Al-Bahir Journal for Engineering and Pure Sciences
BJEPS

Volume 2 | Issue 1 Article 6

Shatt Al-Arab River and the seawater intrusion: causes and solutions

Havan H. Salman
Ministry of water resources/Iraq

Hamdiea Skheel Jazaa
Ministry of water resources/Iraq

REVIEW

Shatt Al−Arab River and the Seawater Intrusion: Causes and Solutions

Havan H. Salman*, Hamdiea S. Jazaa

Ministry of Water Resources, Iraq

Abstract

The scarcity and pollution of water resources led to environmental deterioration in Iraq, where the water needs for agricultural purposes are estimated at about 51 billion m^3 annually to irrigate 11.3 million dunums and about 10 billion m^3 annually for social health needs and 5 billion m^3 annually for industrial, oil needs and electricity production. This paper addresses another factor exacerbating the crisis and posing another challenge to competition, which is pollution from seawater intrusion. Take the Shatt al−Arab as a case study. Shatt al−Arab is the main water source for the city of Basra in southern Iraq, where the Tigris River contributes (35%), the Euphrates River (24%), in addition to the sub-basins of the Karkheh River by (8%) and the Karun River by (33%) in its composition. The water supply in Shatt Al−Arab has significantly decreased and losing over 50% of its water supply Due to the water control by the riparian countries is conducted either through rivers diversions (Iran model) or by building massive dams (Turkey model). This has caused severe deterioration in the water quality and quantity of Shatt al−Arab River, and has also allowed seawater to intrusion, which is known to harm the ecosystem and threaten the city and the region with an environmental disaster. Field data related to the salt's concentration at the population centers on Shatt al−Arab's path were collected as a measure of the salinity impact of the Gulf waters on it, and then solutions were proposed to get mitigate of this effect. This present paper will provide an environmental assessment based on real data analysis and propose practical solutions to mitigate the risk of water pollution.

Keywords: Saltwater intrusion, Salt tide effect, Shatt al−Arab problem, Iraq water Crisis

1. Introduction

The four governorates in southern part of Iraq are; Basrah, Dhi-Qar, Al-Muthanna, Messan.The cities of Basrah, Nasiriyah, Samawah, and Amarah are the capitals of the governorates, reactively. The Euphrates River flows through Nasiriyah and Samawah while the Tigris River flows through Amarah. Basrah, however lies on the Shatt al−Arab which is formed by the confluence of Euphrates and the Tigris and flows to the Arabian Gulf Fig. 1. These river systems are not only the source of water for the four governorates but also are where the governorates sewage is disposed. (UN-ESCWA-BGR 2013, Note).

Shatt al−Arab is a river formed by the confluence of the Tigris and Euphrates rivers in the Qurna district 375 km south of Baghdad. It descends south to its mouth in the Gulf, with a length of approx. From 204 km, but after changing the course of the Euphrates River after it used to meet the Tigris at Medina Al-Qurnah and entered the Marsh of Al-Hammar, from which its waters flow through the stream of Karma Ali, so the section between Qurna and Karma Ali is part of the Tigris, so its length is reduced It reaches about 195 km, and empties into the Arabian Gulf at the tip of the city of Al-Faw, which It is the southernmost point in Iraq Fig. 2. Its width varies from place to place and in an image generally, it gets wider as we approach the estuary [11].

There are obvious spatial and temporal variations in pollutant concentrations in both fluvial (Shatt Al−Arab River, Swage Mainstream, Al-Rubat,

Received 10 December 2022; revised 24 January 2023; accepted 24 January 2023.
Available online 23 February 2023

* Corresponding author.
E-mail addresses: dr_havan@yahoo.com (H.H. Salman), hamdya_sa04@yahoo.com (H.S. Jazaa).

https://doi.org/10.55810/2313-0083.1018

Fig. 1. Stream length of Samawah - Basrah is approx. 330 km. (UN-ESCWA-BGR 2013, Note).

Fig. 2. Basra administrative map.

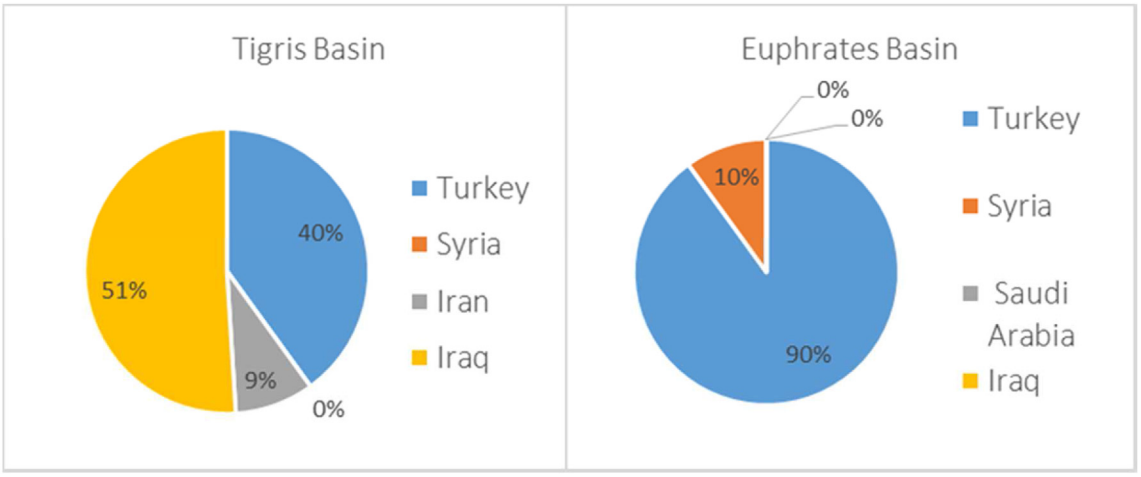

Fig. 3. Iraqi water resources consumption.

AlKhandak, Al-Ashar, and Al-Khorah Creeks) and tap water within the study area. In general, water salinity, major elements, and bacteriological indicators have increased during summer and autumn more than winter and spring. In the meantime, heavy metals and hydrocarbons increased during winter more than they did the summer, with some exceptions. Often, water quality indicators greatly exceeded the WHO acceptable standards. Therefore, the unsuitability of freshwater quality may posed a threat to the human health. However, a variety of urban activities such as domestic, municipal, industrial, and agricultural wastewater effluents, may have played an important role as main sources to water contamination in the study area, along with the combined regional natural and human factors [15].

The available data on the surface water in Iraqi water sources vary, particularly groundwater estimation which is still unclear. According to a 2006 World Bank report, the safe yield of the aquifers is estimated at 1.2 Bm^3 annually, about 2% of the nation's annual water budget, while the UN indicates that the groundwater availability 2009–2010 was 7 Bm^3, which is equivalent to 14% and 50.1 Bm^3 surfers water was which equal to 86% [16]. As for the annual consumption, it changes from one season to another, according to [2]. Figure 3 shows the consumption proportions of available water resources for the winter session of 2021 and 2022. With its tributaries and Euphrates Rivers, Tigris are primary sources of surface water in Iraq; they cover an area of 126,900 km^2 and 177,600 km^2, respectively [16]. The Tigris and Euphrates run for 1850 Km and 2740 Km the Tigris and Euphrates basin areas are about 784,000 km^2, where Iraq has the most significant share, as below (Table 1) and Fig. 4. However, both Rivers are joined in southern Iraq to form the Shatt Al–Arab River (SAR), which eventually follows the Arabian Gulf.

Basrah province is located in southern Iraq and borders Kuwait to the south and Iran to the east. The city of Basrah, which is also the capital, is Iraq's principal port and lies at the base of the SAR. The SAR runs along the Iraq–Iran border, and it is the primary surface water source for daily consumption and agricultural uses. Basrah province is an agricultural region and produces many goods, including wheat, dates, maize, corn, and livestock. Based to the Ministry of planning, the estimated

Table 1. The feeding basin area and the annual water revenue of Tigris and Euphrates rivers for riparian countries [17].

River	country	Actual feeding basin area km^2	Actual feeding basin area (%)	Annual Water Revenue billon m^3	Annual Water Revenue (%)
Tigris River Basin	Turkey	57,614	35	26.2	54.6
	Syria	836	0.5	0.03	0.06
	Iran	24,406	14.7	5.7	11.9
	Iraq	83,237	50.1	16.05	33.45
Euphrates River Basin	turkey	108,000	98.2	29	98
	Syria	2000	1.82	0.6	2
	Saudi Arabia	–	–	–	–
	Iraq	–	–	–	–

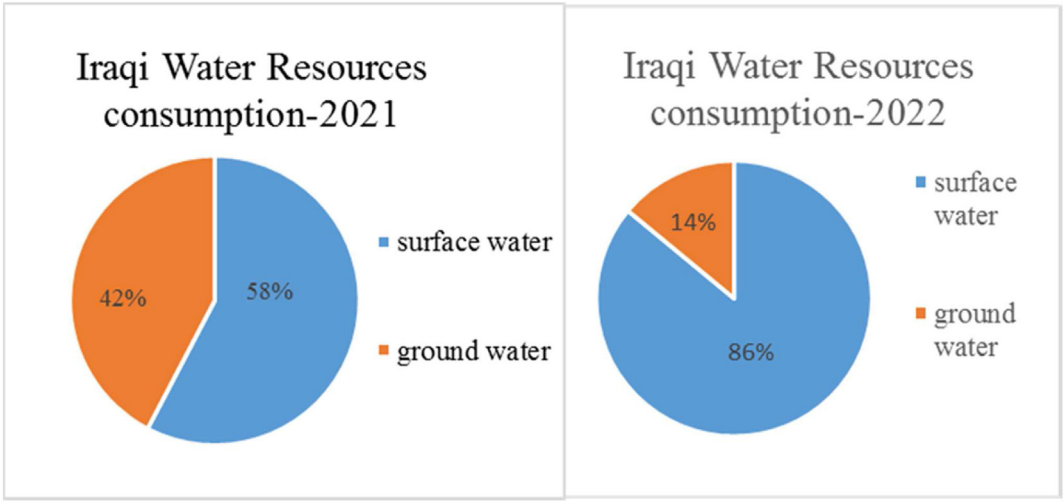

Fig. 4. Tigris and Euphrates Rivers Basins annual discharge percentage.

population exceeds 3.5 billion. Agriculture is dominated by the cultivation of the Date Palm, although during the last 30 years, this sector has experienced a remarkable reduction in the Date palm Grove.

Historically, this area is judged to hold the most significant date palm forest globally. In the mid-1970s, the region included 17 to 18 million date palms trees. Recently only 3–4 million trees exist and are mainly in poor condition [12]. SAR formed

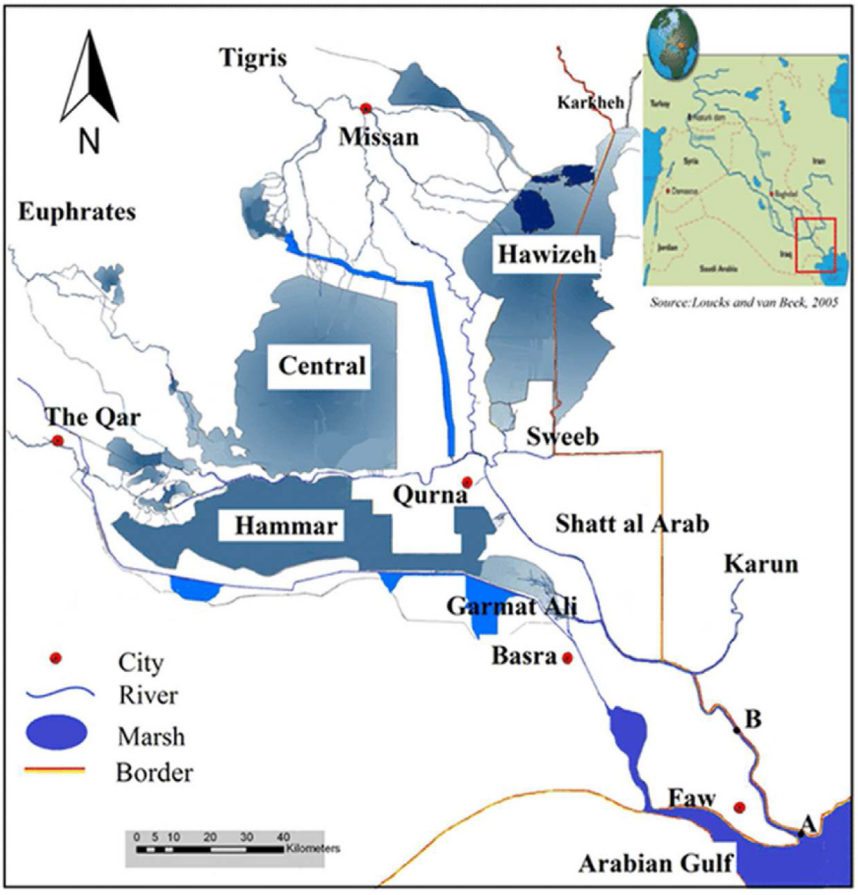

Fig. 5. Shatt al–Arab and its tributaries.

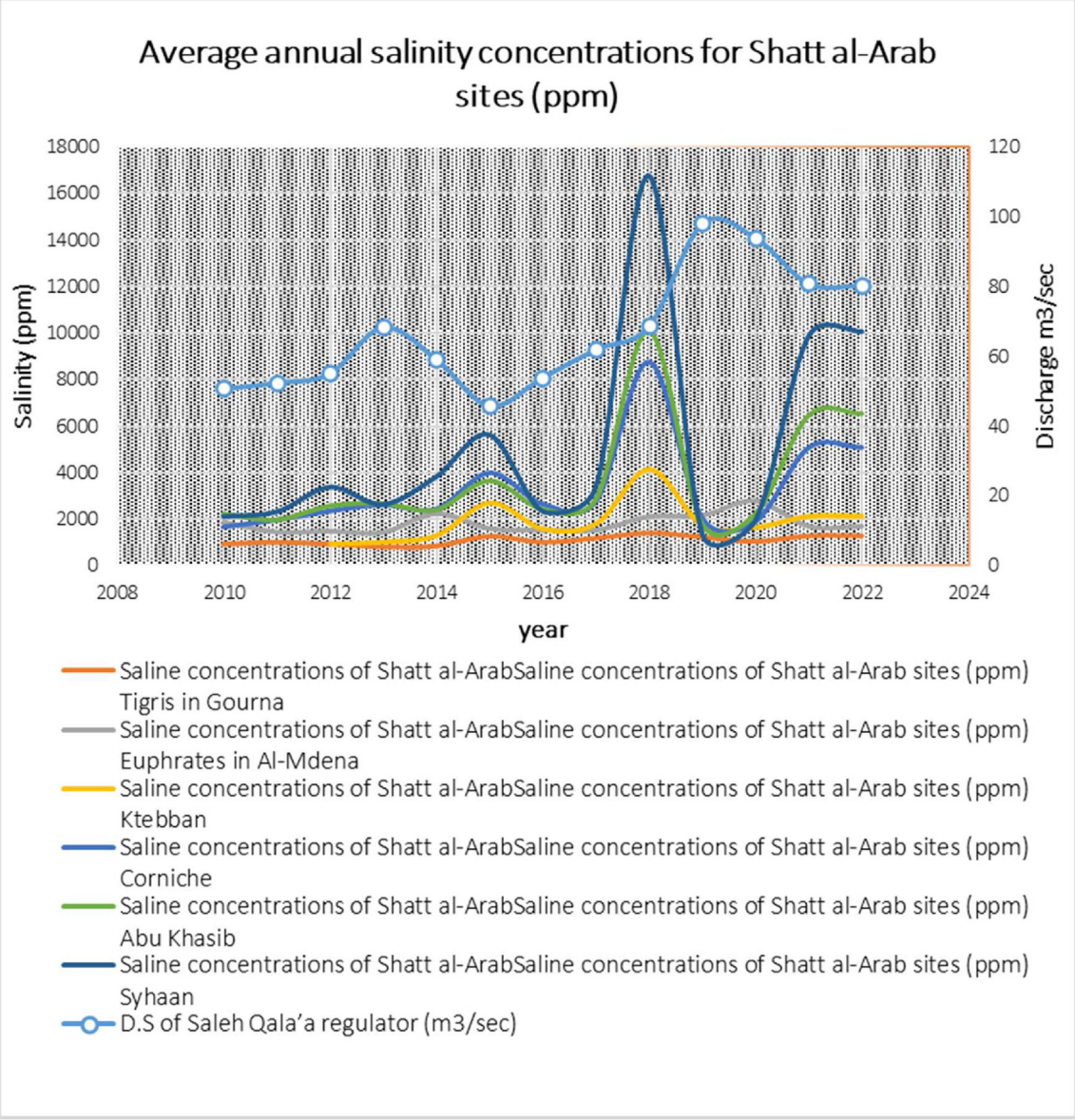

Fig. 6. The relationship between the expansion of the saline tongue and water supply.

by joining the Tigris and Euphrates rivers at Al-Qurna district, with 195 km length, flowing later to the Arabian Gulf for a 5 km loaded with quantities of sediments and silt ranging from Its depth varies between 8 and 15 m, [4]. The catchment area of the SAR is approximately 108,000 km^2 [12], connected with the following tributaries and water networks: The Swaib River, the Hammar and Al-Hawizeh marshes, Shafi Channel, The Garmat Ali Channel, The Karun River, Main Outfall Drain (MOD), Sweet Water Canal, and Shatt Al Basra Fig. 5.

The total discharge from other tributaries, except the Karun, ranges between 0 and 10 m3/s. The available information on the discharge of the Karun is limited and inconclusive. Most relevant is the Ahwaz station in Iran [3,8,9], SAR discharge has had severe fluctuation during the past 40 years, affected by the construction of dams on the Karun River and the diversion of its course to the Bahamiansher River within the Iranian borders Fig. 6 [12]. Same for the Karkheh River, which to dry the marshes, where 17% of the SAR water comes from the swamps. Currently, what remains from the Tigris is the only source of freshwater for the SAR, with discharge below 50 m3/s.

2. Problem statement

The extent of the tide in the Shatt al−Arab is affected by the amount of water discharge of that

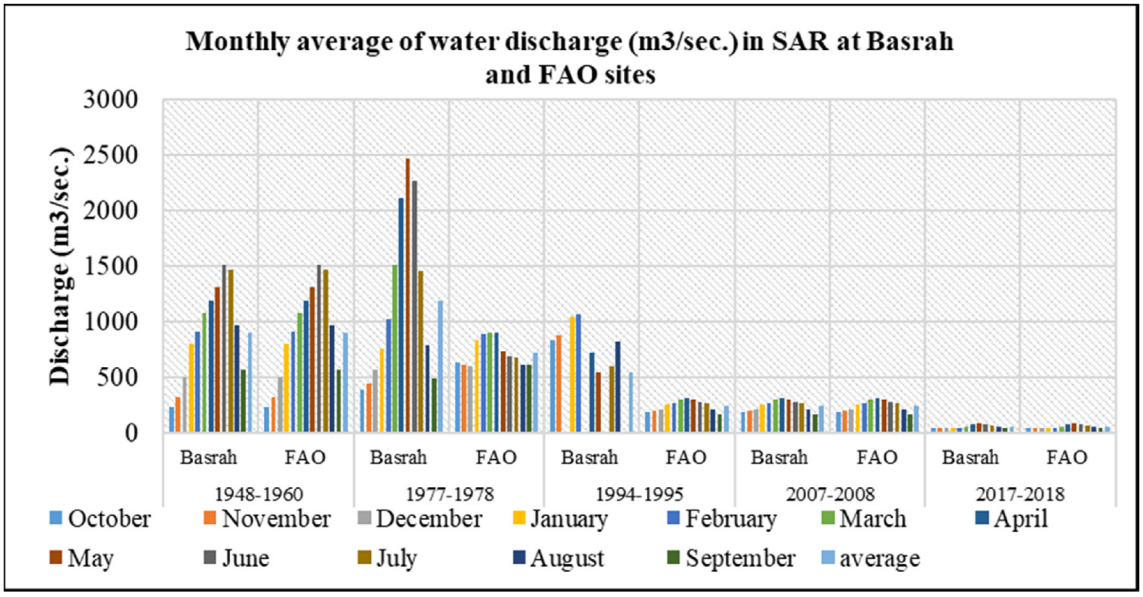

Fig. 7. Monthly average of water discharge in SAR at Basrah and FAO for the last forty years.

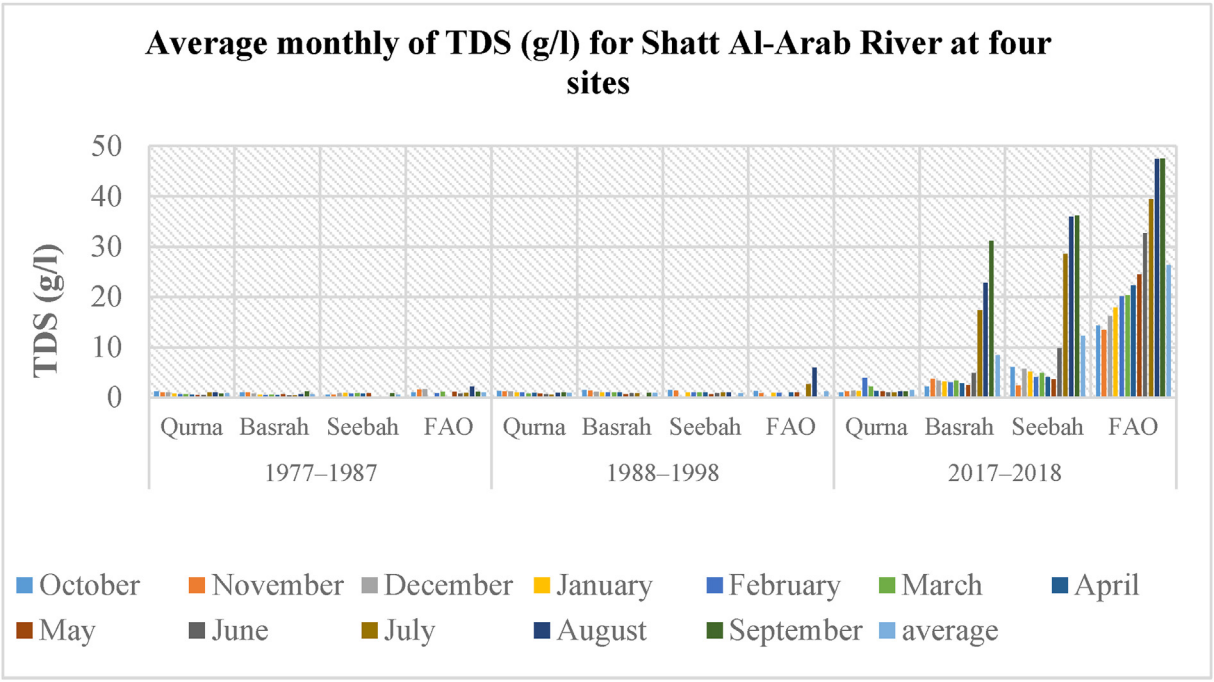

Fig. 8. Monthly average of TDS in SAR from Qurna to FAO for the last forty years.

river Fig. 6, as it decreases the extent of the tide during the period of high discharge, and this tide increases during the period of low discharge, 2 m while the tidal range in this period of low discharge ranges from 150 cm, as the brine-water tongue penetrates during a period of - high drainage 20 High tides that occur during the middle and late lunar month and have little progression During the low tide period, and its progress increases when the southeast wind blows intensify It recedes during the north and northwest winds [5]; 2009).

Salinity intrusion; is a phenomenon of salty seawater progressing upstream. It is a natural phenomenon subject to many factors, such as the river's flow, which is the key to controlling the incursion of seawater. The main reasons for the

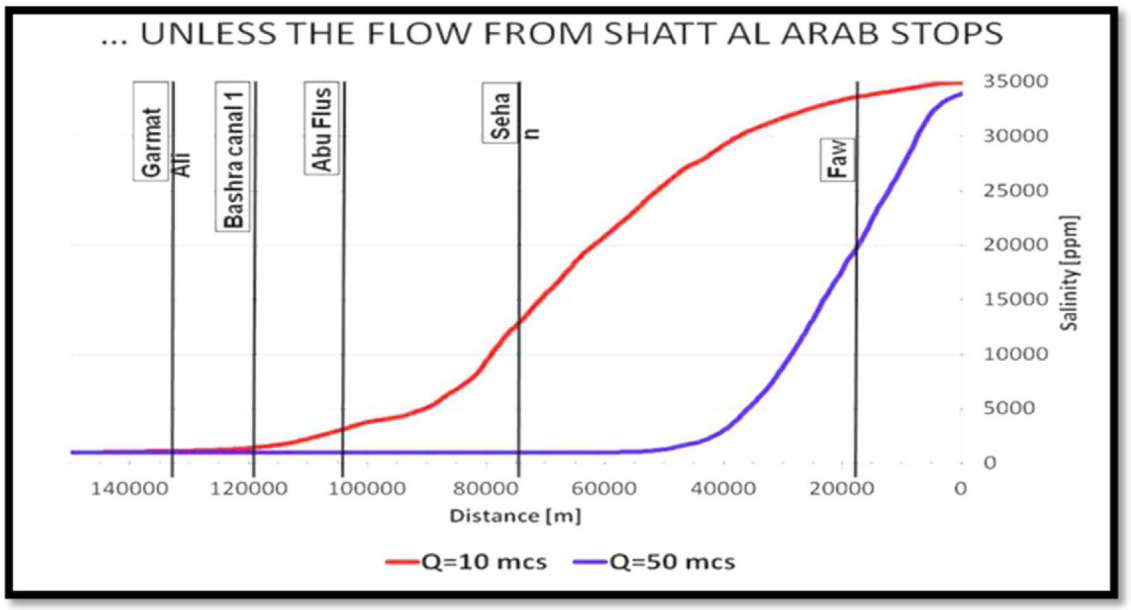

Fig. 9. The minimum environmental flow of SAR.

lack of flow of SAR is the reduction of the water flow from the upstream countries by controlling water resources through massive dams, global climate change, the tidal Rang, the difference in density between seawater and freshwater, and the topography of the river (Bathymetry and Topography) temperature, and sediment (sediment transport) [13]. Hence, SAR is facing severe significant seawater intrusion [1].

Basra province is now facing critical ecological problems, various water management challenges, and water scarcity in water quantity and quality. The alteration of river discharge also affects the estuarine ecosystem in terms of sediments, nutrients, dissolved oxygen, and bottom topography [14]. SAR water's quantitative and qualitative characteristics have deteriorated due to the lack of water supply, which led to a drop in the river level

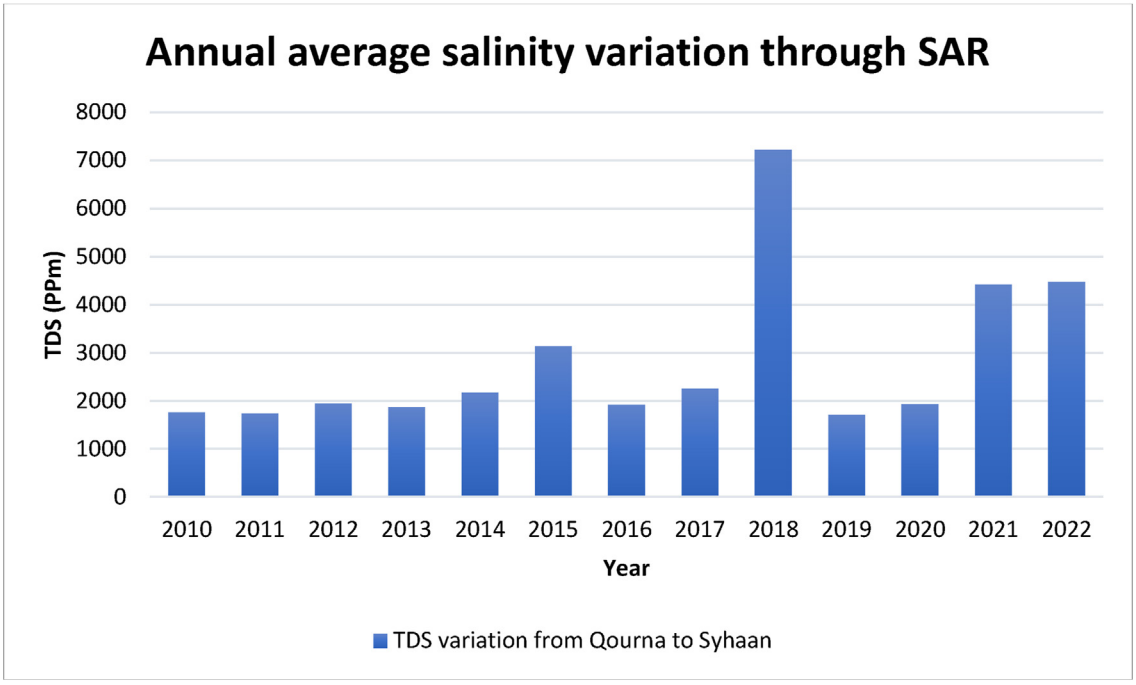

Fig. 10. Annual average salinity variation through SAR.

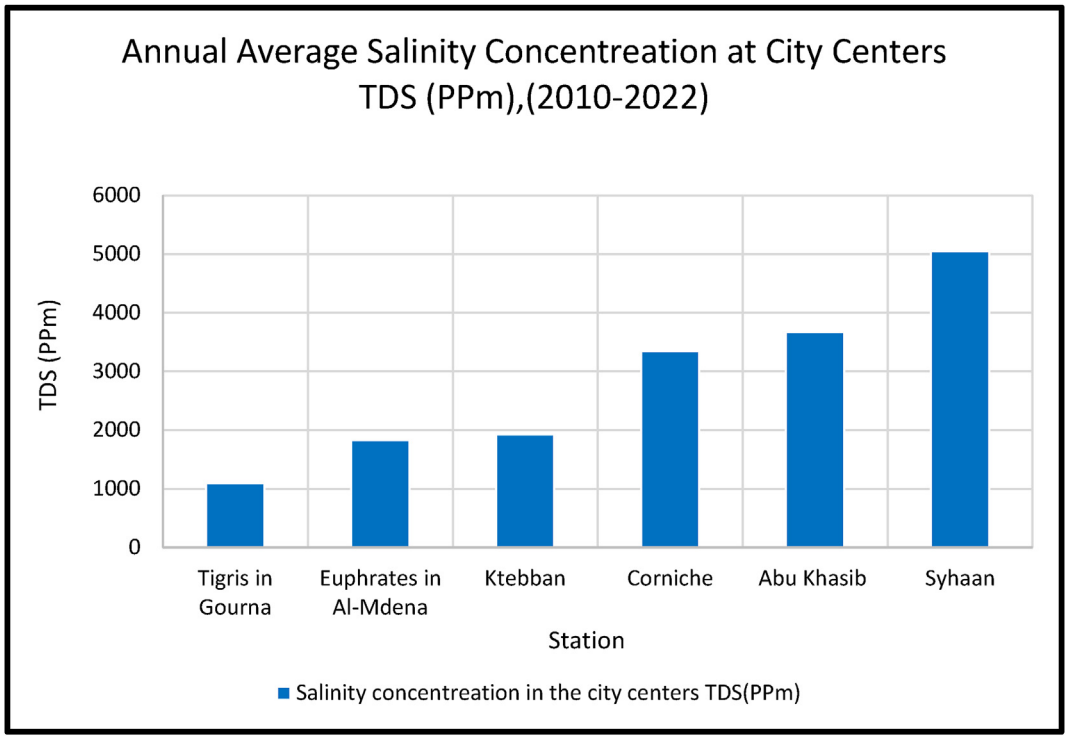

Fig. 11. Annual average salinity variation through SAR Station.

and increased seawater intrusion. SAR has experienced increasing salinization since the first irrigation projects were implemented in the 1950s [10] Fig. 7.

SAR poses a particular problem. The river's water discharge and quality are inevitably affected by any alteration in their catchments upstream. The seawater intrusion phenomenon in the SAR

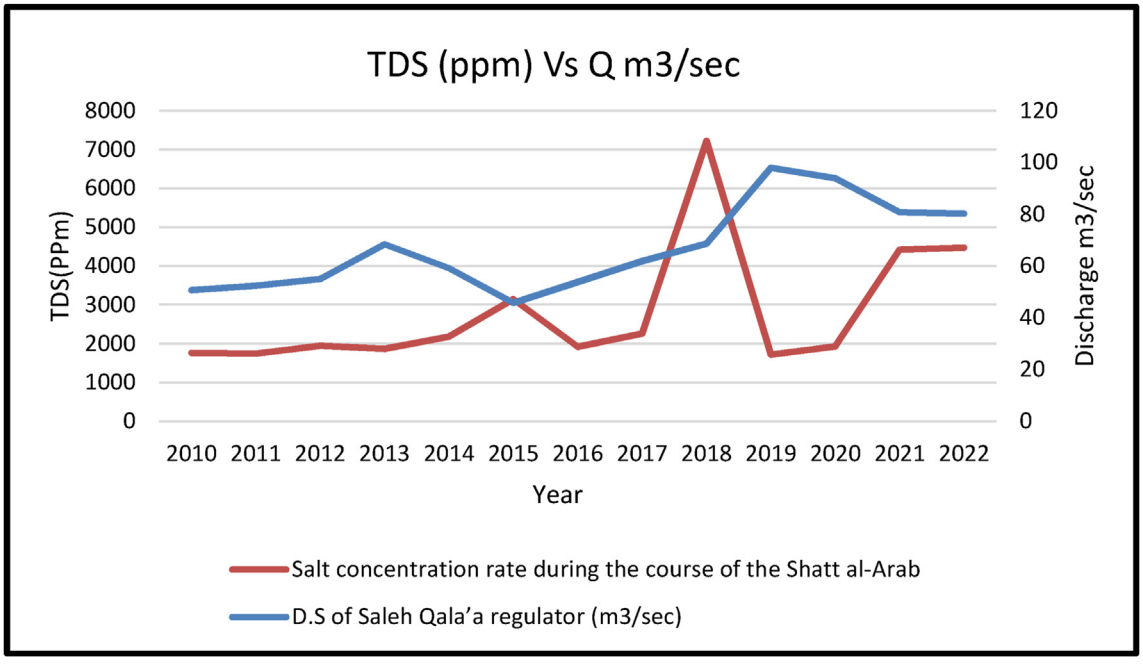

Fig. 12. The relationship between the expansion of the saline (ppm) tongue and inlet water.

might affect but is not limited to the following factors.

- Salinity increases in the surface water due to the outdated irrigation system used upstream. This is coupled with a significant water flow decrease in both Tigris and Euphrates rivers.
- Increase the seawater intrusion due to shortage in water flow that helps to rebalance the water pressure backward to SAR.

The Groundwater; salinity has been affected by the seawater intrusion and increasing dramatically [6]. All the groundwater samples were considered as unsuitable for drinking and irrigation uses. SAR, Na % and PI shows that all the groundwater samples are unsuitable, while MR and RSBC results indicated that most of samples were unsuitable whereas 29.7% of groundwater samples were considered as good irrigation purpose [7].

The industrial and municipal activities discharge directly into the River without further treatment; the increase of salinity due to the seawater intrusion, in addition to the irrigation wastewater is significantly growing and threatens the region (MOWR, 2013).

The Karun River originates from the Zagros Mountain and flows into more than 40 km, and its total annual revenue is about 27 billion m^3. Iran has built several dams to store the water. The discharge of the Karun River connecting to the SAR gradually decreased from the late seventies of the last century, which led to the increase in the salinity in the SAR in the further decades. It is noteworthy that the current supply does not exceed 10 m^3/sec and the salinity concentration is more than 5000 ppm.

Historically, SAR faced many events that affected its water supply that increase salinity accordingly, which we summarize in the following Figs. 7 and 8.

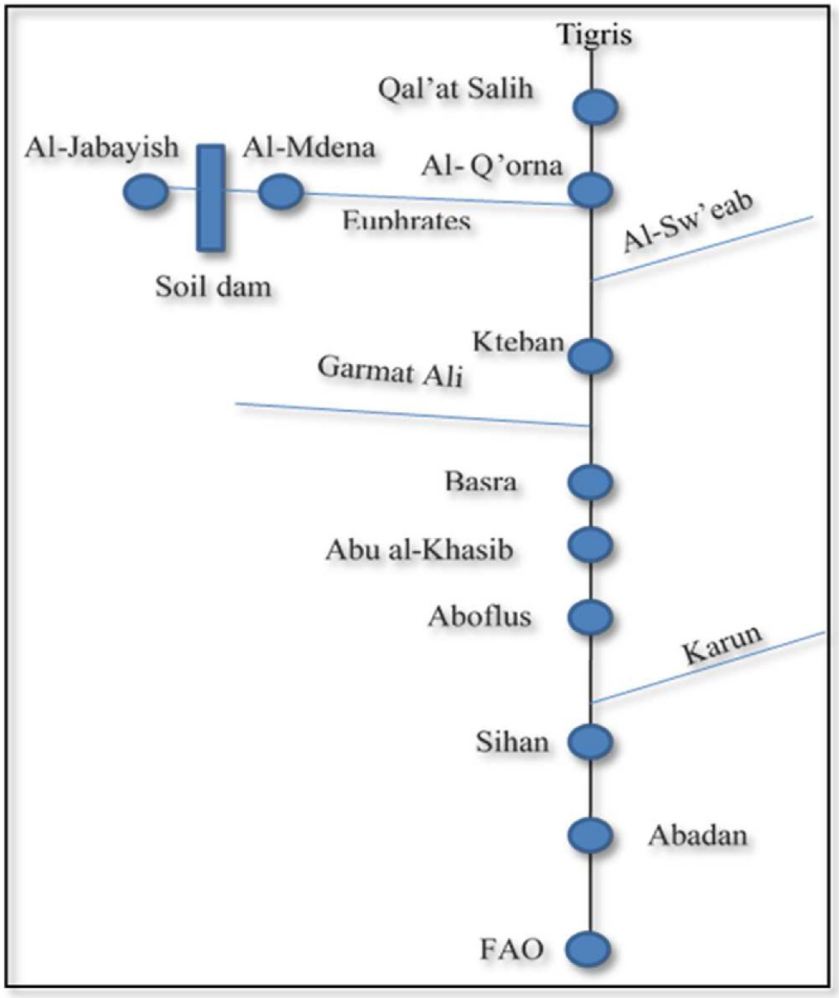

Fig. 13. The Soil Dam location according to SAR.

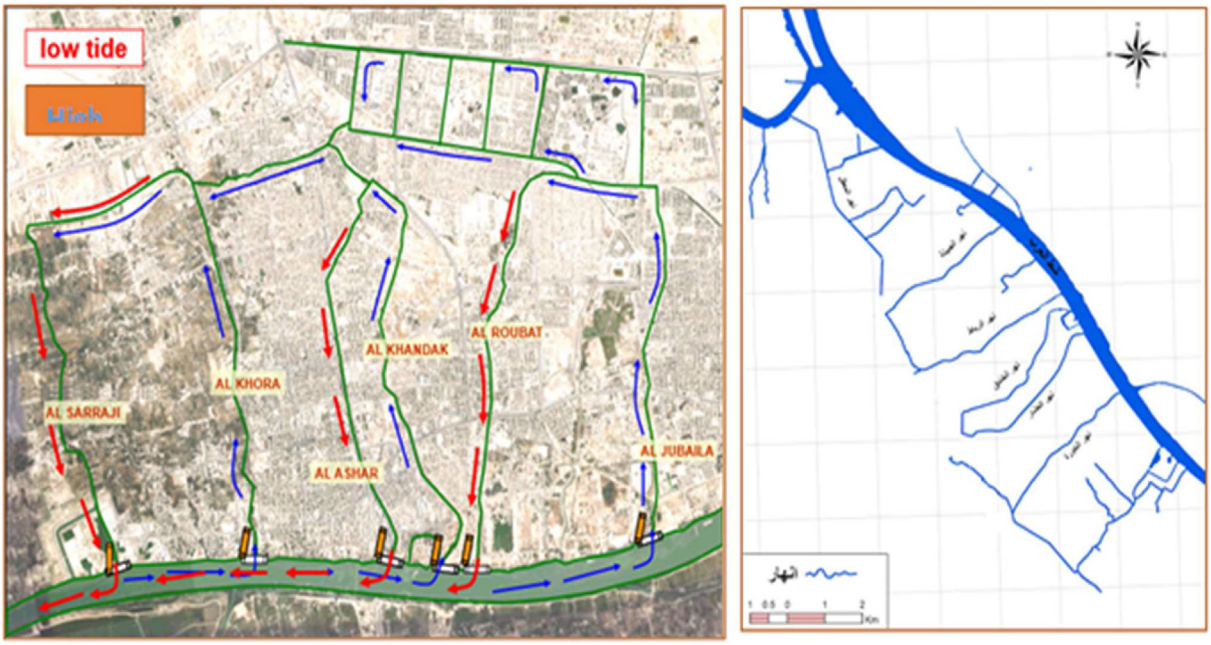

Fig. 14. The main Basrah six rivers.

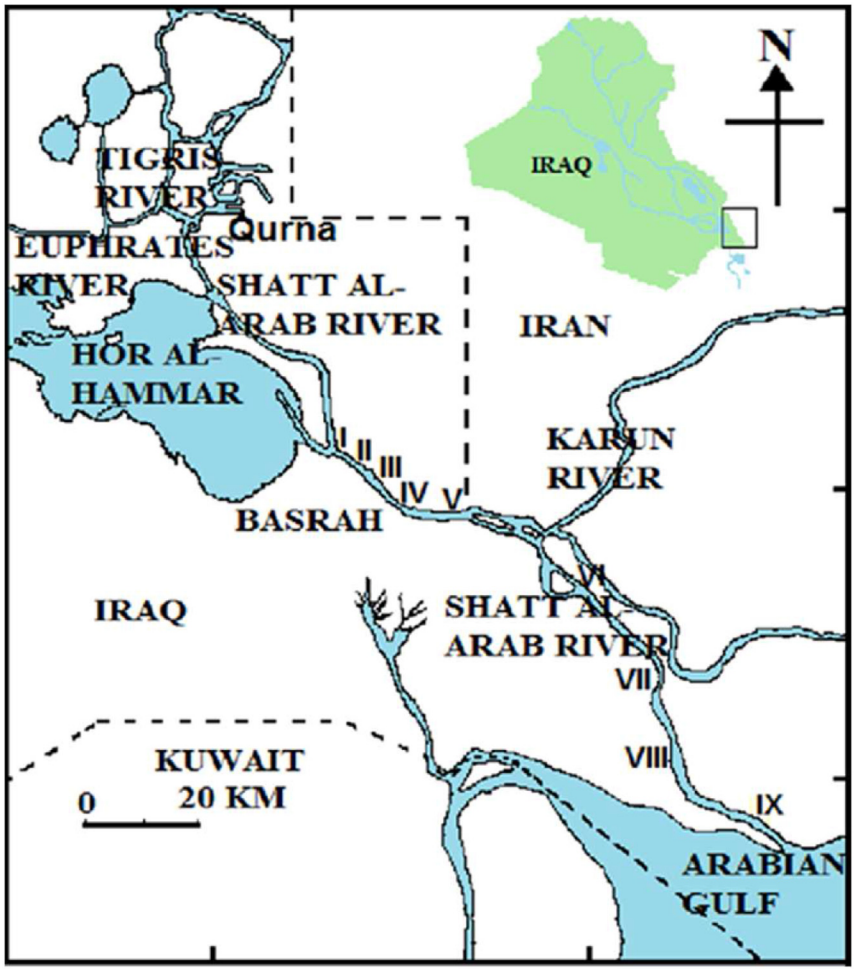

Fig. 15. Hor Al-Hammar

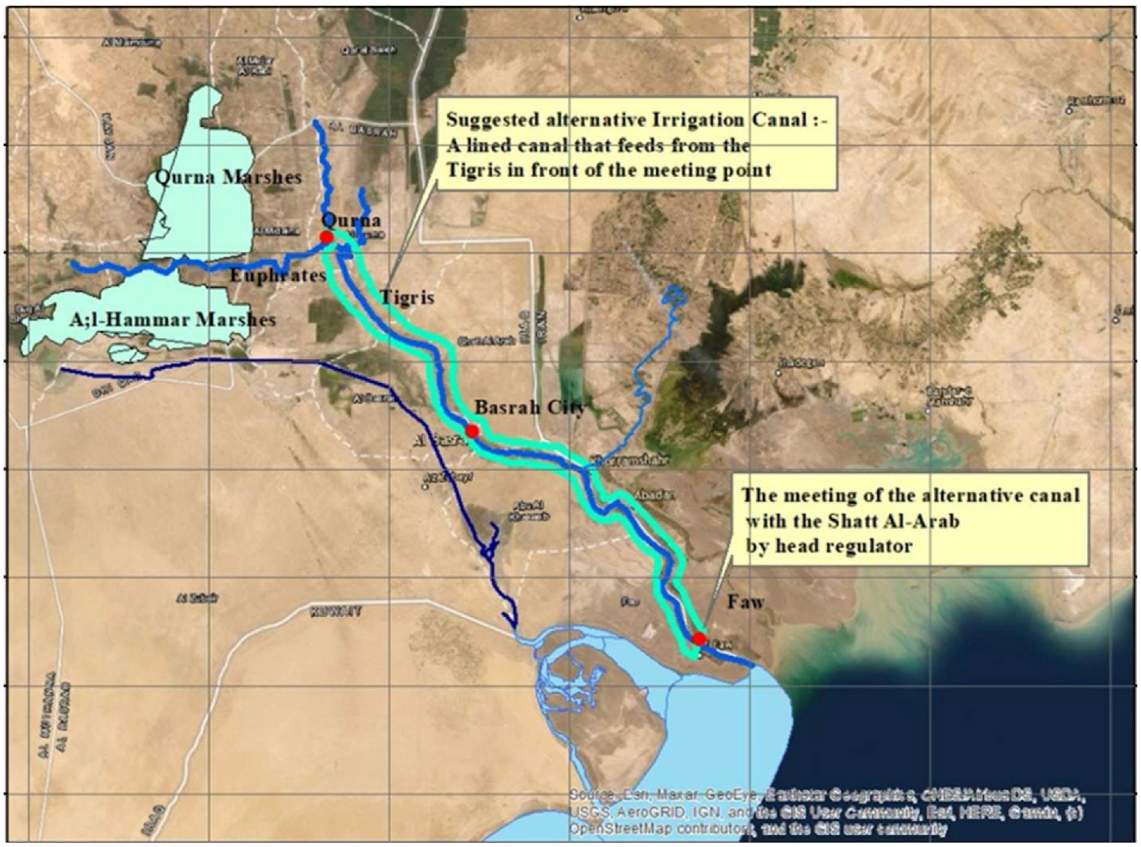

Fig. 16. Alternative irrigation canals.

The average annual freshwater discharge of the Shatt Al–Arab River at the Basrah site was 919 m^3/sec from 1977–to 1978. The water flow of the Karun River increases freshwater discharge in the FAO site to 1189 m^3/sec Fig. 7. The maximum freshwater discharge occurred in April at Basrah and in February at Fao. The rates were 900 and 1064 m^3/sec respectively. In 2010, SAR discharge was utterly dependent on the freshwater flow from the Tigris River only. Therefore, the mean annual discharge of the river dropped to 58 m^3/sec., with a monthly variation limited from 42 to 90 m^3/sec. During October and May, respectively.

- SAR salinity did not exceed (2000 ppm.) during the third and fourth decades of the last century Fig. 7.
- Salinity began to increase during the fifties of the last century, especially in the summer season, when the revenues of the Tigris and Euphrates rivers decreased to SAR.
- Decreasing the discharge of Al- the Karun River into the SAR since the late seventies of the last century led to an increase in the salt concentrations of the river.

The mid of 2009 was a dry year and the decrease in the flow of the Tigris River. The salt tongue expanded in SAR in October/2009. The salinity reach 8500 ppm in Basra city and 13,000 ppm. in Abu Al-Khasib and Seyhan (the discharge of the Tigris River in Qal'at Salih decreased to 9 m^3/s). A soil dam was established on the Euphrates River at the upper junction of the two rivers in 2011 to reduce the SAR figure's salt content Fig. 8.

3. Conclusion

The region is suffering from water scarcity and environmental degradation due to the shortage in water supply and the impact of climate change. The shortage in water flow in SAR has led to seawater intrusion. This seawater impact has been described in several kinds of literature where all highlighted the following conclusion:

The concentrations of total dissolved salts in the waters of the SAR in recent years exceeded the permissible limits for irrigation and drinking animals.

The decrease of the water flow is coupled with manmade activities such as public sector and

industrial residuals pollution by throwing the waste directly into the river without any treatment.

In line with the national strategic plan 2014, ensuring minimum environmental flow (more than 50 m^3/s) will prevent seawater from intruding into the SAR (salt tongue) Fig. 9.

Analysis of salinity through SAR stations shows that the water's salinity of the SAR varies. However, Fig. 10 recognizes a spatial variation along the shore stream.

By analyzing the data of salts and the quantities of water received from Gouma, for the last 13 years the following findings have been recognized:

a. Salinity increases in the city centers, represented by Qurna, Ktaiban, and Al-Asharb, Fig. 11
b. Salinity increases with the decline of water flow to SAR Fig. 12.
c. Salinity increased after Turkey started filling operations of the Ilõsu Dam in June 2018.

The time factor (days, months, years, and different seasons) did not show an apparent effect on the different levels of salinity concentration in the SAR because the hydraulic and hydrodynamic of SAR allowed the mixing of marine waters with the freshwater flow. In a nutshell, salinity increase is caused due to the water supply quantity.

4. Recommendations

The marshlands of Iraq are under global heritages since 2016 (16). There is a need to achieve a strategic water agreement with the upstream countries (Turkey and Iran). It is necessary to find alternative water sources for communities that historically relied on SAR and adopt modern farming methods. Including the use of water desalination techniques, improving the efficiency of water resources management, and developing the water sewage system to avoid pollution, in addition to the following recommendations to ensure community stability. An integrated plan must be adopted to reduce the impact of environmental changes on society, especially for the poorest and most dependent on the elements of the environment in obtaining their livelihoods.

An integrated water resource management plan of the SAR is essential for tackling the external and internal recommendations as follows.

Externally

Negotiating a strategic agreement is essential with riparian countries (Turkey, Syria, and Iran) to guarantee the water quantity and quality. Aligned with the awareness campaign. The intergovernmental hydrological Programmer (IHP/2022–2029) that developing several essential steps that contribute to water resources and dealing with them as a part of societies' systematic and continuous education. Bridging the gap of data and ensuring that data information and knowledge exchange across the region is reliable, and to be used by decision-makers. Furthermore, elaboration of strategies for managing water data between scientific organizations and UN agencies, Member States, and stakeholders is also needed.

Internally, the following technical solutions are recommended.

- Develop the current available Albadaa canal or the Sweetwater Canal (SWC) that carries fresh water from the upstream province Thi-Qar to Basra and replace the open system by close system using water pipelines to reduce the evaporation rates.
- Constructing a barrage across SAR (near Basra city) to prevent seawater intrusion. Yet this proposal has not reached an agreement by the concerned authorities, where a feasibility study is still required. Hence, it is highly recommended to (a) generate a mathematical model to predict the performance of such a project. (b) Strengthening the SAR embankment in both (height and width) so that the collected water does not flow towards the neighboring agricultural lands. (c) Establishing a regulator on the proposal barrage to control the quantity and quality of water within the river basin. Fig.13
- There are six streams in Basra province used now as open sewage and storm drain that directly flow into the river without water treatment. It is highly recommended to clean this system of waterways to work according to the natural systems of the tidal phenomenon and to ensure its self-purification, which must coincide with the prevention of the use of these rivers as sewage and other pollutants Fig. 14. However, an environmental assessment will be required to figure out the impact of such a proposal.
- Organizing the Hammar Marsh streams to divert water from the marsh to the SAR during the flood seasons to avoid the seawater intrusion figure (15).
- Establishing water desalination plants in southern Basra, with a sufficient capacity for all

freshwater uses, as the population growth rate, according to the Ministry of Planning for 2018, is 2.1%, which in turn will lead to an increase in freshwater demined.

- Enforce the groundwater resources' policies to avoid aquifer overuse and depletion. The enforcement should also be coupled with an incentive system that encourages farmers who use groundwater to reach optimal use. i.e., the local government might enable the cooperated farmers by supporting their access to finance and low-interest loans to buy modern machinery.
- Closing the sewage estuaries of the cities of Basra (Al-Maqal, Al-Jubaila, Rabat, Al-Khandaq, Al-Ashar, Al-Khora, Al-Siraji, Abu Al-Khasib, and Abu Flus) that flow into the Shatt Al–Arab and diverting its path by pumping towards the Shatt Al-Basra, as well as the sewage of the cities of Al-Haritha, Al-Deir and Al-Qurnah by pumping its water to the balance basins.
- Create a double lined canal on both sides of the SAR, is intake located in Tigris River upstream Al-Qurna.SAR remain for the tidal wave naturally and preserve the natural landscape of the city.and as intake for desalination plants to secure drinking water for the city Figure (16).
- Preparing a long-term awareness campaign is necessary at different levels to educate both people and decision-makers about the consequences of water shortage and raise slogans in cities, villages, and residential complexes that "excess is the cause of all drought" through the following suggestions process: Awareness of all citizens, regardless of their cultural and age levels, of the importance of saving water using various media (satellite stations, wall posters, indicative signs in public places, educational representations and displaying daily advertisements on how to rationalize consumption in the simplest and best way).

References

[1] Abdullah DA, Masih I, Van der Zaag P, Karim UFA, Popescu I, Al Suhail Q. Int J River Basin Manag 2015;13: 215–27.
[2] Al-Zubedi Ahmed Srdah. Groundwater in Iraq. 2022. ISBN-978-9922-9746-6-8.
[3] Orkhonselenge Alexander, Harbor Jonathan M. Impacts of modern glacier changes on surface water resources in western and northern Mongolia. J Water Resour Protect 2018;10.
[4] Khalil Al-Mahmoud, Hassan. Iraqi J Sci 2009;50(3).
[5] Directorate of Water Resources, Basra. Division of Information Systems, unpublished data. 2001. 2009.
[6] Hameed HA, Ali MH, Aljorany YS, Hassan WF, Al-Hello AAZN. Iraq. Ann. Limnol. - Int. J. Lim. 2013;49:199–206.
[7] Abdulameer Mariam H, Al-mallah Inass A. Evaluation of groundwater quality and the hydro geochemical processes of shallow Dibdibba aquifer in Basra Governorate, southern Iraq. Journal of Basrah Researches ((Sciences)) 2018;44(1).
[8] Afkhami Michelle E, Rudgers Jennifer A, Stachowicz John J. Multiple mutualist effects: conflict and synergy in multispecies mutualisms. Ecology 2014;95(4).
[9] Sadeghian Mohammad Sadegh, Salarijazi Meysam, Ahmadianfar Iman, Heydari Mohammad. Stage-discharge relationship in tidal rivers for tidal flood condition. Fresenius Environ Bull 2016;25(10/2016):4111–7.
[10] Zaman Mohammad, Shahid Shabbir A, Lee Heng. Irrigation water quality. Mitigation and adaptation using nuclear and related. 2018. https://doi.org/10.1007/978-3-319-96190-3. ISBN 978-3-319-96189-7 ISBN 978-3-319-96190-3 (eBook) ,Techniques pp. 113–131.
[11] Hussain Muhammad H. Shatt al-Arab, a study in geography Historical, (Journal of Basra studies eleventh year/issue (22). Republic of Iraq/Ministry of water resources/center of studies and engineering designs. 2016 [Technical Report, Volume II].
[12] Republic of Iraq/Ministry of Water Resources (MOWR). Center of studies and engineering designsviii. Technical Report; 2014.
[13] Al-Taie Samer Adnan, Abdullah Sadiq Salem, Lafta Ali Abdel Reda. Patterns of longitudinal transition of salinity in the Shatt al-Arab estuary and their causes. JKAU: Mar Sci 2014;25(2):205–21.
[14] Sklar FH, Browder JA. Environ Manag 1998;22:547–62.
[15] Al-Hassen Shukri I. Environmental pollution in Basra city, Iraq. A thesis submitted to Ph.D. Degree in geography requirements. University of Basra; 2011.
[16] UN Iraq. Water in Iraq fact sheet. 2013.
[17] Zakzok, Schmandt Jürgen, Alam Paying, Oueidat Haytham. The Middle East studies center at the. Ohio State University; 2016.