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Hydrodynamic characteristics of Khor Al-Zubair Channel, Southern Iraq

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ABSTRACT

The hydrodynamic features of the Khor Al-Zubair, a mixed, predominantly semidiurnal tidal channel situated in Southern Iraq at the northwest tip of the Arabian Gulf, were investigated using in situ measurements taken in 2015. The data utilized in this study, which spanned nearly a year, is unique, particularly for currents and waves, which were never previously available in this area. The results illustrated that the water level exhibited a spatial and temporal variation ranging from hourly to seasonal oscillation. However, the hourly water level highest annual range recording during the study period at St1 (Umm Qasar port) and St2 (Khor Al-Zubair port) was about 4.77 and 5.88 m, respectively. Correspondingly, the results showed that the current speed is high at both flood and ebb tides, exceeding 1 m/sec, and in general, the ebb currents are stronger than the flood currents. The highest current measured was 1.83 m/sec. Moreover, the results revealed that the highest and lowest wave height (Hs) recordings in the Khor Al-Zubair channel (KAZC) reached 0.22 and 0.03 m, respectively. Correspondingly, our results demonstrated that the wave period's maximum, minimum, and average were 5.51, 3.96, and 4.5 sec, respectively.

Keywords: Khor Al-Zubair Channel, Arabian Gulf, water level, current, waves, hydrodynamic.

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INTRODUCTION

The coastal water systems, particularly lagoons and estuaries, are essential for future development in different aspects, such as navigation, tourism, industrial and domestic uses. So, Many industrial facilities, including oil ports, commercial harbors, and various industrial factories, have been established close to these water systems to take advantage of their capabilities in providing their water need or flushing out their wastewater [1]. Studying of the hydrodynamic behavior of lagoons or estuaries is essential, especially for navigation safety, coastal infrastructure, and future development near these water bodies [2–6].

The Khor Al Zubair channel (KAZC), previously classified as an estuarine lagoon [7], is situated west of Basrah province in southern Iraq, northwest of the Arabian Gulf. KAZC is highly important for the country since it is historically regarded as an internal navigation channel. Consequently, the most important Iraq ports, named Umm Qasar Port and Khor Al-Zubair Port, were established on its banks [8]. In addition to these ports, and to take advantage of the features provided by this water body, four industrial plants, the petrochemical, steel, Umm Qaser cement, and fertilizer plants, were established near the KAZC. Moreover, there are plans to use water from KAZC in the oil production industry in southern Iraq by injecting water into oil fields.

A few studies have examined the hydrodynamic behavior of KAZC, particularly those based on actual measurements of water levels, currents, and waves. Al-Ramadhan (1988) [7] investigated the residual currents in KAZC and demonstrated that in the wet season, the residual currents flowed seaward in the upper layer and landward in the lower layer. However, in the dry season, the flow was reversed. However, this study is based on only observations made over one complete tidal cycle. Lafta et al., (2019) [8] examined the properties of the tidal wave in the KAZC and Khor Abdullah channels, and they demonstrated that the tidal type is a mixed, predominantly semi-diurnal tide. They also showed that the tidal wave undergoes several changes when propagating toward the upper reaches of KAZC. Consequently, the study area needs more investigations, in particular, that are based on actual records of hydrodynamics parameters with long enough observations. This study aims to highlight the characteristics of the water level, currents, and waves based on a realistic measurement and for relatively long observations of these parameters at KAZC.

MATERIALS AND METHODS

Study area

KAZC extends approximately north-northwest from Khor Abdullah for about 40 km. The KAZC is covered by an extensive branching network of intertidal channels draining large tidal flats. The KAZC lower limit lies at Warba Island, approximately 8 km southeast of Umm Qasar (Fig. 1). The navigational channel depth is between 10 and 20 m. In 1983, the Shatt A-Basrah Canal was completed to link the Euphrates River with KAZC, transforming the area from a hypersaline lagoon to an estuarine lagoon [7, 9]. In 1993, the Shatt Al-Basrah canal connection with the Euphrates River was blocked. A new connection was established with the MOD (Main Outfall Drain) around 10 km from the canal's head.

To control seawater flow from KAZC to Shatt Al-Basrah canal during flood tides, a barrage (Al-Basrah Barrage) was built around 22 km relative to the canal head. The climate in the study area is an arid desert, and the hot season, which spans from May to October, is marked by high wind speed and evaporation. The region has two predominant winds: northwest winds that generate dust storms frequently in summer months and southeast winds that dominate throughout the fall and winter [10].

Data source and measurements

This study's data is acquired from the Basrah Oil Company (BOC). However, the BOC has a project called the Iraq Common Seawater Supply Project package that will employ KAZC

water in the southern Iraq oil industry. BOS signed with Tatweer Company in early 2014 to perform a bathymetric survey for the Iraq Common Seawater Supply Project. However, this survey contains various measurements at KAZC, including water level, currents, and waves. The measurement intervals were 10 minutes for water level, 15 minutes for currents and wind, and one hour for waves. Table 1 contains the water level, current, and wind and waves measurement stations' locations, instruments, and temporal coverage.

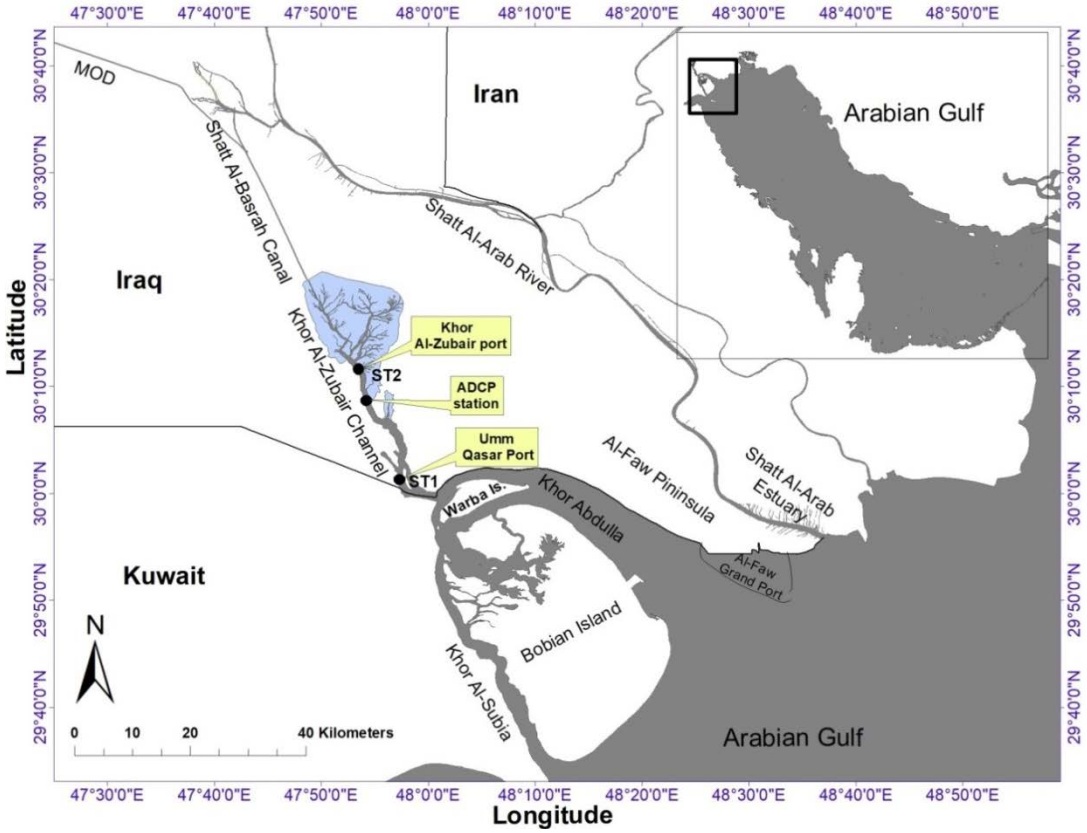

Figure 1. Geographic location of the area shown the measurement stations

Water levels

Water level data were recorded at two locations along KAZC, namely Umm Qasar port (St1) and Khor Al-Zubair port (St1 2) (Fig. 1). The water level measurements are referenced to the local vertical datum, the FAW 1997 datum (mean sea level in FAW city). Water level measurements were conducted using a Valeport Tidemaster tide gauge at both locations.

Currents

Water current data in KAZC are frequently scarce, and when they are available, they are usually for just a short time, not longer than one tidal cycle. The current measurements were conducted by ADCP to measure the current profile for the entire water column. The ADCP measures water speed and direction every 0.5 m throughout the water column. The ADCP was deployed at an average depth of 14.4 m during the measurement period. The current measurements were taken using an ADCP equipment type, Nortek Aquadopp. However, this instrument is set up to record Current profiles, Waves, Water levels, and Temperature. The current profile was measured at an interval of 15 minutes.

Waves and wind

Wave measurements did not previously exist at the KAZC. So, this data of waves represents the first available data and is unique in this area. However, the ADCP device that is installed to measure the current profile were also used to measure the wave parameters, including height and period. The wave parameters were measured at an interval of 1 hour.

Measured wind speed and wind direction were conducted by installing a weather station type Gill MetPak RG Base Station. The geographical location of this weather station is given in Table 1.

Table 1. Geographic locations of the measurement stations and temporal coverage

Station Name/instrument type	Latitude	Longitude	Start date	End date
Station 1 Tide gauge	30°0'49.32"N	47°57'15.5"E	2015-01-11	2015-02-16
Station 2 Tide gauge	30°11'23.8"N	47°53'17.85"E	2015-03-03	2016-01-16
ADCP Currents	30°9'23.54"N	47°53'50.92"E	2015-01-19	2016-01-16
ADCP Waves	30°9'23.54"N	47°53'50.92"E	2015-03-03	2016-01-16
Weather station	30°7'30.84"N	47°54'18.98"E	2015-01-11	2016-01-18

RESULTS AND DISCUSSION

Water level variability

Measurements of the water level in the KAZC displayed significant fluctuations, oscillating from hourly to seasonal variations. The greatest annual range of water level at St1 and St2 was about 4.77 and 5.88 m, respectively. This high tidal range is the largest range observed in the whole Arabian Gulf region. AlOsiri et al., (2018) [11] reported a comparable range in Kuwait Bay, near the investigated area. The largest ranges are often observed in the spring tide, whereas the tidal range in the neap tide seldom reaches 3 m (Fig. 2). The tidal regime in the Khor Al-Zubair Channel is mixed, predominantly semi-diurnal [12]. However, water level data at St2 showed that the highest water level was noted during the summer months, while the lowest was found during the winter months. This phenomenon might be attributed to the behavior of the water level in the northern Arabian Gulf, which showed a rise in spring and summer and a decline in fall and winter seasons because of major atmospheric factors [13–15]. The water level measurements revealed a significant increase in the highest height water (HHW) when the tidal wave moved from St1 (Umm Qasar port) to St2 (Khor Al-Zubair port). During the study period, the highest height of water (HHW) was 1.77 m at St1 and 2.2 m at St2, while the lowest elevation of Lowest Low Water (LLW) was -3 and -3.5 m at St1 and St2, respectively. However, the convergent nature of the studied area could be responsible for the increase in water level height towards the upper reaches of KAZC. The convergence effect, which occurs as we move away from the Arabian Gulf to the upper reaches of KAZC, causes the tidal energy from the Arabian Gulf to be concentrated in a confined area, resulting in an amplification of the tidal wave amplitude and, thus, an increase in water elevation. Similar results were observed in many water systems [16, 17]. The inflow of the Shatt Al-Basrah canal towards KAZC is minimal; although the discharge from the Shat Al-Basrah canal results in a net southward flow, its magnitude is much smaller than the actual tidal discharge across the KAZC. However, the inflow from Shatt Al-Basrah has been reduced recently as a large amount of canal water has been converted to supply the Iraq marshes in southern Iraq [18]. So, the flow field in the entire KAZC is dominated by tidal

variations propagating from the northern Arabian Gulf. Therefore, the inflow through the Shat Al-Basrah canal from the north (and its variations in time) does not have any significant impact on water levels and current speeds across KAZC.

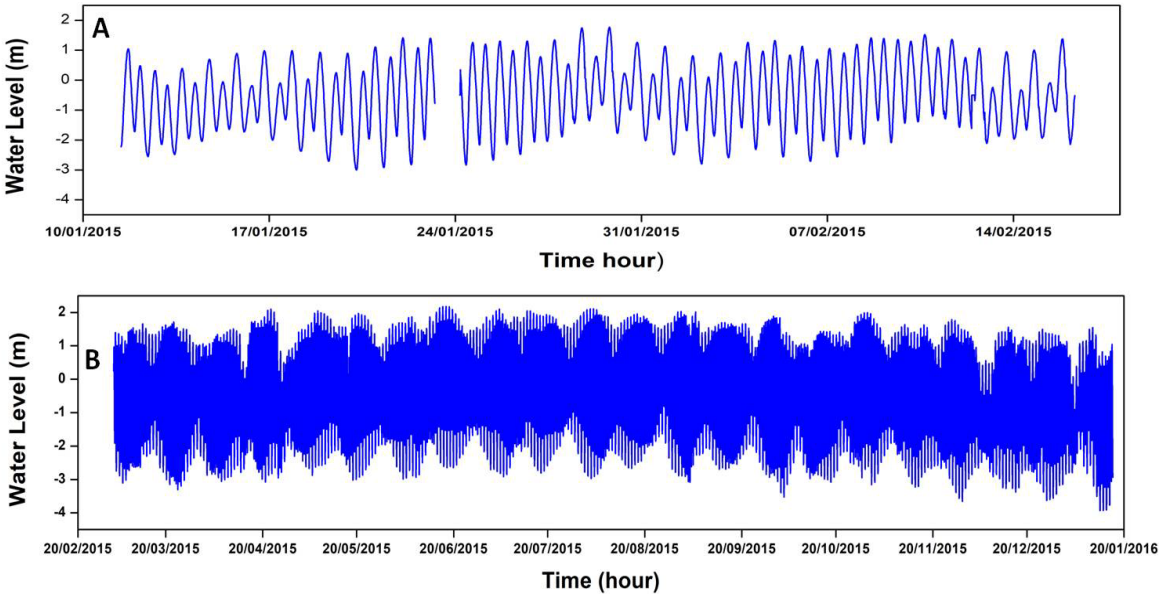

Figure 2. Hourly water level at A: St1 and B: St2

Current pattern variability

The time series of the depth-averaged current speed is shown in Figure 3A. However, the results showed that the current speed in KAZC is high at both flood and ebb tides, exceeding 1 m/sec. In general, the ebb current is higher than the flood current.

The highest recorded velocities occurred during the ebb phase of the tidal cycle. However, these findings align with the findings of Lafta (2023) [19] at the entrance of Khor Abdullah. The maximum current velocity measured throughout the research period was 1.83 m/sec. The monthly means of current velocities revealed that the average ebb velocities were greater than the average flood velocities during the summer and winter months. In contrast, the opposite occurs during the spring and fall months (Table 2).

The current directions exhibited two distinguished directions based on the orientation of the KAZC at the measurement location. The first ranges between North and North-Northwest (N-NNW) during flood tide, while the other ranges between South and South-Southeast (S-SSE) during ebb tide (Fig. 3C). Other tidal current directions were observed; however, they were all extremely weak and observed during the transition time from ebb tide to flood tide and vice versa (Fig. 3C).

The frequency of occurrence of different current velocity classes is shown in Figure 3B. This figure showed that flood currents are slightly greater for lower velocity groups, but ebb currents exceed flood currents for higher velocity classes. The frequency of ebb currents indicated that many common velocities range from 0.4 to 0.6 m/sec, with a frequency of over 23%. The second most common class of ebb velocities was 0.6-0.8 m/sec, with a percent of occurrence of 20%, followed by 0.2–0.4, 0–0.2, and 0.8–1 m/sec, which have a percent of occurrence of 19%, 18%, and 11%, respectively. Furthermore, the results explain that the maximum velocities occur frequently during the ebb tide, particularly velocities greater than 1.2 m/sec, in contrast to flood currents, which rarely reach 1.4 m/sec.

Similarly, for flood current, the most common velocity classes are 0.4–0.6 m/sec with an occurrence of 29%, followed by 0.6–0.8, 0.2–0.4, and 0.8–1 m/sec with a percent of occurrence of 26%, 22%, and 13%, respectively.

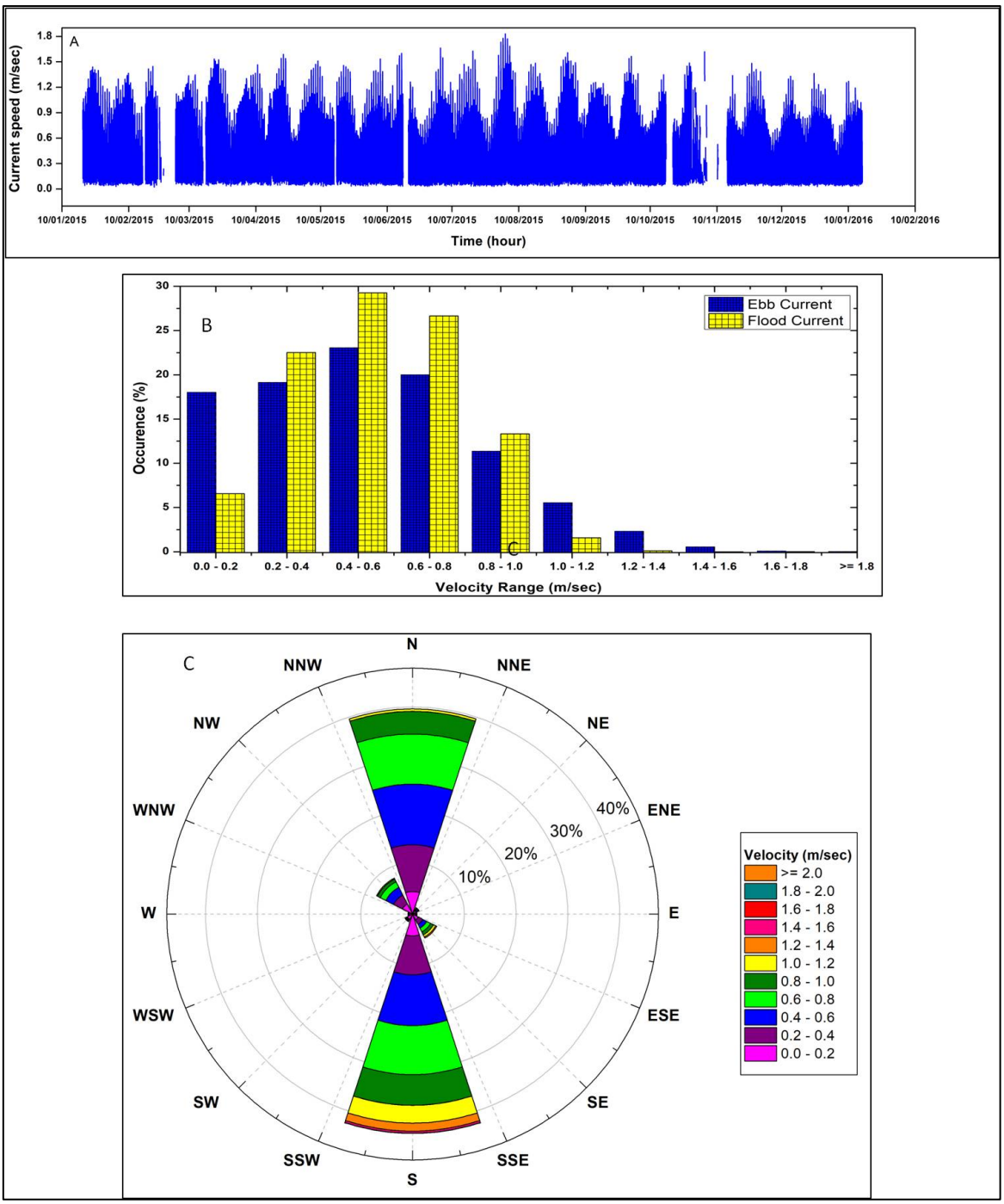

Figure 3. Current speed (A), frequency of various velocity classes for flood and ebb current (B), current rose (C)

Table 2. Statistical of food and ebb currents during 2015

Month	Flood		Ebb	
	Mean	Max.	Mean	Max.
January	0.587	1.226	0.595	1.440
February	0.515	1.060	0.5817	1.446
March	0.588	1.159	0.557	1.534
April	0.593	1.139	0.532	1.587
May	0.573	0.985	0.551	1.509
June	0.377	0.860	0.509	1.599
July	0.479	0.782	0.518	1.662
August	0.530	1.066	0.562	1.830
September	0.549	1.068	0.550	1.607
October	0.578	1.245	0.531	1.565
November	0.553	1.620	0.505	1.482
December	0.507	0.991	0.466	1.362

Wind and wave variability

Figure 4A depicts the measured wind speed. The wind patterns indicate monthly and seasonal fluctuation. However, the maximum recorded wind speed was 19.34 m/sec from the southeast on February 20, 2015. Various wind systems blow on the study area from different directions (Fig. 4B). The Northwest wind (NW/NNW/WNW) dominates throughout the year, followed by the southeast wind (SSE/SE/ESE). The frequency of winds over KAZC is the highest from WNW (18.9%), followed by NW (18.6%) and NNW (5.6%), while the lowest is from NNE (0.9%). The percentage occurrence of various wind speed classes is displayed in Figure 4C. By this figure, the low wind (0–3) has the largest percentage of occurrence, with a maximum occurrence of approximately 47%, followed by (3–6), (6–9), and (9–12), with percentages of 30%, 17%, and 4.5%, respectively. Meanwhile, high winds had the lowest frequency of occurrence, accounting for only around 1% of all wind ranges in the study area.

Similarly, the time series of significant wave height (Hs) recordings in KAZC shows that this parameter's maximum and minimum values reached 0.22 and 0.03 m, respectively (Fig. 5A). Figure 5C displays the frequency of various Hs classes. The figure shows that 61% of the waves are between 0 and 0.05 m, 36% are between 0.05 and 0.1 m, and the rest are higher than 0.1 m. However, wave heights rarely exceed 0.2 m at KAZC, although many high winds have been observed from different directions throughout the study period. Lafta and Al-Fartusi (2022) [20] showed that the wave pattern in Iraq's marine water is a wind wave, with the wave's highest height frequently being associated with the southeast wind due to a longer available fetch for generating the high wave. The situation in KAZC is different since the channel is narrow, with a width not exceeding 1,000 m in spring tide. This results in a limited fetch available to generate waves with considerable height.

Correspondingly, the average wave period (Tp) was 4.5 sec, with the maximum and minimum at 5.51 and 3.96 sec, respectively (Fig. 5B). The frequency of various wave period ranges is shown in Figure 5D. The most common range is 4–5 sec, with a percentage of occurrence reaching 96%. The rest wave ranges, i.e., 3–4 sec and 5–6 sec, are rarely frequent in KAZC.

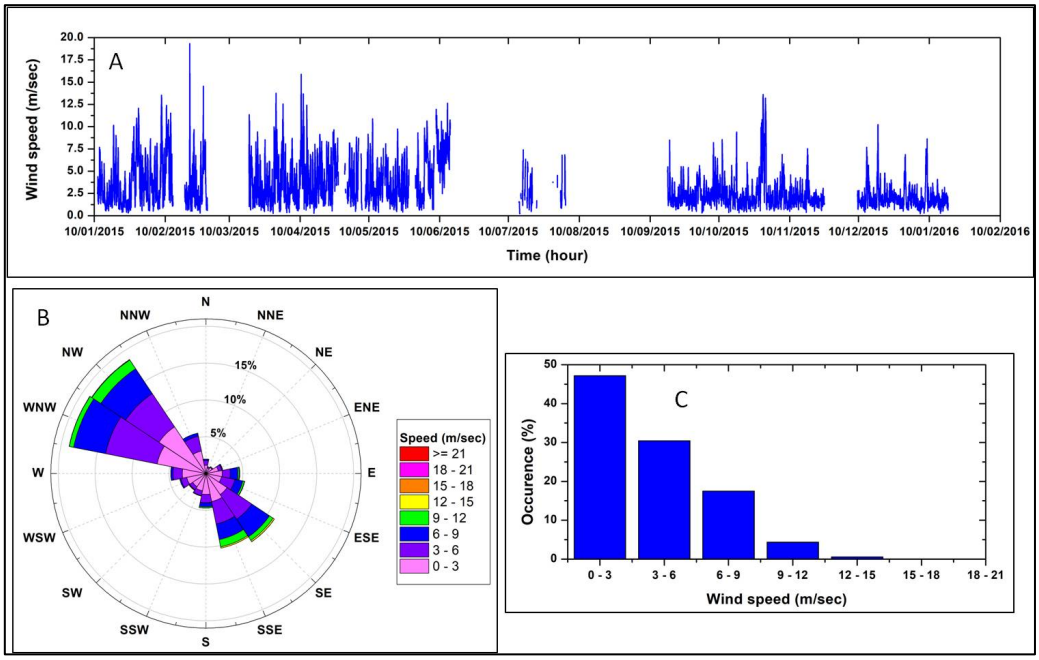

Figure 4. Hourly wind speed (A), wind rose (B), and percentage of various wind classes (C)

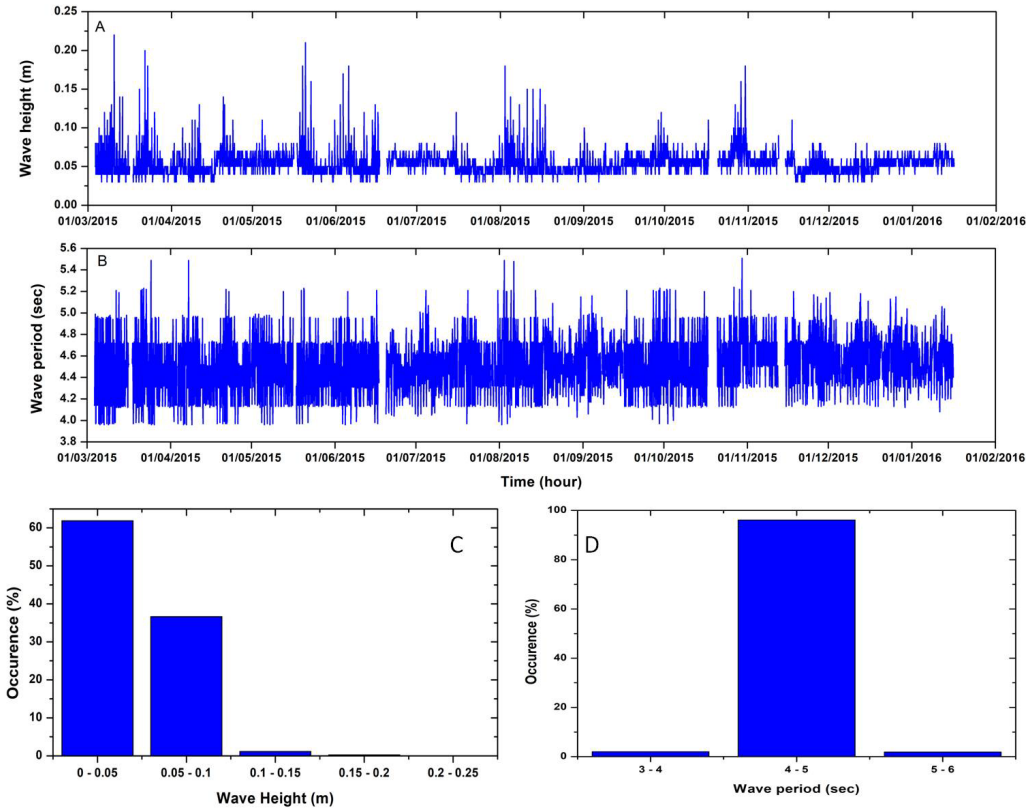

Figure 5. Hourly wave height (A), hourly wave period (B), percentage of various wave height classes (C) and percentage of various wave period classes

CONCLUSION

The hydrodynamic characteristics of KAZC, located in southern Iraq, are examined using realistic observations of water level, current speed and direction, and wave height and period over approximately a year. The results showed that the water level in the KAZC experiences significant fluctuations, ranging from hourly to seasonal variations. Additionally, the results illustrated that the highest high water level increases gradually from St1 towards St2. Correspondingly, the water level measurements showed that the highest high-water level was observed during the summer months, while the lowest high-water level was found during the winter months. The results for the current patterns in the KAZC revealed that the current speeds are strong, exceeding 1 m/sec during both the flood and ebb tides. Furthermore, the results exhibited that, in general, the ebb current is stronger than the flood current. The highest recorded velocity of the ebb currents reaches 1.83 m/sec, while the highest observed flood current was 1.62 m/sec. Furthermore, ebb velocities' monthly averages were higher throughout the summer and winter than flood velocities. In contrast, during the spring and fall months, the monthly averages of flood velocities were greater than those of ebb velocities. The results show that there are two distinct directions of the currents. The first ranges between north to North-Northwest (N-NNW) during flood tide, while the other ranges between south to South-Southeast (S-SSE) during ebb tide. However, the wave patterns revealed that, in general, the studied area has relatively small waves with heights no higher than 0.22 m. The wave measurements during the study period show that 61% of the waves in KAZC are between 0 and 0.05 m, 36% are between 0.05 and 0.1 m, and the rest are more than 0.1 m. Correspondingly, our results illustrated that the wave period has a narrow range, with the most common range being 4–5 sec, with a percentage of occurrence reaching 96%. The results obtained could be beneficial for future developments in the KAZC. However, more investigations are needed to explore the hydrodynamics characteristics in this area, particularly those based on long-term measurements of these variables, as well as utilizing the numerical modeling technique to describe spatial and temporal variations of such parameters.

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