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Some Features of the Physical Oceanography in Iraqi Marine Waters

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ABSTRACT Iraqi marine water is the major estuarine part at the north Arabian Gulf. The harmonic constituents of tide M2, S2, K1, and O1 in Outer Bar station was found of order of 0.66, 0.18, 0.46 and 0.26 m, respectively. The type of tide is mixed, dominant semi-diurnal with range between 1 –3 m. Salinity values (4 ‰ – 39 ‰) are effected heavily by the rate of the Shatt Al-Arab discharge and the state of tide. Water temperature fluctuates during winter and summer, reaching 12.5˚C to 33.5˚C respectively. Thermocline and halocline developed according to the season and state of tide. Different types of currents were observed including tidal current, coriolis force, wind current, density current and Arabian Gulf current. Generally, tidal current in the area are strong and reaching 0.8 -2 m/sec.

INTRODUCTION

The general description of the physical oceanography in an area is one of the major factors affecting navigation, fisheries, coastal environment, coastal configuration and marine construction.

Few investigations were made on the physical oceanography in the Iraqi territorial waters. Some aspects of the physical oceanography in the Iraqi marine waters have been reviewed by Mohamed *et al.* (1995), Al-Mahdi and Abdullah (1996), Abdullah *et al.* (1999), Hussain *et al.* (1999), Al-Mahdi (2001) and Abdullah (2002). Some of these studies were limited either to specific area or to short period. This paper gives general descriptions of some oceanographic conditions, since the area represent the estuarine part of the Arabian Gulf, which pertains to diurnal variations (13hr) during low and high discharges as well as through different tidal phases of neap and spring.

Study Area

The Iraqi marine water is the most northern-western part of the Arabian Gulf. This water body consists of Shatt Al-Arab Estuary (shallow, average depth of 5 meter at low water) and several open lagoons such as Khor Al-Kafka and Khor Al-Amaya (deep and narrow, average depth of 25 m at low water) besides Khor Abdullah (Fig. 1).

Shatt Al-Arab River is the main source of freshwater to the northern zone of the Arabian Gulf. Shatt Al-Arab River is formed from the confluence of the two major rivers, Tigris and Euphrates with total average outflow of 1200 m^3/sec (Al-Mahdi & Salman, 1997).

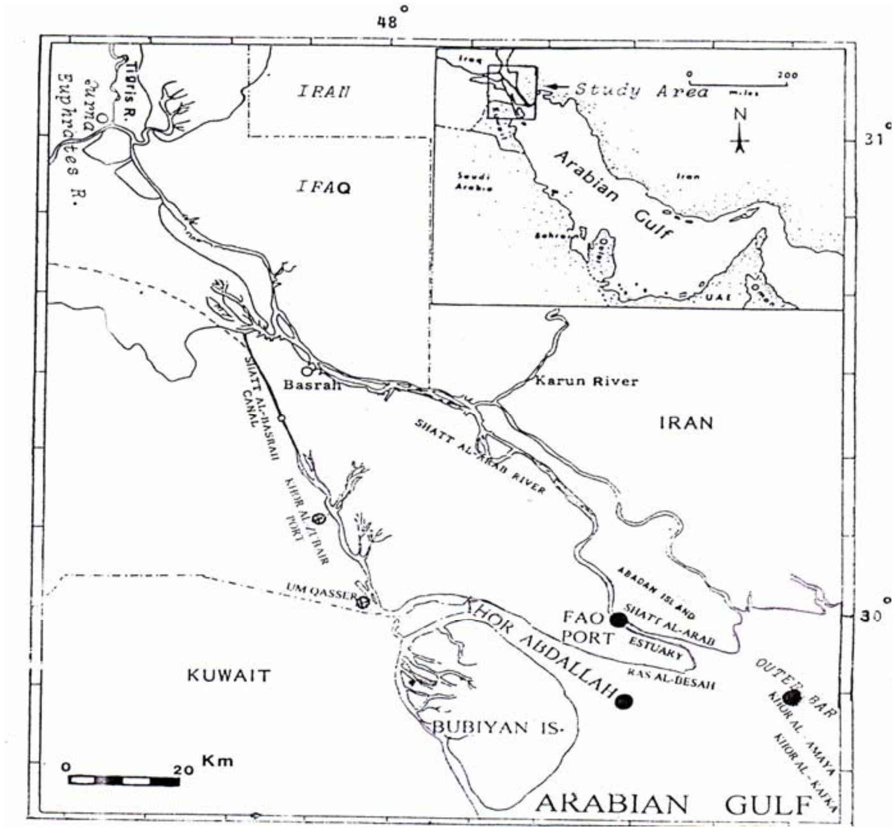

Fig. 1: Map of the NW Arabian Gulf showing sampling locations.

The annual discharge of the Shatt Al-Arab River is varied seasonally in accordance with its tributaries contribution. In the Iraqi marine water, the temperature and salinity distribution is heavily dominated by the influx of the Shatt Al-Arab River.

The study area is characterized by arid climate that have a small annual rainfall of order of 150 mm/year and high rates evaporation (<2000 mm/year), most evaporation occurs during winter owing to the higher wind speeds (Reynolds, 1993).

The surface circulation in the Arabian Gulf seems to be counter clockwise, passing northwesterly along the Iranian coast and recession water southeasterly along the Arabian coast (Emery, 1956) (Fig. 2). The most famous, and notorious, weather phenomenon in the Arabian Gulf is a NW wind (locally called Shamal), which becomes particularly strong in early summer. This wind belows down the Gulf with a speed of as much as 100 km/hr (Williams, 1979). In winter the SE wind (known locally Koss) dominates in the region. It is strong enough to stop commercial navigation.

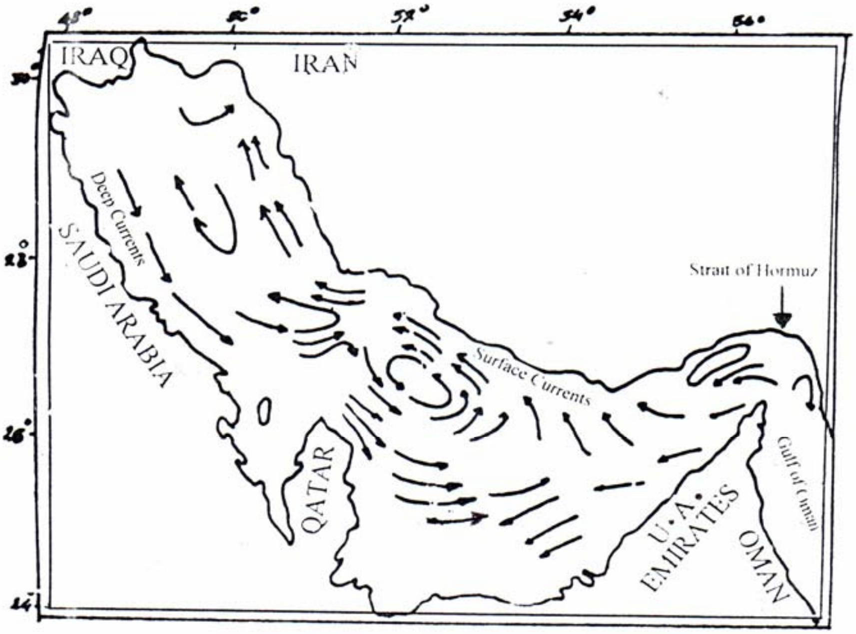

Fig.2. General circulation of surface (Iranian coast) and deep currents (Arabian coasts) (after Emery, 1956).

MATERIALS AND METHODS

Field measurements were made during the period September 1993 to August 1994 and include salinity, temperature, current and depths. Sampling area covered most of the Iraqi marine water such as the head and the mouth of Shatt Al-Arab Estuary and inlet of Khor Abdullah. Three main stations were selected as shown in Figure 1. The first station is located in the Al-Fao port, the second in the Outer Bar area and the third is situated in the inlet of Khor Abdullah. Observations were made during 12 cruises of R.V. OLOUM. Additional information were taken from previous studies.

Water samples were collected by using reversing water sampler Model 1506. Water temperature was measured by using reversing protected thermometers Model P 80-10. Salinity determinations were made by conductivity measurements using digital salinometer Model E-202. Measurements of current velocity and direction were made by using current meter Model CM-2. Except for water temperature, all measurements were done with 2-meter intervals in deep water and 0.5 meter in shallow depths. Depths survey were made by using an Echo Sounder Model OSK 3336.

All observations were made during low and high discharges and for different tidal phases (neap and spring). The average salinity depth $\langle \acute{s} \rangle$ and velocity $\langle \tilde{u} \rangle$ over the tidal cycle were determined by their weight along the depth.

RESULTS AND DISCUSSION

Tidal Regime

Tidal regime in the Arabian Gulf is very complex because of the semi-enclosed arm at strait of Hormuz. The Arabian Gulf illustrates two major oscillations of diurnal and semi-diurnal tides, driven primarily due to propagation of the tidal energy through the strait of Hormuz from the Gulf of Oman.

Generally, the tide in the Arabian Gulf is consisted of adversity of tidal fashions as shown in Fig. 3. It is characterized by predominantly semi-diurnal types.

The four harmonic constituents of the tidal regime in Outer Bar station are M2, S2, K1 and O1 which are of order of 0.66, 0.18, 0.46 and 0.26 m, respectively. Subsequently, Abdullah (2002) found that type of the tide in the mouth of the Shatt Al-Arab Estuary (Outer Bar station) is mixed, dominated by semi-diurnal. This postulation is corresponds to the form number value (F) which is 0.85 according to the classification of Smith (1980). There are two high and low waters occurred daily, with inequalities in heights and time.

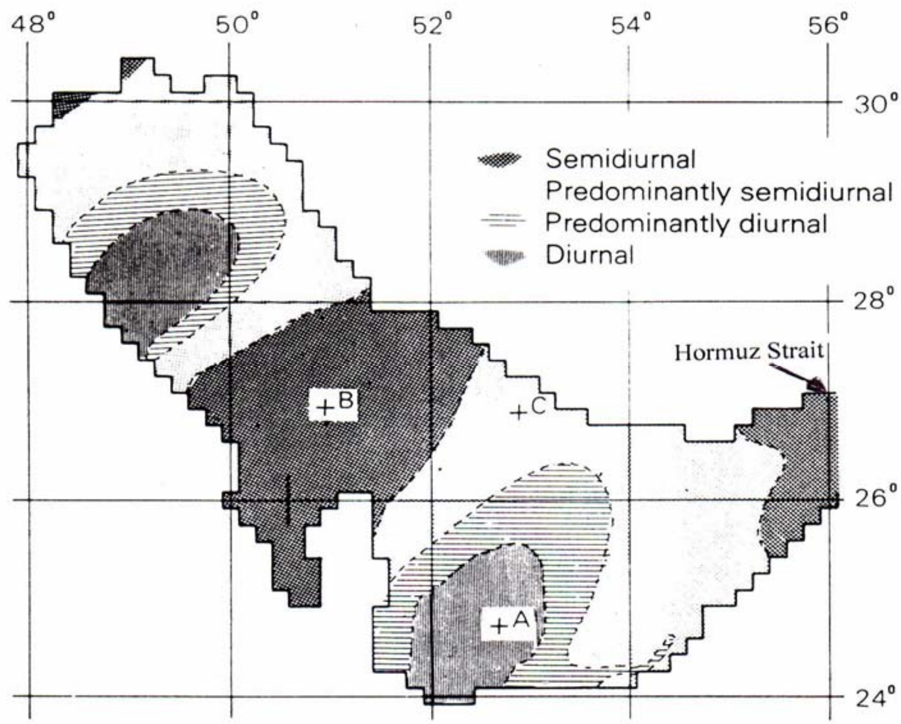

Fig . 3. Tidal types classification. (From: Evans-Roberts 1979)

Tidal Range

Tidal range fluctuations in the Iraqi marine water are affected by two main factors. The first is the prevailing Northerly winds tend to keep the tide dribble, and Southerly winds have the opposite effect, especially in the open sea. The second is the monthly rhythm of spring and neap tides which are controlled on the inland area.

Tidal ranges are large in the study area being over 2.50 meter in the open water and exceeding occasionally 4.00 meter during spring tide in Khor Al-Zubair.

Table 1 shows mean values of tidal ranges at both phases of tide (neap – spring). Because of the interest subject of the tidal range, data of Mahdi (1990) is used for comparative in Um Qasser and Khor Al-Zubair areas.

Table 1 exhibits that high values were recorded in Um Qasser port during spring tide 4.30 m and neap tide 3.60 m. This trends due to narrow width of the channel and increasing depths which reach 18.0 meter at high water. The type of the tidal ranges are considered as meso tide according to Smith (1980). Generally, the tidal range in the open sea is less than that in Khor Al-Zubair area for the previous interpretation and more than in Al-Fao station.

In the study area, highest tides occurred during summer (Jul.-Aug.) and the lowest tide during winter (Dec.-Feb.). High summer tides tend to occurs during the day and the low tide occur through the night .Therefore, the shore line is largely exposed at night and covered by the tide at day. This circumstance is inversely encountered during winter.

Table 1. Mean tidal range of Nnap and spring tides at the study area.

Station	Mean Tidal Range (m)	
	Spring	Neap
Al-Fao Port	3.00	2..40
Outer Bar	3.50	2.52
Khor Abdullah	3.25	2.60
Um Qasser*	4.30	3.60
Khor Al-Zubair Port*	3.50	3.30

* after Mahdi.1990

Salinity Variations

Salinity distribution in the Iraqi marine water is mainly affected by freshwater discharge of Shatt Al-Arab River. Whereas, the other parameters such as precipitation, evaporation and phase of tide have less influence on salinity fluctuations. It is known that the Shatt Al-Arab River as two periods of flood. The first wave from Karun River during February – March, which followed, by the second wave from Tigris and Euphrates Rivers during April - June (Sudgen, 1963).

The head of the Shatt Al-Arab Estuary (Al-Fao station) is considered as a control station due to the oncoming freshwater. Therefore, mean surface salinities were plotted against the annual discharge at Al-Fao station (Fig. 4). This figure shows two inverse peaks, the first peak occurred during June and associated with the high freshwater discharge (1863 m^3 /sec) and low salinity (1.03 ‰). The another peak was occurred during August and associated with low discharge (580 m^3 /sec) and relative high salinity (3.12 ‰). Figure 4, showed that the lowest salinity was recorded during February, which is of the order of 0.84 ‰. This tendency may be due to Karun River flood during this period. Because of the prevalence of freshwater in this location (Al-Fao station) over the year, the range of the surface salinity is very low (1.1 – 3.9 ‰) and (0.98 – 1.80 ‰) during low and high discharges, respectively.

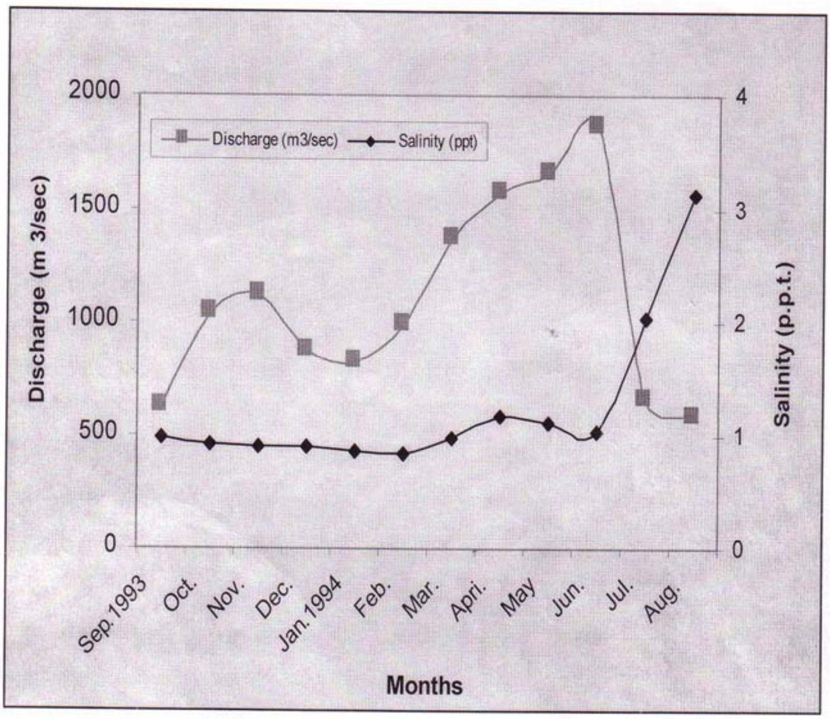

Fig. 4: Relationship between surface salinity (ppt. and discharge (m^3/sec) at Al-Fao staion.

In the Outer Bar station the influence of freshwater during the ebb is limited to the first meter of the water column during low discharge. But, during high discharge the invasion of freshwater is extended to the middle depth. Therefore, there are insignificant fluctuations in surface salinities during low discharge (34.5–36.4 ‰) and wide changes during high discharge (21.5 – 33.8 ‰). Khor Abdullah station had the highest salinity over the study period in comparison with the other stations.

The increment of salinity values were due to the effect of Shatt Al-Arab inflow as well as Corioles effect. However, the freshwater influence is very effective on the surface layer during the flood season. The lowest and the highest surface values were of the order of 32 ‰ and 37.55 ‰ during high and low water discharges respectively.

Generally, surface salinity values near the shore are higher than those offshore, especially during summer which reached 40‰, this is due to high rates of evaporation induced by high air temperature and northern wind (Locally called Shamal) beside the shallow depth. But no extreme salinity (more than 45 ‰) were recorded in the Iraqi marine water as that documented in other parts of the Arabian Gulf (Anderlini *et al.* 1978).

Table 2 shows the vertical salinity gradient during low and high discharges as well as the typical neap (19, October, 1993) and spring (29, April, 1994).

Table 2. Mean salinity gradient during low and high discharges at the typical neap and spring tides.

Station	<ś> ‰							
	Discharge				Typical Tide			
	High		Low		Spring		Neap	
	Sur.	Bot.	Sur.	Bot.	Sur.	Bot.	Sur.	Bot.
Al-Fao	1.03	7.00	3.12	22.00	1.45	2.80	0.96	0.96
Outer Bar	25.00	36.00	35.50	36.80	35.90	37.00	34.40	36.75
Khor Abdullah	34.00	36.90	36.25	36.90	36.00	37.55	35.00	37.25

As shown in Table 2, there were noticeable changes in salinity values between low and high freshwater discharge at the Al-Fao station. In the Outer Bar station, salinity values were rather similar during low freshwater discharge, but vertical stratification occurred during high discharge (Z/h=0.50). At Khor Abdullah, vertical salinity gradient occurred during high discharge but mostly limited to the surface layer (Z/h=0.05). These observations are in accordance with those of Abdullah *et al.* (1999). No significant vertical salinity gradient were observed during typical spring and neap tides, but slight gradients occurred at the open sea stations during neap tides.

In general, changes in river outflow create large scale of salinity gradient in comparison with changes of the tidal phase.

Longitudinal salinity gradient is evident in the study area as shown in Table 2, but the intension of the gradient increased largely between Al-Fao and outer Bar station. Halocline was evident in deeper Iraqi marine water especially at Khor Al-Kafka and Khor Al-Amaya (Fig. 1) during spring flood of the Shatt Al-Arab River which induce strong halocline even in shallow area of the Shatt Al-Arab Estuary. While during the rest of the year, a weak halocline developed in the Shatt Al- Arab Estuary (Hussain *et al.*, 1999).

Water Temperature

Generally, the maximum and minimum surface temperatures were recorded during August and January, respectively at all stations (Table 3). This is mainly due to the semi tropical climate prevailing in the region. Table 3 shows that highest water surface temperature (32.7°C) was recorded at Al-Fao Port station. Lower temperature was recorded at the other stations. Al-Fao Port is effected by the Land (earth radiation), whereas the other stations are influenced by the sea breeze, particularly during the afternoon.

During summer (August), surface water temperature is relatively higher than that on the bottom at the open sea stations, while during winter no differences were observed. There was a slight vertical temperature gradient (0.8°C) at Al-Fao station and may be a result of low freshwater discharge (580 m^3 /sec).

Table 3: Maximum and minimum water temperatures at the surface and bottom of the three sampling stations.

Station	Water Temperatures °C			
	Max.		Min.	
	Surface	Bottom	Surface	Bottom
Al-Fao Port	32.7	33.5	12.9	13.1
Outer Bar	29.9	29.6	12.7	12.8
Khor Abdullah	29.4	29.0	12.5	12.9

Currents

Currents in the Iraqi marine water resulted from the effect of tidal force, density variations, winds, slope differences, corriolis effect and current of Oman Gulf. It is Known that surface current in the Arabian Gulf seem to be counter clockwise, moving along the Iranian side in the north west direction and recessing along the Arabian side in the south east direction (Emery, 1956). This movement cause a density current driven along the Iraqi coast (Hunter, 1986).

Density differences resulted from Shatt Al-Arab River runoff in the Arabian Gulf which provide force to generate currents. Density currents are caused by evaporation and high water temperatures. These density driven currents are strong and effective but seasonally variable.

Shatt Al-Arab River flows in the northern Arabian gulf induce a cyclonic circulation that would otherwise be anticyclonic (Al-Mahdi & Abdullah, 1999). Reynold (1997) postulated that the northern Gulf circulation is predominantly wind driven, this is a true case since north western wind is dominant in the area by more than half of the year (55 %). Winds tend to push the waves and the surface current to north east direction (Purser and Seibold, 1973).

Because there are available data on the currents at Al-Fao station, current speed (m/sec) are draws with partial depth (z/h) of the water column as shown in Fig. (5).

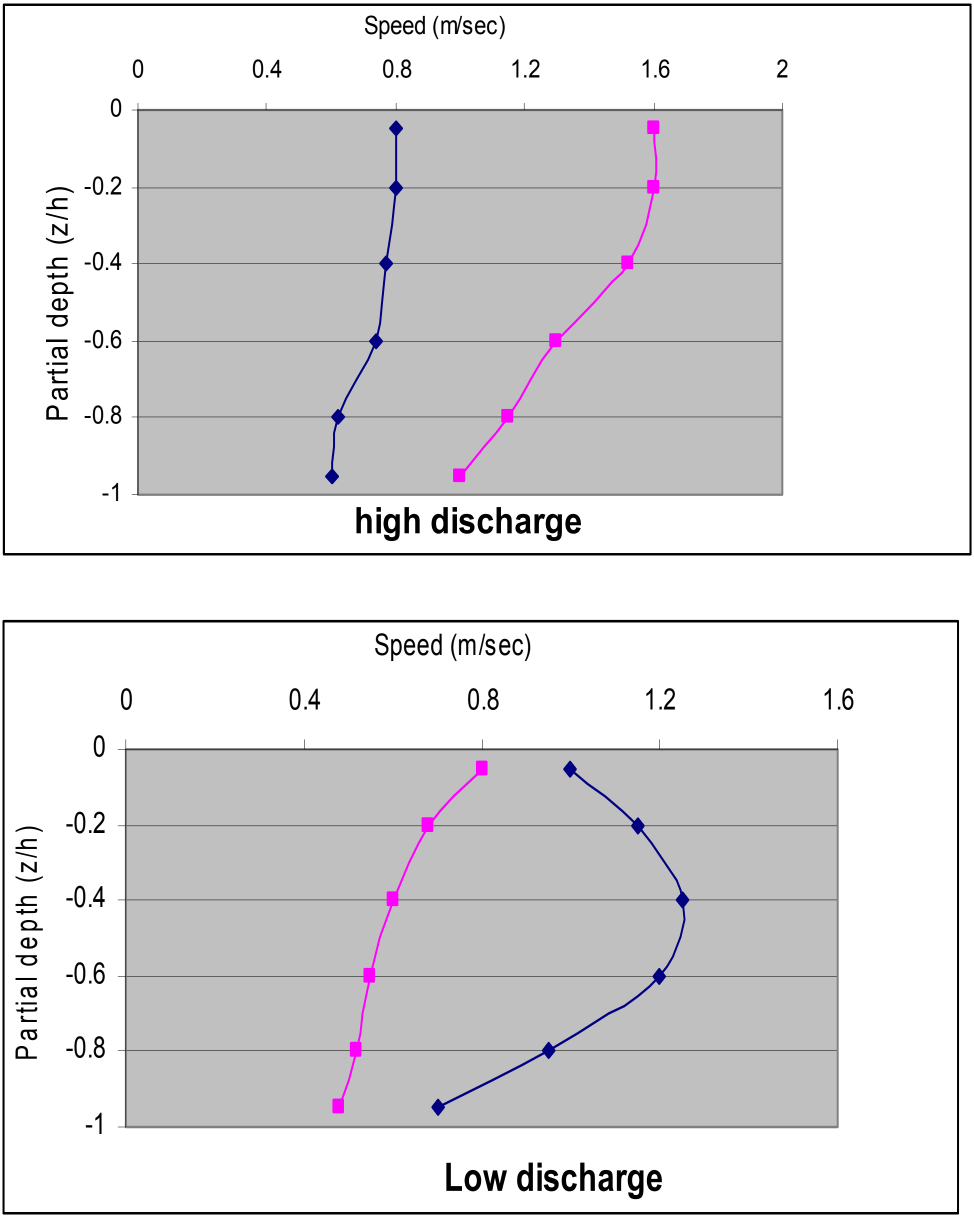

Fig. 5: Current speed distribution during the high and low discharge at Al-Fao station (flood ◆, ebb ■).

It is apparent that the speed of the current during the high discharge was more than that during the low discharge. During the high discharge, ebb speed values were greater than those of the flood. The maximum ebb and flood speeds were of the order of 1.6, 0.8 m/sec, respectively. These high velocities were noted near the surface layer only which extend from the surface to a partial depth of 0.25.

The ebb and flood duration were close to 8 and 5 (hours) during the flood season. The fashion of the speed distribution seems to be widely homogenous from the surface to the bottom, with the exception of the typical ebb period.

While, during the low discharge the status will be mutate. Figure (5) infers that the flood speed values were more than that during the ebb. It also shows that there was a conspicuous gradients in speed values at both phases of tide. The values of the flood speed decreased with depth which was close to 1.0 m/sec. The maximum ebb speeds was recorded near the surface (0.8 m/sec) and decreasing with depth.

The strong tidal currents of Khor Abdullah (1-2 m/sec) and the rest of the Iraqi waters provide good turnover of the water masses, flood tide currents in general were faster than ebb currents.

CONCLUSIONS

1-Tidal range was large in the Iraqi marine waters being over 2.5 meter in the open water and reaching occasionally over 4.0 meters to ward land (Um Quser) during the spring tide.

2-Salinity fluctuations were basically influenced by the freshwater discharge. Whereas, the others parameters such as precipitation, evaporation and phase of tide had less influence on salinity distributions.

3-The highest salinity was recorded at Khor Abdullah and the surface salinity near the shore was more than that offshore, especially during the summer season which reached 40‰

4-There was no significant vertical salinity gradients at all the stations during the typical spring and neap phases. But longitudinal salinity gradient was very clear between the head of the estuary (Al-Fao station) and the mouth of it (Outer Bar station).

5-The highest (32.7 °C) and lowest (15.2 °C) surface water temperatures were recorded during the summer season (August) and winter season (January) at Al-Fao and the Outer Bar stations, respectively. So, seasonal temperature differences play a major role in the fluctuation of salinity especially during summer months.

6- Currents in the Iraqi marine water were complex, but the most major factor was tidal current which provide good turnover of water masses.

7-Tidal currents in Khor Abdullah during the flood were faster than the ebb. While, in Al-Fao the ebb speed values were greater than the flood speed during the high discharge and the status mutate during the low discharge.

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بعض معالم الأقيونوغرافيا الفيزيائية للمياه البحرية العراقية

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المستخلص المياه البحرية العراقية تشغل جزءا هاما من مياه مصب شط العرب شمال الخليج العربي. مركبات المقومات المدية المسجلة في محطات السد الخارجي (M2, S2, K1, O1) من مرتبة 0.66، 0.18، 0.46 و 0.26 مترا على التوالي. إن نمط نظام المد والجزر في المياه البحرية العراقية هو من نوع النمط المختلط الذي يسوده النصف اليومي حيث يتراوح مدى المد والجزر فيها ما بين 1-3 متر. قيم الملوحة المسجلة في منطقة الدراسة تتراوح ما بين 0.4‰ الى 39‰ والتي تتأثر بعاملين اساسين هما تصريف شط العرب وحالة المد. درجات حرارة المياه السطحية تتذبذب خلال فصلي الشتاء والصيف والتي تصل الى 12.5 و 33.5 م° على التوالي. لوحظ في منطقة الدراسة منحدر ملحي وحراري ويعتمد ظهوره على فصل الجريان وطول فترة المد. تتأثر المياه البحرية العراقية بالعديد من التيارات كالتيار المدي وتيار الكثافة وتيار الرياح وتيار الخليج العربي والتيار المتولد بفعل ظاهرة كوريوليس، إلا ان تيارات المد والجزر هي السائدة في منطقة الدراسة والتي تتراوح سرعتها ما بين 0.8 الى 2.0 م/ثا.