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Research Article

Study the Impact of the Anthropogenic Activities on the Marine Environment of Fujairah Offshore Waters of UAE Based on Baseline Surveys and Buoy Data

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As Fujairah comprises extremely diverse natural landscapes which enforce us to protect and understand possible risks and challenges faced by the coastal waters of Fujairah, it is critical to mitigate, reduce, and eliminate the risks. The aim of this study is to assess and evaluate the effect of such anthropogenic activities on the offshore waters of Fujairah. Accordingly, two buoys were deployed after conducting a baseline survey for 30 locations targeting areas affected by the anthropogenic activities. Furthermore, two sites were chosen for the buoy deployment, nearshore which is across the desalination plant (Qidfa) and offshore which is across the oil and gas facility port (Skamkam). After analyzing the water quality measurements taken for 1 year from both deployed buoys and compared it with the baseline survey measurements, an indication of water quality deterioration in nearshore and offshore buoys was evinced, and the nearshore site which located in Qidfa has a higher deterioration in water quality measurements compared to the offshore site located in Skamkam. A long-term monitoring program needs to be conducted to gather additional data on water quality over several years to help identify the seasonal variations, trends, and long-term changes in water quality.

1. Introduction

Fujairah is the fifth largest emirate in the United Arab Emirates which contains diverse terrains and marine environments, and it is rightly trumpeted regionally and internationally as a welcome tourist destination that contains various assets as natural resources. Among these invaluable assets, coastal waters stand out as a primary natural resource, contributing significantly to its sustenance while remaining highly susceptible to environmental impact. Fujairah is the second largest bunkering port in the world, owing to its strategically advantageous location [1]. However, this prominence poses significant environmental challenges, primarily stemming from the heightened maritime traffic, which in turn increases the risk of oil spill incidents. Moreover, the coastal ecosystem faces multiple threats, including the direct discharge of brines from desalination facilities, the proliferation of harmful algae blooms, and industrial outfalls. If these issues remain unaddressed, they could erode the unique and attractive characteristics of the coastal environment. Such concerns make Fujairah coast an interesting area for research purposes. Coastal areas are assets to Fujairah, and preserving these resources holds much more importance for ecological as well as economic growth of Fujairah. Without conservation efforts, Fujairah's status and its future aspirations could be compromised.

This study is aimed at investigating how anthropogenic activities, such as a high volume of ship traffic, oil spills, and desalination plants, impact the marine environment in

Fujairah's offshore waters. To achieve this, we will compare baseline data with measurements from marine buoys. This analysis will help us assess the water and marine environment quality along Fujairah's coastline and establish a reference point for future monitoring efforts. The findings from this research will support the development of comprehensive management and mitigation strategies.

2. Materials and Methods

Two buoys are deployed in Fujairah's Ocean, Gulf of Oman, following baseline survey result analysis. The baseline surveys were conducted to identify the problem areas and priority areas needing protection and help select the most appropriate locations for the deployment of water quality monitoring buoys. A total of thirty locations were chosen for water quality measurements (Table 1 and Figure 1), which are temperature, conductivity, pH, turbidity, dissolved oxygen (DO), chlorophyll-a, and blue-green algae (BGA).

The baseline survey is divided into transects that run perpendicular and parallel to the coastline. The perpendicular transects in SEZ (special economic zone) extend more than 8 km in the SEZ into the anchorage area. The precise locations are shown in Table 2 and on the map (Figure 1). Some locations are near sensitive infrastructures such as the port of Fujairah, the coastguard, the navy, and the desalination plants. These information/results are used as the basis for selecting the sites for the deployment of the buoys.

Two buoys are deployed for further analysis in the Fujairah's Ocean, Gulf of Oman (Table 2 and Figure 2). Nearshore buoy is in Qidfa across the desalination plants, located to the north of the Fujairah SEZ coastline, deployed at about 1000 m from the shoreline at a depth of 17 m. The offshore buoy is in Skamkam located across from the oil and gas port facility, deployed at about 3528.81 m from the shoreline at a depth of 23 m. Both buoys are supported by sensors, data loggers, antenna, and telemetry to measure the quality of the water such as temperature, salinity, dissolved oxygen, pH, turbidity, and chlorophyll-a. The data from buoys are transferred via the 3G or cellular modem and/or satellite to a secure web data center, which provides an online interface for viewing the data. Further, the extracted raw data is cleaned and processed. The obtained and studied marine water quality data is only for 1 year, from Feb 2020 to May 2021 for both buoys.

3. Results

The characteristics of the seawater for all the thirty locations that have been chosen for the baseline survey are mentioned in Table 1.

The characteristics of the seawater for both nearshore and offshore buoys are mentioned in Table 2. The nearshore site is shallow (17 m), whereas the offshore site had a depth of around 23 m.

The water temperature measures during the baseline survey showed that most sites surveyed are indicative of a well-mixed water column, with minimal variation in water temperature and no indication of stratification. The only exception was FB-27, where an inverse thermocline was observed, with a temperature of 29.29°C at the surface compared to the average temperature at the Qidfa-nearshore buoy which was 28.23°C and at Skamkam-offshore buoy which was 28.21°C.

The salinity did not vary significantly from site to site. Most sites also exhibited minimal variation in salinity with depth and in salinity within the water column. Again, the only exception to this was FB-27 where salinity was shown to be elevated at the base of the water column. On the other hand, the average salinity was 37.47 ppt and 36.844 ppt, at Qidfa-nearshore and Skamkam-offshore buoys, respectively.

A slightly lower pH range was seen at FB-05 and FB-29. These sites exhibited a pH range between 7.48 and 7.95, whereas other sites ranged between 7.97 and 8.74. The average pH recorded at Qidfa-nearshore buoy was 8.137 and at Skamkam-offshore buoy was 8.136; both sites almost have the same pH values.

The oxygen saturation and concentration displayed a uniform trend in most of the sites. However, many stations were also found to have a low bottom oxygen saturation level (<90%). The lowest dissolved oxygen level was found to be as low as 50.7% at FB-26 at 49.5 m depth. The average dissolved oxygen at Qidfa-nearshore buoy was 6.774 mg/l (107.21) and at Skamkam-offshore buoy was 6.566 mg/l (103.572).

Chlorophyll-a concentration was low and showed little significant variation from site to site during the baseline survey. However, some sites had higher blue-green algae (BGA) and chlorophyll-a, while the average chlorophyll-a concentration in Qidfa-nearshore buoy was 9.988 μg/l and in Skamkam-offshore site was 3.531 μg/l. The nearshore chlorophyll-a concentration can be seen higher during the winter season.

The turbidity levels were low across all sites and at all depth profiles. The average turbidity in Qidfa-nearshore site was 51.5728 NTU and in Skamkam-offshore site was 22.0941 NTU.

4. Discussion

The baseline measurements were recorded in 30 different locations at 1-meter intervals from the top to the base of the water column using a precalibrated multiparameter intelligent water quality logger. The measured parameters were temperature, salinity, conductivity, dissolved oxygen, turbidity, blue-green algae, pH, and chlorophyll-a.

Nearshore buoy is in Qidfa across the desalination plants, located to the north of the Fujairah SEZ coastline, deployed at about 1000 m from the shoreline at a depth of 17 m. In this area, there has been a decline in water quality, particularly near environmentally sensitive sites, economically vital areas, and critical infrastructures. This region frequently experiences pollution or harmful algal bloom incidents, demonstrating both seasonal and spatial variations.

The offshore buoy is in Skamkam located across from the oil and gas port facility. The port supplies carry liquid gas and petroleum products to hundreds of large tankers for worldwide distribution; the tankers wait in a designated anchorage area before entering the port for refilling, and this intense navigation of tankers across from the Skamkam facilities and its

Table 1: The 30 locations for its baseline survey with their coordinates, depths, and water quality characteristics.

Site number	Coordinate	Depth (m)	Temperature (°C)	Salinity (ppt)	pH	Dissolved oxygen (mg/l)	Chlorophyll-a (μg/l)	Turbidity (NTU)
FB-01	25° 07.739 056° 21.840	7.5	27.15	37.35	8.19	6.68	5.1	0.7
FB-02	25° 07.735 056° 22.274	14	27.5	37.16	8.57	6.52	6.3	0.4
FB-03	25° 07.700 056° 22.611	18.2	27.46	37.23	8.65	6.5	19.7	9.5
FB-04	25° 09.153 056° 21.888	13	27.61	37.11	8.74	6.42	5.5	0.7
FB-05	25° 09.215 056° 22.304	15.7	27.69	37.09	7.95	6.43	3.5	0.6
FB-06	25° 09.172 056° 22.693	20.4	27.65	37.11	8.26	6.4	3.1	0.4
FB-07	25° 10.321 056° 22.351	17	27.57	37.21	8.28	5.5	1.9	8.4
FB-08	25° 10.307 056° 22.793	22.2	27.7	37.14	8.48	5.88	7.7	0.7
FB-09	25° 10.283 056° 23.418	27.5	27.41	37.33	8.42	5.96	3.2	3
FB-10	25° 10.317 056° 24.418	41	27.93	37.02	8.16	6.55	3.7	0
FB-11	25° 11.465 056° 23.888	38.5	27.63	37.25	8.29	5.35	3.3	4
FB-12	25° 11.338 056° 25.344	56	28.05	37.05	8.44	6.38	2	0
FB-13	25° 12.868 056° 22.478	16.3	27.88	37.1	8.08	NA	3.6	3.2
FB-14	25° 12.842 056° 22.988	26.3	27.90	37.09	8.05	NA	0.9	1.8
FB-15	25° 12.683 056° 23.730	36.6	27.97	37.18	7.87	5.42	4	5.6
FB-16	25° 12.565 056° 24.631	52.9	28.12	37.04	8.08	5.81	3	1
FB-17	25° 14.124 056° 22.816	22.9	27.83	37.16	8.31	5.66	1.2	1.5
FB-18	25° 14.139 056° 23.320	29.7	28.05	37.07	8.05	5.96	14.5	0.7
FB-19	25° 13.989 056° 24.052	36.3	27.81	37.05	7.88	6.09	17.6	0
FB-20	25° 16.050 056° 22.741	15.6	27.58	37.2	8.35	5.82	6.3	2.8
FB-21	25° 15.937 056° 23.388	29.1	27.84	37.09	8.42	5.95	1.8	0.3
FB-22	25° 15.918 056° 24.019	42.8	27.75	37.1	8.36	6.37	1.4	0.3
FB-23	25° 17.679 056° 22.792	14.6	27.63	37.08	8.23	6.31	1.9	0
FB-24	25° 17.643 056° 23.263	24.8	27.67	37.18	8.31	5.95	10.3	0.7
FB-25	25° 17.574 056° 23.690	30	27.75	37.08	8.14	6.32	1.5	0.3
FB-26	25° 17.522 056° 24.303	49.5	27.87	37.08	8.38	6.14	4	0.4

Table 1: Continued.

Site number	Coordinate	Depth (m)	Temperature (°C)	Salinity (ppt)	pH	Dissolved oxygen (mg/l)	Chlorophyll-a (μg/l)	Turbidity (NTU)
FB-27	25° 18.654 056° 22.867	18.3	27.46	37.24	8.4	6.17	16.8	1.4
FB-28	25° 18.317 056° 23.331	31.2	27.34	37.30	8.16	6.33	3.8	4.4
FB-29	25° 18.535 056° 23.790	38.7	27.7	37.07	7.56	6.37	2.3	0.4
FB-30	25° 18.475 056° 24.363	49	27.79	37.07	8.48	6.26	2.5	0.3

Figure 1: The survey's precise locations: the pins represent each sampled point.

anchorage area which locate about 7.5 km offshore affects the water quality.

The inverse thermocline observed in site FB-27 is a signature of effluent discharge and desalination plants. Effluent streams characterized by elevated temperature and salinity are discharged from the desalination plant. The higher density effluent plumes sink to the base of the water column and disperse along with the seabed [2], while the average temperature in both the onshore and offshore buoys is showing the same temperature.

The salinity measurement was within the normal range. However, in the buoys, the nearshore buoy records showed a higher salinity than the offshore buoy due to the unavoidable product of seawater desalination which is the brine effluents released from the reserve osmosis (RO); this has a negative impact on the marine environment and its biodiversity [3]. The nearshore highest salinity was 39.96 ppt on 23rd of May 2021 at 3:30 (Table 2). This high salinity has an impact on the seabream juveniles within 30 minutes, decrease in the swim bladder inflation of the larvae, and longer time for the hatching of eggs and affects the development of the larvae for red abalone, purple urchin, and sand dollar [3].

The lower dissolved oxygen found in station FB-26 at 49.5 m depth was not highly surprising, as it is due to the decomposition of organic matter at the seabed with reduced mixing of oxygenated water at deeper depths [4]. The offshore site was significantly lower than the nearshore site, which is located across the oil and gas facility port; the possible reason for this decrease is the petroleum refinery effluent or/and oily wastewater released from the oil and gas facility port, which contains compounds polycyclic aromatic, sulfur, nitrogen, heavy metals, and other chemicals that could be used during the petroleum refining; the presence of this compounds may reduce the dissolved oxygen content because the microbes whose growth is encouraged by the presence of these organic substances consume dissolved oxygen to decompose the organic waste, which is harmful to the aquatic environment [5]. The Arabian Gulf water is considered as hypoxia if the total amount of dissolved oxygen level was less than 2 mg/l [6]. The dissolved oxygen level in Fujairah's seawater ranges from 6.82 to 6.9 mg/l [7]; thus, it is not considered hypoxia. This may result from the accumulation of nutrients where the heavy metals are discharged intensively and poor water circulation which causes high concentrations of nitrate and phosphorus, stimulating algal bloom formation (nearshore buoy). As per our results, the nearshore dissolved levels were 6.332-7.431 mg/l which is not considered hypoxia.

Some sites during the survey had higher BGA and chlorophyll-a concentrations in the top 2-3 m. This is an indication of phytoplankton growth in the surface waters. But none of these readings suggested the formation of phytoplankton blooms. The nearshore chlorophyll-a concentration was higher from August to January due to the desalination plants by-products causing nutrient enrichment mainly in the nitrogen and phosphorus contents in the presence of high intensity sunlight [8], which exaggerate the eutrophication process [9], leading to an increase in the phytoplankton biomass (chlorophyll-a). Similarly, the offshore site exhibits a sudden increase in the chlorophyll-a concentration for the month of January 2021.

The nearshore site exhibits higher turbidity than the offshore site, where it is exposed to pollution from the desalination plant wastewater discharge or/and the chlorophyll content.

After careful evaluation of the baseline survey data, the marine buoys have been deployed. Most parameters measured from the 30 survey sites did not vary significantly from site to site. Temperature and salinity were largely similar and consistent across the different survey sites. Sites FB-05 and FB-29 had pH ranges that were slightly lower than the other sites. Chlorophyll-a concentration and turbidity levels were found to be generally low with little variation from site to site. However, despite this homogeneity, different trends of dissolved oxygen concentration throughout the water column were seen across all survey sites. Several stations (FB-07, FB-11, FB-15, and FB-17) were found to have low surface oxygen concentration levels. These locations are located near port entrances, single point markers (SPMs), and holding points for large tankers. These locations are associated with

Table 2: Nearshore and offshore buoys deployed in Fujairah's Ocean, Gulf of Oman (the average for 1 year).

Site number	Location	Coordinate	Habitat	Name of location	Depth (m)	Distance from the shoreline (km)	Temperature (°C)	Salinity (ppt)	pH	Dissolved oxygen (mg/l)	Chlorophyll-a (μg/l)	Turbidity (NTU)
1	Nearshore	25.3039167 56.3840556	Across the desalination plant	Qidfa	17	~1 (992.45 m)	28.23	37.47 *34.95 **39.96	8.137	6.774	9.988	51.5728
2	Offshore	25.1296944 56.3916389	Across the oil and gas facility port	Skamkam	23	~3.5 (3528.81 m)	28.21	36.844 *33.64 **39.09	8.136	6.556	3.531	22.0914

*Lowest salinity value. **Highest salinity value.

Figure 2: The nearshore and offshore buoy locations.

heavier vehicle traffic and a higher potential for oil slicks to occur on the water surface, potentially lowering the surface oxygen concentration levels. The lowest surface dissolved oxygen level was found at FB-11 at 5.35 mg/l (Table 2). The measurements of water for the 30 sites showed that 8 points out of 30 are low in quality due to their locations. FB-26, FB-27, and FB-29 are located across the desalination plants, while FB-05, FRB-07, FB-11, FB-15, and FB-17 are located across the oil and gas port and the holding points for large tankers and vehicles, so, the locations of the two marine buoys were decided based on this analysis.

5. Conclusion

The baseline survey measurements showed that 8 points are lower in quality, 3 points are located across the desalination plants, and 5 points located across the oil and gas port; therefore, two marine buoys were deployed across these two locations. The results showed that there is no significant difference between nearshore and offshore buoys seen in the temperature and pH, while the salinity, dissolved oxygen, chlorophyll-a, and turbidity results were higher in the nearshore buoy than in offshore buoy. The nearshore site presents a water quality declining, reflecting the anthropogenic activity pressures on that site. The decrease in the water quality was evinced by the results of salinity, dissolved oxygen, chlorophyll-a concentrations, and turbidity, which were particularly higher than the offshore site. A further study is needed for implementing an integrated management plan to achieve sustainability premises.

Data Availability

The data presented in this study are available on request from the corresponding author due to legal restrictions and privacy concerns surrounding its release.

Disclosure

This study is a part of employer Fujairah Environment Authority and Fujairah Research Centre.

Conflicts of Interest

The authors declare no conflicts of interest.

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