sea pollution," *KISR 7045*. 2004.

[11] Y. Li, Q. Zhang, Y. Cai, Z. Tan, H. Wu, X. Liu *et al.*, "Hydrodynamic investigation of surface hydrological connectivity and its effects on the water quality of seasonal lakes: Insights from a complex floodplain setting (Poyang Lake, China)," *The Science of the Total Environment*, vol. 660, pp. 245-259, 2019.

[12] A. Malik and M. Ahmad, "Seasonal variation in bacterial flora of the wastewater and soil in the vicinity of industrial area," *Environ. Monit. Assess.*, vol. 73, pp. 263-273, 2002.

[13] C. L. Soo, T. Y. Ling, and N. Lee, "Assessment of the characteristic of nutrients, total metals, and fecal coliform in Sibu Laut River, Sarawak, Malaysia," *Appl. Water. Sci.*, vol. 6, pp. 77-96, 2016.

[14] M. Devlin, A. Smith, C. A. Graves, C. Petus, D. Tracey, M. Maniel, *et al.*, "Baseline assessment of coastal water quality, in Vanuatu, South Pacific: Insights gained from in-situ sampling," *Marine Pollution Bulletin*, vol. 160, p. 111651, 2020.

[15] Standard *Methods for the Examination of Water and Wastewater*, A. APHA, WEF, 2017. 22.

[16] KEPA, *Guidelines for Water Discharge into Kuwait Seawater*, Kuwait, Al-Youm, 2017, p. 1355.

[17] KEPA, *Guidelines of Bacterial Indicators in Recreational Coastal Water*, 2017, p. 1355.

[18] Fondriest Environmental, Inc. (Mar. 2014). Conductivity, salinity and total dissolved solids. *Fundamentals of Environmental Measurements*. [Online]. Available: https://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/>

[19] G. Shtereva, V. Velikova, and V. Doncheva, "Human impact on marine water nutrients enrichment," *Journal of Environmental Protection and Ecology*, vol. 16, no. 1, pp. 40-48, 2015.

O. Bushaibah is an engineer and a senior research associate who obtained a bachelor's degree in industrial and system engineering in 1998, from Kuwait University. In 2001, she joined the Kuwait Institute for Scientific Research (KISR), the Environmental and Life Sciences Research Center (ELSRC), and participated in several projects in KISR Environmental Department as a project leader and a task leader in Environmental Impact Assessment (EIA), and as a health and safety officer in 2018 in Quality Health and Safety in Work Environment Division. She has a NEBOSH Certification (2015) on International General Certificate in Occupational Health and Safety, Certification for Achieving the Management of International Health and Safety, Certification for Achieved Controlling Workplace Hazards, and Certification for Achieved Health and Safety Practical Application 2015. She is a member of the International Society for Trainers & Developers (ISTD). She has been invited and participated in many national and international conferences and is a keynote speaker at IEEE international conferences and as a speaker at many other conferences.