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Effect of Karun River on the salinity status in the Shatt Al-Arab River, Basrah - Iraq

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Abstract - The present work presents key results for the effect of Karun River on the salinity status in the Shatt Al-Arab River, in which the Total Dissolved Solid could be described the salinity status. The salinization of water is a problem of many Rivers, especially, the Rivers of Iraq. The water of Shatt Al-Arab River in the south of Iraq is experiencing a salty problem due to the lack of freshwater discharges that started since the last decade of the last century due to anthropogenic and natural causes. The path of Karun River has been diverted temporary into the Iranian territory since 2009, which is the only stream into Shatt Al-Arab River at the southern part of its sharing course with Iran. However, there is a positive role of the temporary water releases from the Karun River in reducing the salinity of the water in some locations near the mouth and in the course of the Shatt Al-Arab River during Autumn and Winter and some months of the Spring. This has confirmed by the following-up of the behavior of salinity along the path of the River over the period 2008-2017. The present study showed that the monthly TDS rates at Shatt Al-Arab River stations (i.e. Basrah, Abu Al-Khaseb and Sehan) have affected by the Karun River releases. As there is a decrease in the values of TDS at Abu Al-Khaseb and Sehan stations during the high and low tide. However, the negative effect of Karun River occurred through increasing the TDS trends, and hence the salinity, during March and Summer

تأثير تدفق نهر الكارون على حالة التراكيز الملحية في مياه نهر شط العرب

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مركز علوم البحار، جامعة البصرة، البصرة - العراق

المستخلص - الدراسة الحالية تقدم نتائج مفتاحية لتأثير نهر الكارون على حالة الملوحة في مياه نهر شط العرب، حيث ان مجموع المواد الصلبة الذائبة يمكن استخدامها لوصف حالة الملوحة. يعد تملح المياه مشكلة تعاني منها الكثير من الانهار وبالأخص انهار العراق التي تجري في عروض مدارية جافة، وتشهد مياه شط العرب في جنوبي العراق مشكلة تملح شديدة بسبب نقص التصارييف المائية التي بدأت منذ العقد الاخير من القرن الماضي لأسباب طبيعية تتعلق بالجفاف وزيادة فعاليات الخزن والاستهلاك في منابع انهار دجلة والفرات والكارون فضلاً عن تجفيف الاهوار المتصلة بالنهر، وبدأت الملوحة الشديدة تهدد حياة السكان والفعاليات الزراعية والصناعية والخدمية خلال السنوات الاخيرة لزيادة توغل المياه البحرية لعشرات الكيلومترات داخل المجرى، ويعد نهر الكارون الرافد الوحيد لنهر لشط العرب الذي يصب فيه في الجزء الجنوبي من مجراه المشترك مع ايران، وجرى تحويل مجرى نهر الكارون ليجري داخل الاراضي الابرائية منذ العام 2009، ومع ذلك فان هنالك دور ايجابي وموقعي للإطلاقات المائية المؤقتة من نهر الكارون في تخفيف ملوحة المياه في بعض المواقع القريبة من مصبه في مجرى نهر شط العرب خلال اشهر الخريف والشتاء وبعض اشهر الربيع، وهذا ما اثبته متابعة سلوك الملوحة على طول مجرى الشط للفترة 2008-2017. بينت الدراسة ان المعدلات الشهرية لمجموع المواد الصلبة الذائبة عند محطات نهر شط العرب (مركز البصرة - ابي الخصيب - سيحان) للفترة 2008-2017 فيها تأثير واضح لإطلاقات نهر الكارون وهو الرافد الوحيد لشط العرب الذي يصب في الجزء الجنوبي من جهة ايران، اذ ان هنالك انخفاضاً في قيم مجموع المواد الصلبة وبالتالي ملوحة النهر في ابي الخصيب خلال المد، وفي محطة سيحان خلال الجزر. أما اشهر الصيف وشهر اذار فلا تأثير فيها لنهر الكارون على حالة الملوحة في شط العرب وبالتالي زيادة التأثير الخطي لمجموع المواد الصلبة الذائبة والملوحة.

الكلمات المفتاحية: ممر شط العرب المائي، التسلسل الملحي، نهر الكارون، انهار بلاد ما بين النهرين.

Introduction

River is one of the important water resources. It provides potable water. Also, it can be used for industrial, agricultural, tourism, navigational and fishery activities (Ahmadi *et al.*, 2015). Shatt Al-Arab River is the main source of fresh water in Basrah Province. It is associated with all activities of the population of more than 3 million people (Ministry of Planning, 2017).

Shatt Al-Arab River is a link between the largest Rivers of Mesopotamia (i.e. Tigris, Euphrates, and Karun Rivers). Karun is the largest River in Iran, originated from Zagros mountain ranges and finally flowing into the Arabian Gulf (Mohammad *et al.*, 2014). The confluence of Tigris and Euphrates Rivers was at the city of Qurna (previously) on the Iraqi side and then runs south-eastwards for a distance of 204 km to its mouth in the Arabian Gulf, which is the real distance during the lowest water level at low tide. Hence, the waters of Tigris, Euphrates and Karun Rivers (i.e. about 35.3 km³) flowed into the Arabian Gulf, with tens of millions of tons of sedimentary deposits (Al-Mahmood 2012, Al-Mansoury, 2008) (Fig. 1).

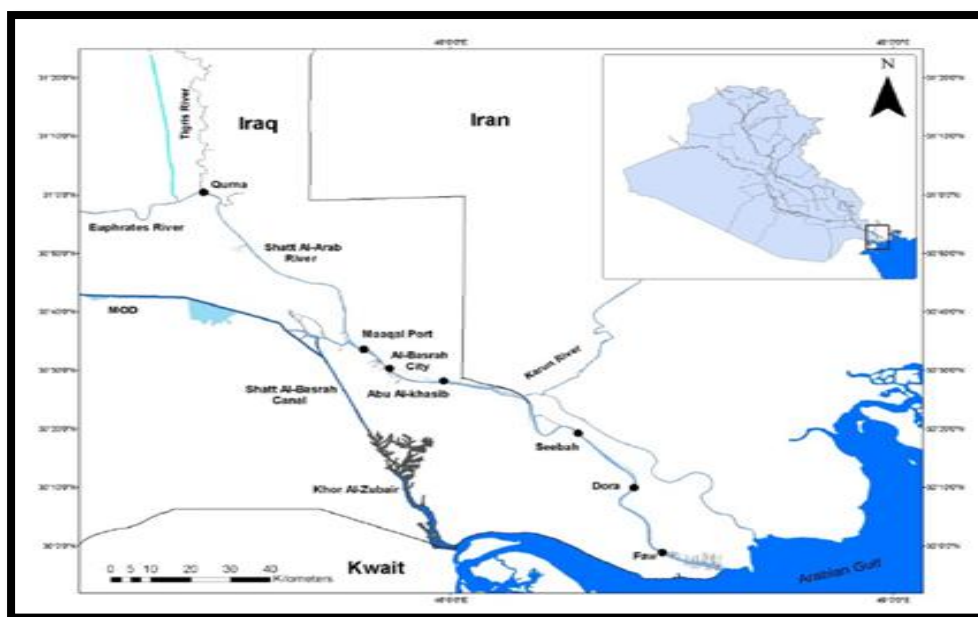


Figure 1. The geographical setting of Shatt Al-Arab River (Abdullah, 2016).

Thus, Shatt Al-Arab River is a mixture of a set of hydrological effects of major Riverine systems with a slight slopping bottom (Cai *et al.*, 2015). Recently, the hydrology of these Rivers has changed significantly causing changes, so the physical and chemical properties of the Shatt Al-Arab River. The great impact of the Karun River on the hydrological characteristics of the Shatt Al-Arab River in its southern part has been confirmed (Al-Mansoury, 1996). As the relationship of some geomorphological phenomena in the Shatt Al-Arab River with the hydrological effect of the Rivers have been identified (Al-Mulla and Abdul Karim, 2005). The link and overlap of the geological history of the Mesopotamian valley between the two Rivers system in Iraq and Iran have been confirmed (Al-Mansoury and Salman, 2011), and before that, the inevitability of historical geographic information of the head of the Arabian Gulf has been identified (Hansman and Historica, 1980). In addition, previously Karun River was the main water source for the Shatt Al-Arab River (Abdullah *et al.*, 2016).

The discontinuity of Karun River, which fed the southern part of the Shatt Al-Arab River, led to increase salinity concentration. The contribution of Karun River exceeded half the waters of Shatt Al-Arab River (Al-Mansoury, 1996). However, Iran has built dams since 2002 on the Karun River, causing reduction in the flow of Karun into the Shatt Al-Arab River until in 2009 the Karun was completely cut off (for special purposes) by the diversion of the River flow into the Iranian territory (Al Mahmood, 2015).

Thus, the flow of Karun waters became directed towards the Arabian Gulf via the Bhmanshir channel (parallel to Shatt Al-Arab River to the east), which is a second estuary of the Karun River (Fig. 2). The periods of flow of Karun waters into the Shatt Al-Arab River is only during the periods of excessive discharge (out of control temporary).

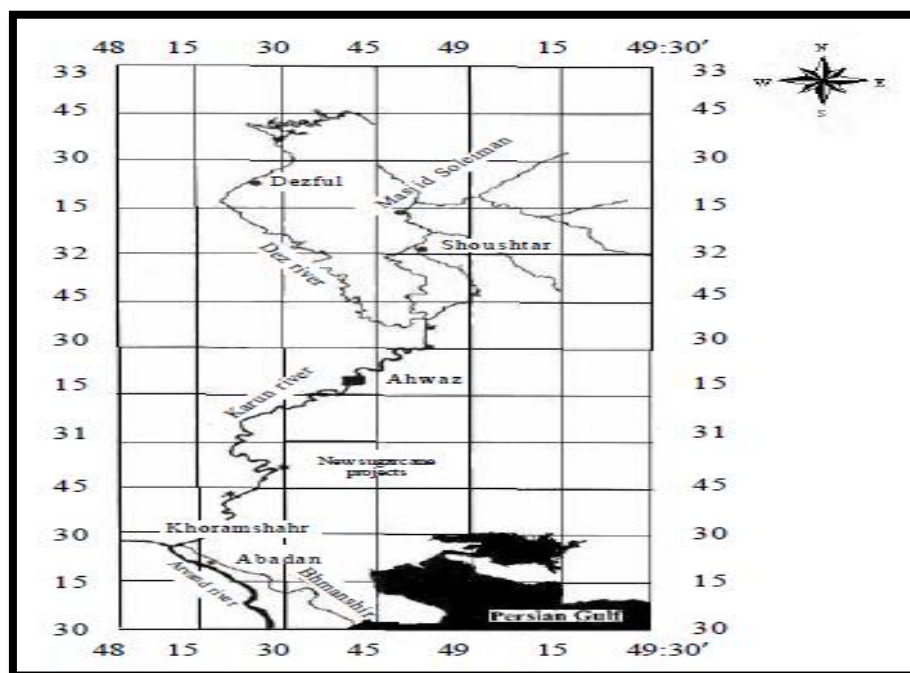


Figure 2. Karun River and the erected dams before its outlet in the Shatt Al-Arab River (Afkhami *et al.*, 2007).

The contribution of Karun River increases the freshwater during the precipitation peaks in Winter, Autumn and Spring. However, fewer contributions occurred during the rest of the year but they affect the reduction of high salinity through the intrusion of salinity due to the reduction in freshwater discharge values (Al-Mansouri and Al-Mahmood, 2006). With the decline of freshwater discharge of the Shatt Al-Arab River due to the growth of investments in the upper Tigris and Euphrates Rivers basin together with the decline in the rate of discharge due to the occasional cutting off the flow of Karun River, the flow of Karun River requires monitoring to determine its impact on the water discharge of the Shatt Al-Arab River. Hence, the aim of the present study is trying to investigate the effect of Karun River on the salinity status of the Shatt Al-Arab River.

Salinity of Shatt Al-Arab River:

Shatt Al-Arab River is characterized by yearly rates of discharges, with high discharge in some years, and low discharge in others, depending on the characteristics of the water year, which is

determined by the Tigris River, as the only source of supply to the Shatt Al-Arab River after cutting off the Euphrates River. Salinity is varied with the variation of discharge which is decreased during Autumn and Winter, and increased during Summer and Spring due to decreasing discharge from the source and increasing water consumption. The salinity varies daily as well during the tidal wave due to the incursion of saline and marine waters. While salinity decreased during low tide due to increasing the flow of freshwater coming from the upstream of the River and the decline of the saline tide during the hours of low tide.

Materials and Methods

Fieldwork:

In the present work the Total Dissolved Solids (TDS) were measured in ppt., by using Multimeter, type CRISON, Spanish manufacture. Five stations were selected (Al-Mdaina, Al-Qurna, Basrah, Abu Al-Kaseb and Sehan) and monitored during the years 2008-2017 for the highest and lowest tides depending on the forecasts of the total tide program version V1.0.11.0. (i.e. with cooperation of the Directorate of Water Resources in Basrah). The TDS concentrations have been adopted for describing the salinity status as there is a linear relationship between the TDS and salinity (Mahmood *et al.*, 2019).

Office Work:

1. The daily mean averages of TDS values for the period 2008-2017 have been converted to monthly mean averages, by using the system of excel sheet. The data collected indicate that the TDS (or the salinity) status could be monitored at the water surface.
2. The correlation coefficients and regression equations were applied to the monthly TDS changes by using the system of excel sheet with high accuracy.

Results and Discussion

The concentrations of TDS indicate the number of soluble substances that carried by the Rivers during their flow. It is an important indicator of the important hydrological characteristics that characterize the features of the Rivers' water and the possibility of their use for different purposes (i.e., human, industrial and agricultural). The study of the nature of Riverine discharge and soluble materials is of great importance in engineering and agricultural fields (Al-Mahmood *et al.*, 2015). It is, therefore, necessary to know the reason for the expected change in the characteristics of Shatt Al-Arab's water in its various districts, which is, a major resource for the city of Basrah, and to show the relationship between the quality of water and the size, seasonality of water releases. The values of TDS in the Shatt Al-Arab River have changed since the 1980s after the surface water was managed according to the conditions of freshwater discharge, which is decreased significantly in the recent years. Actually, there have been significant changes in the streams of Euphrates and Karun, in which all of these Rivers have been cut recently. Where the Karun River was cut in 2009 (temporary) and the Euphrates River was cut in 2010 (Al-Mahmood *et al.*, 2015).

Thus, the Shatt Al-Arab River is fed only by the Tigris River and by a particular discharge estimated about 50 m³/s (Directorate of Water Resources in Basrah). However, this amount of freshwater is not being complied with by the governorates of Kut and Maysan, through which the Tigris River passes during its way to Basrah. Moreover, this amount of water is often reduced to less than that in case of the lack of freshwater discharges. For these reasons, Shatt Al-Arab River has become a focal point between many types of saline sources from the upstream due to population concentrations in the cities and from the sea, which mixes the waters of Shatt Al-Arab River during

the tides. The most important source of TDS (the salinity) in the Shatt Al-Arab River is the seawater at the south (i.e. Arabian Gulf), (Fig. 1). Where the impact of the tide has increased in recent years due to the decline of freshwater discharge into the Shatt Al-Arab River and inability of discharge to push the sea front back towards the Gulf.

Thus, the extent of the salt intrusion (Fig. 3) varies according to the freshwater influx into the Shatt Al-Arab River from the Tigris River in the North. In addition, the temporary water releases from the Karun River also affect the water salinity concentration in the Shatt Al-Arab River at some sites. These two factors will determine the distance of salinity intrusion in the Shatt Al-Arab River. The tidal wave and the distance of penetration with low freshwater discharge from the upstream have influenced the TDS values to reach its highest values in 2008, 2009, 2015 and 2017 (Fig. 3). The salinity values in 2009 were 27.8 and 37.62 g/l in Al-Seebah and Al-Fao stations, respectively (Al-Mahmood *et al.*, 2015). The salinity of the marine waters coming from the Arabian Gulf during these years is penetrating into the Shatt Al-Arab River at depths of 1-9 meters, and the increase in the surface salinity is followed by a similar increase in penetration and longitudinal distance as well as in salinity intrusion upstream. The largest salt intrusion occurs in Spring and Summer months. However, the lowest penetration of the surface salinity was in Autumn and Winter.

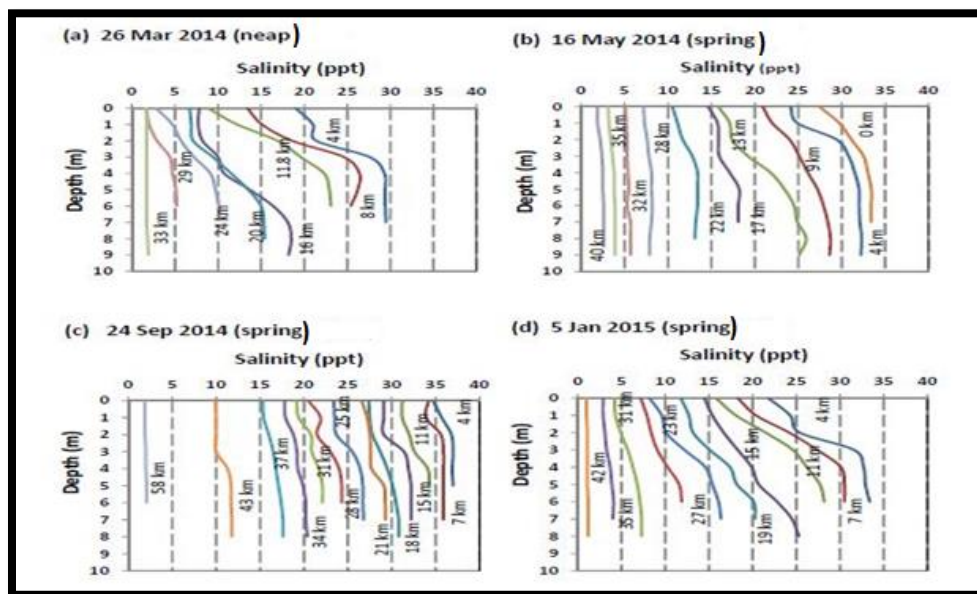


Figure 3. Salinity concentrations (ppt.) according to the extent of salinity intrusion from the downstream in the southern part of the Shatt Al-Arab River during 2014 in the highest high tide and lowest low tide (Abdullah, 2016).

During the study period 2008-2017, the highest concentrations of TDS was recorded at the south of Shatt Al-Arab River at Sehan station (approximately 50 km) north of the estuary (Fig. 4). Clear differences in the TDS values were obvious, which are affected by the discharge of Tigris and Karun Rivers. The years 2008, 2009, 2015 and 2017 recorded the highest TDS (salinity rates) in the Shatt Al-Arab River. Where in 2009, the Karun River was closed off against the Shatt Al-Arab River and it transformed towards the Bhmanshir channel. However, the year 2015 was the driest

hydrological year in the headwaters of the Tigris and Karun Rivers in comparison with the highest values of the years 2002-2017.

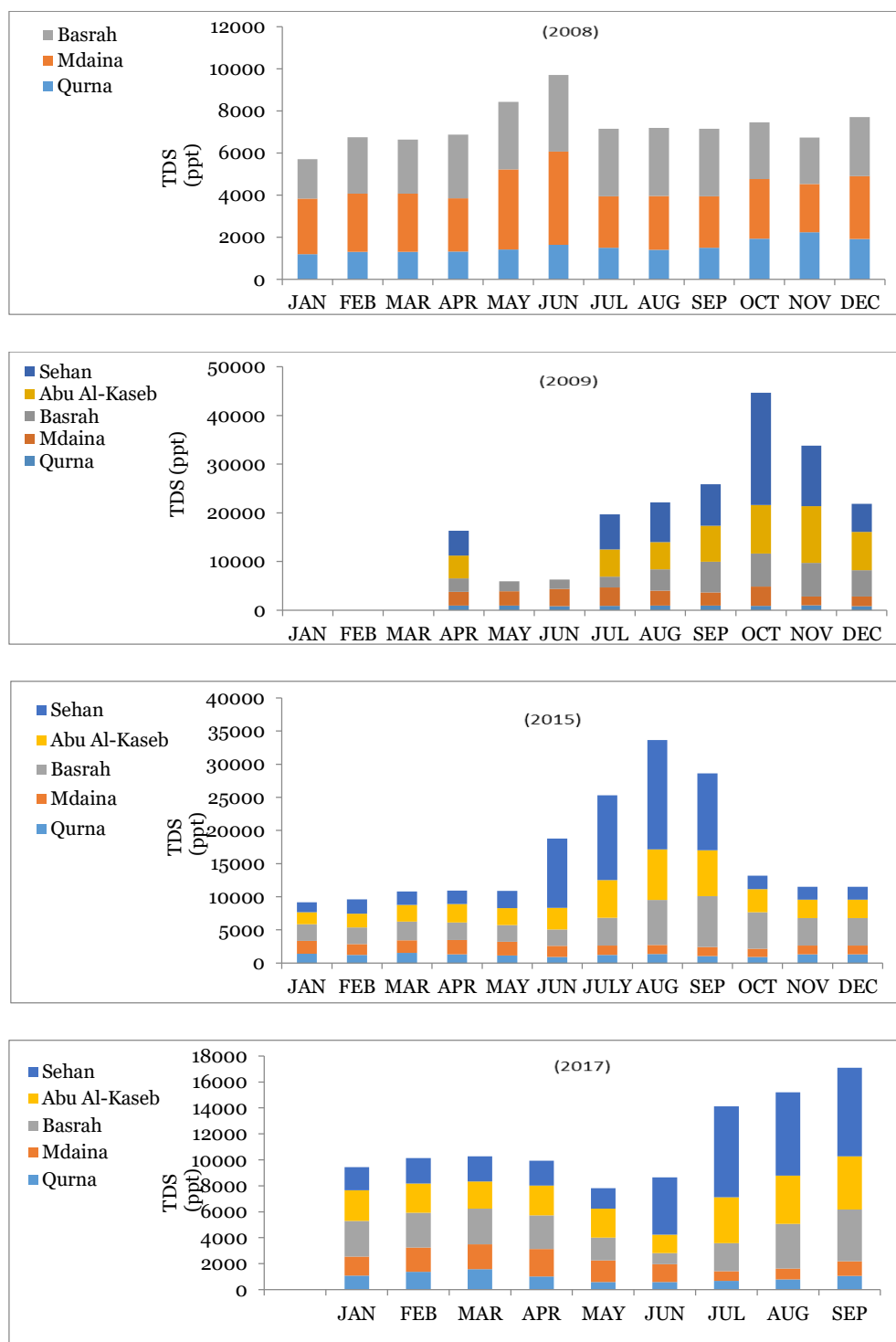


Figure 4. Monthly means TDS (ppt) values of the stations (i.e. Sehan, Abu Al-Kaseb, Al-Basrah, Al-Qurna and Al-Mdaina) for the years 2008, 2009, 2015 and 2017.

Other changes occurred in the TDS values of Shatt Al-Arab River at the stations of Sehan (south of the Karun estuary) and Abu Al-Kaseb (north of the Karun estuary). These changes are related to the influence of Karun River in the south of Shatt Al-Arab River within semidiurnal tide cycle. Although the TDS of Karun River is high in its southern part, it is much lower than the TDS of the Shatt Al-Arab River at its contact point in Al-Fao. Where this value does not exceed 2.3 ppt. (i.e. 3.6 mmho/cm), see Table (1), and this is due to some excess water releases in some days which contribute in reducing the TDS of the Shatt Al-Arab River water (i.e. registered during the field work with the Directorate of Water Resources in Basrah). In addition, this value of TDS is less than its value in the middle part of the Shatt Al-Arab River, which rises because of human activity along the path of more than 120 km starting from the upstream station to the mouth of Karun River in the Shatt Al-Arab River.

Table 1. Municipal sewage effluent entering Karun River from the major Cities along the River (Afkhami *et al.*, 2007)

City	Discharge (m ³ /sec)	Volume (km ³ /year)	Ec (mmho/cm)
Ahvaz	4.5	140	4
Abadan	0.7	19	3.6
Khorramshahr	0.5	14	5.4
Dezful	0.6	19	2.1
Shoushtar	0.3	8	2.1

The monthly changes of the TDS concentrations, indicates higher values during the Summer (i.e. June, July and August at Sehan) (Fig. 5 and Table 2). This period is preceded by heavy consumption of water in agricultural and domestic usage without compensation of the missing water from the source states, due to the long dry season. There are also site differences over most months of the years, especially, during the dry hydrology years. As the TDS trend values in the stations of Sehan, Abu Al-Kaseb and Basrah have deviated in most of the months about the positive trends (i.e. March, June, July, August and September-Sehan station), (i.e. February, March, July and August-Abu-Al-Kaseb station), (i.e. January, February, March, July, August and September-Al-Basrah station), respectively (Fig. 5). These gradients are very clear in the years of 2009, 2015 and 2017, in which the lowest discharges were recorded in comparison with the other studied years. So the TDS trend values will be very close between the stations of Al-Basrah and Abu Al-Kaseb during July and August. Where as in Abu Al-Kaseb, which is about 14 km north of the Karun estuary, and it is less saline than Al-Basrah in some months (i.e. January, February and March), although the last station lies about 20 km north of Abu Al-Kaseb station. This is may be due to the clear effect of the Karun River by the dilution of the TDS in the waters of the Shatt Al-Arab River (i.e. in the north and south of the estuary). When reviewing the monthly TDS rates of the Shatt Al-Arab River stations (i.e. Basrah, Sehan and Abu Al-Kaseb) over the period 2008-2017, a clear effect is evident of the Karun River, which is the only source of fresh water to the Shatt Al-Arab River. As shown in Figure (5), there is a decrease in the TDS values at Sehan, Abu Al-Kaseb and Basrah stations during the tide periods and these changes appear in some months (i.e. January, February, April, May, October, November, and December-Sehan station), (i.e. January, April, May, June, September, October, November and December - Abu Al-Kaseb station), (i.e. April,

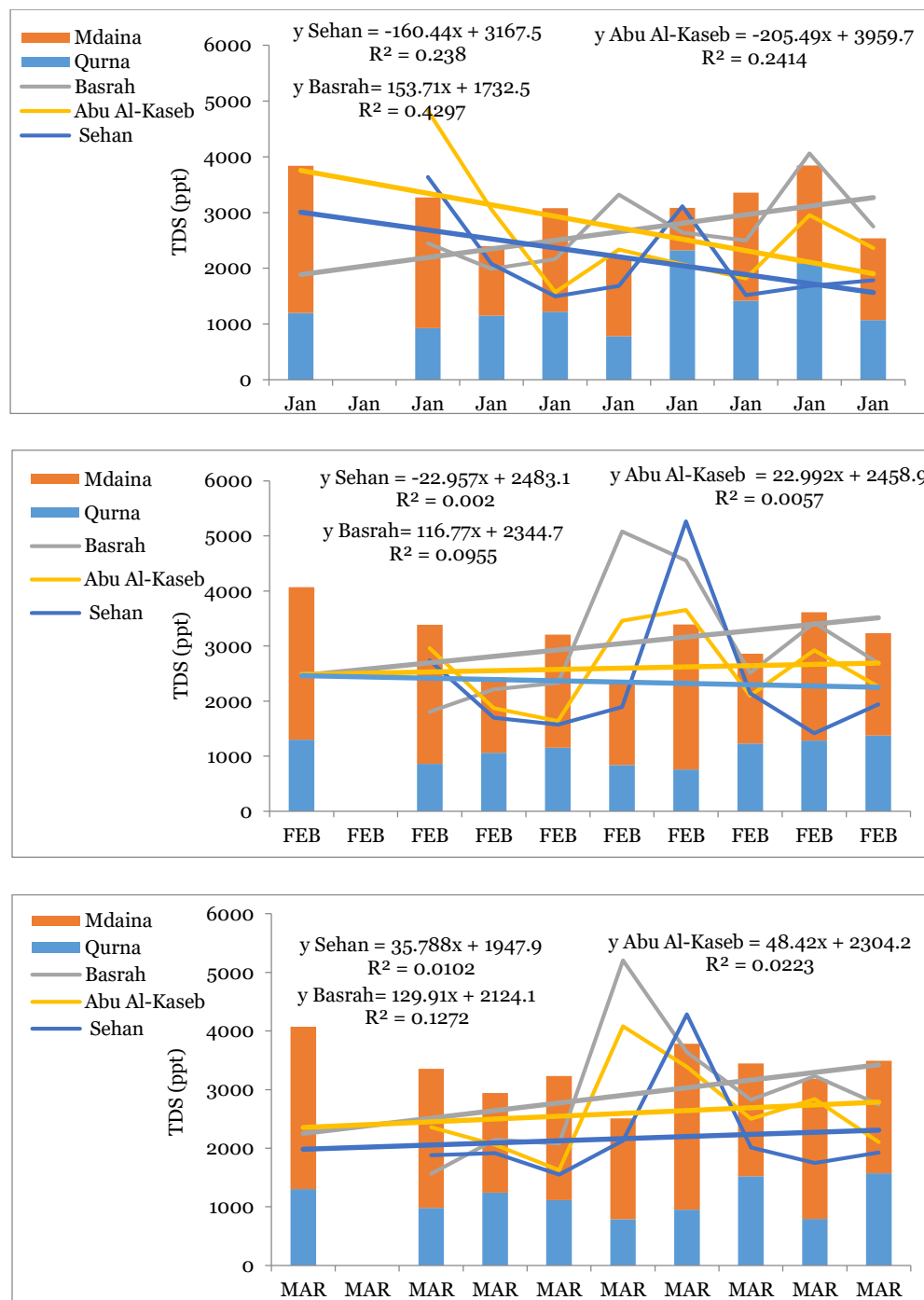


Figure 5. TDS (ppt.) variations at the stations (Sehan, Abu Al-Kaseb, Al-Basrah, Al-Qurna and Al-Mdaina) during (January-December) over the period 2008-2017, respectively.

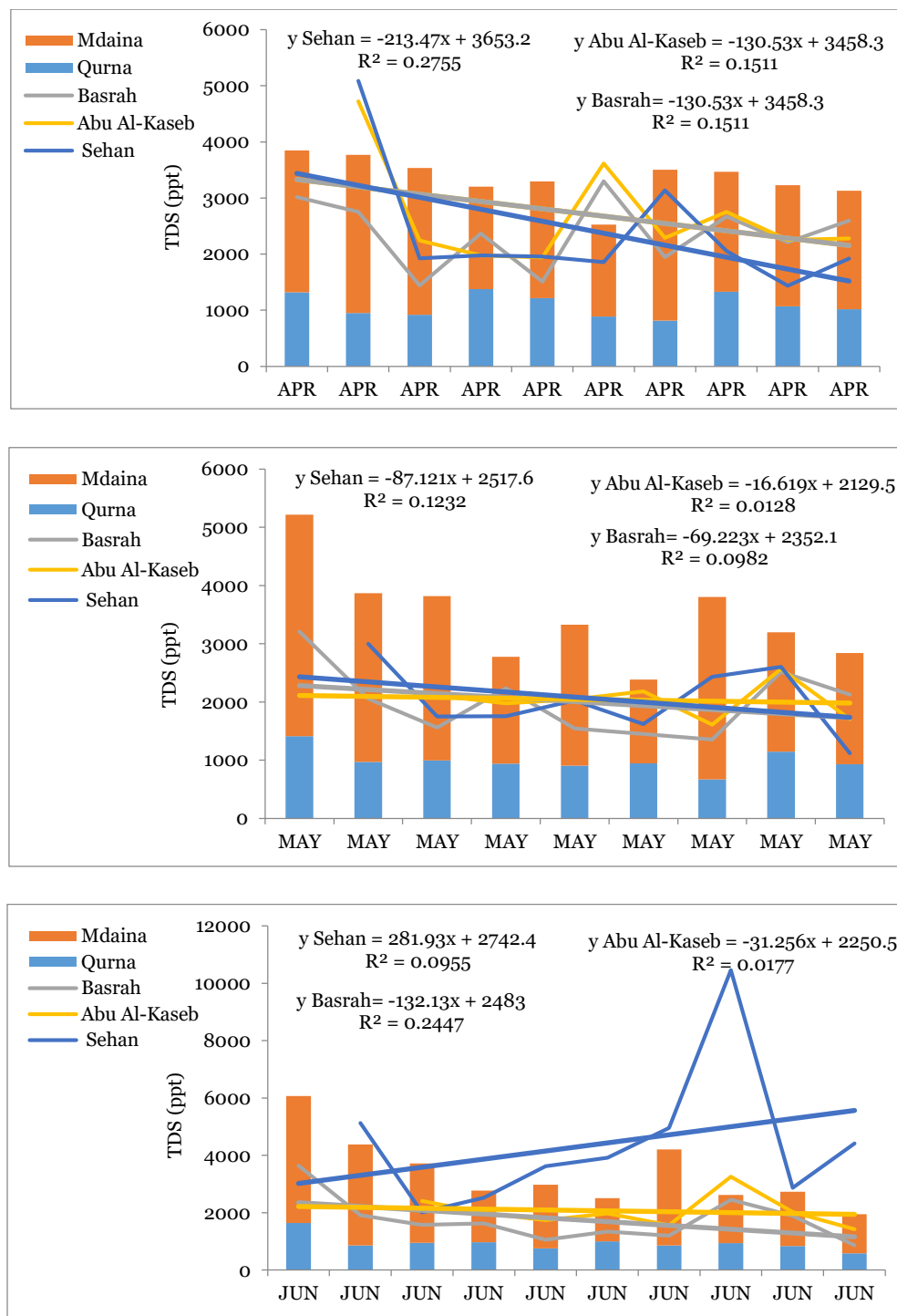


Figure 5. Continued ...

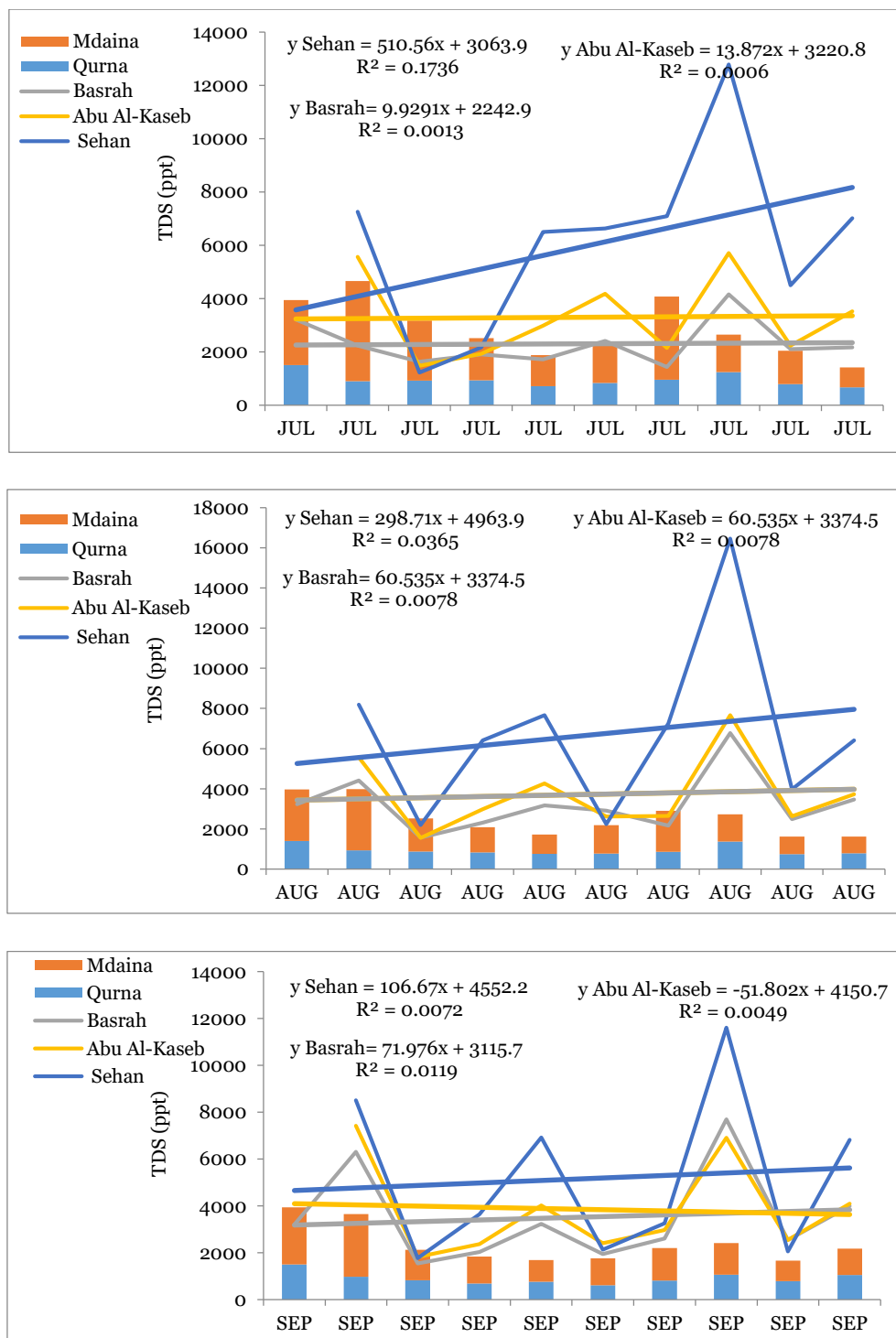


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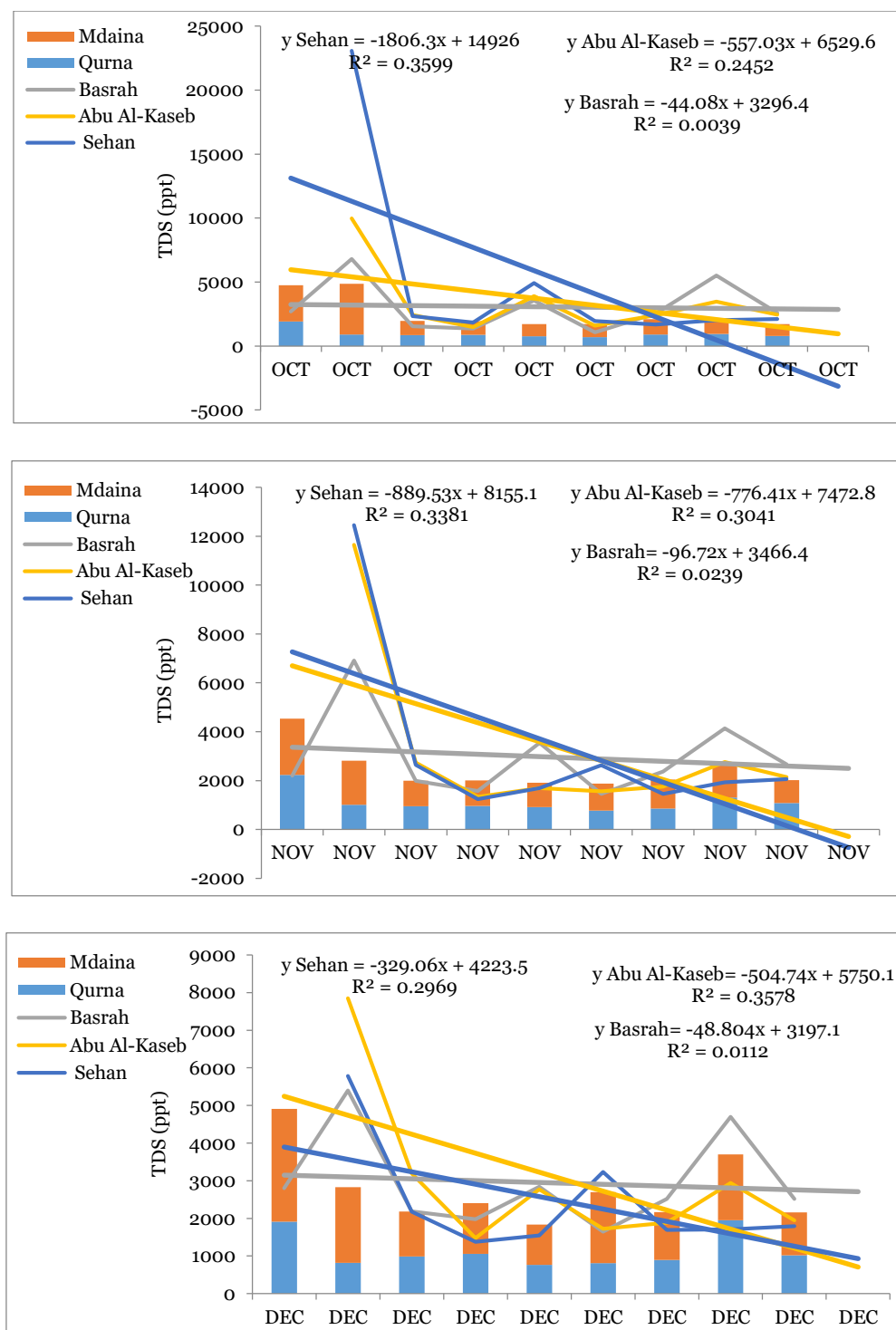


Figure 5. Continued ...

May, June, October, November, and December-Basrah station), respectively as negative trend values. Thus, in these months, the positive effect of Karun River will appear by reducing the TDS concentrations. While, there is no effect appears to reduce the TDS and hence the salinity in the Shatt Al-Arab River by Karun River in summer months (i.e. June, July and August), as presented

by positive values of trends. That is possibly due to a great demand and high consumption of water inside Iran, as well as due to very high salinity, severity of the drought, large consumption and increased evaporation in the mentioned stations at the Shatt Al-Arab River. Although the observed reduction is slight in TDS, it does refer to a positive effect due to the excessive release of Karun river, which is very few water releases, but can make a difference in the quality of the southern and central waters in some drought years. There are effects of Karun River during the high tide at Abu Al-Kaseb station, which is located at the top of Karun mouth about 16 km, as presented by negative trend value. This effect is to reduce the TDS and salinity in the water mass of Shatt Al-Arab River at the North, whereas the effect will make an opposite difference occurred in Sehan station, although it is the shortest distance from the mouth of Karun River in comparison with Abu Al-Kaseb station because it is a very saline area by the influence of the local driver. Thus, the TDS and the salinity at low tide water is slightly higher in Sehan station than the salinity of high tide, due to the existence of agricultural discharge waters that flowing into the Shatt Al-Arab River in the context of Karun River influence. That is, the Karun River's water quality is heavily influenced by each of the industrial wastewater discharges, urban and agricultural discharges, and that affects the electrical conductivity of this River (Emamgholizadeh *et al.*, 2014; Kevin *et al.*, 2015 and Ahmadmoazzam *et al.*, 2017). In addition, there is no source of fresh water in the distance of 50 km between Sehan and the mouth of the Shatt Al-Arab River in the Arabian Gulf. Finally, there is no any abnormal values of TDS via the Karun River discharge into the Shatt Al-Arab River stream, that is, there is no any influence for the Iranian Paracensis waters affect the TDS and the salinity levels over the studied period.

Conclusions

Increasing the distance of seawater salinity intrusion with the decrease of discharge from the upstream, and diversion of the Shatt Al-Arab waters are combination of marine and fresh water (brackish water), and the most saline water is in Sehan. The marine effects reached the central part of the course (Basrah station) about 110 km north of Al-Fao. With the temporary release of the Karun River, there is a positive and local effect in reducing the TDS and the salinity of the water in some locations near its outlet in the Shatt Al-Arab River during Autumn and Winter and especially at the stations of Sehan and Abu Al-Kaseb, while there is no effect of Karun River in these stations in March and Summer. Finally, there is no any flow for the Iranian Paracensis waters within the Karun River discharge into the Shatt Al-Arab River waters, where there is no any indication via the TDS values referring to that issue.

Recommendations

Activation of continuous environmental monitoring of the southern and middle part of the Shatt Al-Arab River because it is exposed to cases of salinization particularly during Spring and Summer months. Constructing a mathematical model to simulate the behavior of the TDS and the salinity in Shatt Al-Arab River.

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