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Iraq's inland Water quality and their impact on the North-Western Arabian Gulf

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Abstract

This review examines the changes in water quality that have taken place in the main Iraqi rivers, the Tigris, Euphrates and the Shatt Al-Arab River over the past few decades; and in particular, the effects of a reduction in fresh water supply, the pollution of these waterways and the impact of these aspects on the north-western Arabian Gulf.

A change in the quantity and quality of water due to the effects of upstream damming has significantly reduced the water flow to Iraq. In addition, the water quality is continuing to deteriorate in the absence of adequate river basin management programs, the direct dumping of untreated domestic and municipal wastes, agricultural chemicals, and hazardous industrial substances into the waterways. Such conduct is exerting an immense impact with harmful effects on public health and the environment.

Major evidence so far of environmental stress is the increasing infringement of marine waters into the Shatt Al-Arab estuary and its tributaries, which is dramatically affecting agricultural activities and the livelihood of farmers residing in the area. This encroachment has introduced some marine species to what was a previously brackish water environment. Further evidence is the aesthetic presentation of the Shatt Al-Arab River and almost all its branches were rubbish including plastic bottles and bags, other solid wastes and sewerage directly disposed. Further studies of these issues are required to determine the short and long-term environmental impacts on both the marshes and the Arabian Gulf.

Introduction:

Iraq is almost totally dependent on the surface water crossing its borders from neighbouring countries. More than 90% of the Euphrates originates within the highlands of Turkey; it acquires very little water in Syria and none in Iraq. While almost 50% of the headwaters of the Tigris originate in Iraq and the rest are spread across Iran and Turkey. Both rivers follow a south eastern route across arid land of Syria and Iraq. The Euphrates and Tigris merge in southern Iraq to form the Shatt Al-Arab, which in turn flows into the Arabian Gulf (Fig. 1).

The climate in Iraq is considered of the continental, subtropical semi-arid type, while its mountain regions in the north and north-eastern having a Mediterranean climate. During July and August, daily temperatures usually rise above 38° C. while winter temperatures averaging about 7° to 13° C. during January; they rarely drop below freezing (UNESCO). Hamdan, *et al* (2009) cited some references about the climate of the Mesopotamian Plain represented by Basrah's Climatic data that show long-term (1920–1980) average annual temperature of 24.4°C, with the highest temperature (24 h average) at 34.5°C in July and the lowest at 12.2°C in January. The very hot and humid summers of southern Iraq, where temperatures can reach over 50° C in July and August, causes high evapotranspiration rates to reach up to three meters per annum, IMOS/UNEP (2005)

Rainfall is seasonal and occurs mainly between December and February, with the exception of the northern mountains, where it occurs from November to April. Annual rainfall ranges from less than 100 mm in the south to 1,200 mm in the northeast with an annual average of 154mm (Zaitchik, et. al, 2005). Rain in southern Iraq is considered rare and hardly has any impact due to the high evaporation that causes the loss of about 70% to 80% of the falling rain (Chapagain and Hoekstra, 2004). Precipitation of the Euphrates river basin has higher gradients of a north humid highland and arid plains in the south (Fig. 2). Rzóska (1980) measured the mean annual precipitation to be about 100 mm on the northern edge of the marshes and about 150 mm to the south, with most precipitation falling from November through April, and little in summer.

Iraq was the first riparian state to develop engineering projects in the Euphrates Tigris basin between 1911 and 1914 (Hindiya Barrage) to prevent flooding and transfer water to canals for year-round irrigation (Beaumont, 1999). In the 1950s Iraq built a second barrage for flood control and irrigation (Naff and Matson 1984). Both Syria and Turkey were slow to develop use of the waters of the two rivers before the 1960s.Turkey began constructing the Keban Dam on the Euphrates in 1966; production of electricity began in 1974. Since 1986 Turkey started to build a group of dams as part of the South-eastern (Grand) Anatolia Development Project (GAP) includes 22 dams and 19 hydroelectric power stations to be built on the Euphrates-Tigris (Fig. 1).

Up till now, each of the Euphrates Tigris watersheds riparian has developed its water use policy separately, with no regard to the needs of the other riparian, or the negative impacts their policies have on the environment, or the actual capacity of the basin. Water quantity is not the only concern facing Euphrates Tigris basin countries. The water quality is also increasingly being affected by withdrawals and irrigation return flows. A large portion of the water entering Iraq already consists of agricultural return flows containing both agricultural chemicals and high salinity (Rahi & Halihan 2009; UNEP, 2001, 2007). Attempts to establish joint management of the basin have not yet succeeded, mainly due to the constantly shifting political situation and in part because of the complexity of the hydrologic regime (Lorenz, 2006).

Water quality and quantities along the two rivers Euphrates and Tigris, and their tributaries in Iraq has been suffering due to internal and external factors. Internally these rivers, similar to the general environment of Iraq are suffering from a wide range of environmental problems, including environmental degradation stemming from ill-advised development , delayed development or functional decline of environmental infrastructure due to lack of funds, and reckless exploitation of natural resources. Adding to this, the decades of unsustainable damming, both within and outside Iraq and the impact of the climate change including the long periods and frequency of droughts that influence the whole watershed region have weakened both rivers. Also Iraq lacks clear water management and policies.

Without meaningful regional oversight, the absence of institutions for cooperation and multi-lateral agreements reflected in the lack of coordinated water resources and planning between Turkey, Syria, Iran and Iraq the issue of water allocation has continued to cause some friction between these governments since late1980s. There are no basin-wide management plans with respect to water use, water quality, and water discharge.

It is predicted that demands on water resources will increase in this millennium, as will the levels of pollutants for the region due to expected population growth rates experienced by all the watershed countries during the last century. By 2025, Iraq's population is projected to grow to 43.5 million, a 66% increase or more than twice the global average (UNEP, 2001). In order to achieve sustainable utilization of freshwater resources without compromising the economic viability of the coastal areas, new approaches to water and river basin management are required (UNDP, 2007).

Water quality, Environmental Issues and Management of the Euphrates and Tigris rivers

Historical records indicate that salinity and high water table have been a problem for the Euphrates Tigris rivers plain as early as 2400 BC (Ayers & Westcot, 1994). The Euphrates and Tigris rivers, which run the length of Iraq, sustain life in the region. However, Iraq does not exercise sole control over these precious waters.

The Euphrates and Tigris used to have two primary flooding periods. The first, from November to March, is mostly due to rainfall. The second, occurring during April and May, results from snowmelt and generates 50% of the annual runoff (Cullen and deMenocal, 2000). According to Aqrawi (2001), the highest river discharge is restricted to the spring season, particularly April.

About 52% of the Tigris (whose total length is around 1,900 kilometres), annual flow originates in the south eastern part of Turkey, while 48% comes from north eastern Iraq where most of its course lies. The Tigris headwaters in Turkey are located in the remote border region with no large-scale development activities. As a result, Iraq has benefited from the use of most of the Tigris water until recently (Kobayashi 2004). The long-term average annual volume of the Tigris River water passing the Turkish/Iraqi border is about 19.35 Billion

Cubic Meters (BCM). While the long-term average annual volume of the Tigris in Iraq, reaches up to 43.95 BCM.

The balance of the Tigris flow is produced by a series of major left bank tributaries descending from the Zagros Mountains of Iran and Iraq. Prior to dam construction, estimates of the mean annual runoff of the Tigris at Baghdad ranged from 49.2 - 52.6 BCM (billion cubic meters), which is considerably greater than that of the Euphrates at Hit ranging between 28.4 – 32.4 BCM (Partow, 2001). However, in recent years Turkey has started a large project (GAP Project) in order to develop hydropower and irrigation for agriculture. Syria also has access to a 20 km stretch on the right bank of the Tigris, which forms its extreme northeast border with Turkey, just recently started to plan an irrigation scheme. Baghdad normally has water with salinity of 500-600 ppm for the Tigris, which increases to around 800 ppm as it reaches the city of Kut 170 kilometres to the south of Baghdad. The Tigris suffers from many of the same problems as the Euphrates, though there is less upstream development.

The long-term average annual volume of Euphrates River water passing the Syrian/Iraqi border is about 23.19 BCM (97% from Turkey). 89% of its annual flow of 35 BMC comes from eastern Turkey and (11% from northern Syria). The river flows through the plain of Syria and goes into Iraqi desert before reaching the sea (Kobayashi, 2004), and a significant portion of the waters of the river actually evaporate due to the extreme desert heat (Beaumont, 1999).

Erdem, (2003) confirmed that in addition to the water allocation issues among the Euphrates Tigris watershed riparian, concerns about water quality arose more recently. The return flow from irrigation in Turkey and Syria causes water pollution, which in turn affects Iraq. Natural causes including high rate of evaporation and sharp climatic variations are common to both rivers worsen the deleterious effects of human pollution that causes the accumulation of salts and sediments, poor drainage and soil quality in the lower reaches of the Tigris and Euphrates rivers. The water quality of the Euphrates flowing through Syria is highly polluted with agricultural pesticide runoff, chemical pollutants, and high salt content. Syria often has to restrict drinking water and hydro generation for the major cities of Damascus and Aleppo (Klaas, 2003).

The water salinity of the Euphrates River as it enters Iraq, has more than doubled compared to that of 1973. The annual average total dissolved solids (TDS) at Al Nassiriah, in the lower reaches of the Euphrates, has increased from 1.08 part per thousand (ppt) in 1979 to more than 4.50 ppt in 2001. The deterioration of the Euphrates water quality in Iraq is likely to be due to the decreased flow entering Iraq, diverted flows to the river from Al Tharthar Lake, and irrigation-return flow (Rahi and Halihan, 2009).

Dieleman (1963) noted about the salinaization of soil in Iraq that, “with inadequate drainage and the resulting high water tables that developed, there was no way to control and permanently leach any significant portion of the salts being applied in the irrigation water. Salts slowly accumulated and productivity declined”.

Odemis, et.al (2010) reported on long term data collected (1971 to 2002) from 14 stations over the Euphrates River and seven stations over the Tigris River in Turkey that water quality for agricultural irrigation is not posing salinity hazard for crop productivity and soil fertility. However, with the start of irrigation in the GAP region, these semiarid watersheds may suffer from soil salinity and alkalinity, with excessive use of irrigation and high evapotranspiration rate.

Ayers and Westcot (1994) shows the water quality for the Euphrates and Tigris in the seventies of the last century (Table 1). Calculating salinity from the electric conductivity indicates that it ranges between (3.00 – 9.00 ppt).

Rahi and Halihan, (2009) also quoted from other researchers to show that over the length of the Euphrates and over time, salinity has increased from approximately 500 ppm to over 4500 ppm.

In the seventies of the last century the Euphrates TDS ranged between 261ppm at its entrance to Iraq to (420-710ppm0 at about 385Km from Syrian boarders at Al-Faluja station (Fig. 3). Rahi & Halihan (2009) also plotted the TDS profile along the Euphrates River from Al-Qaim (Syrian border) to Al-Nassiriah for the water year 2000–2001 (Fig. 4). The profile shows salinity of about 1,000 ppm in Al-Qaim, 1,100 ppm in Al- Hindia, 2,000 ppm in Al-Samawa, and about 4,000 ppm in Al-Nassiriah.

The river's total salt content has increased gradually over the last 3 decades (Partow, 2001). The first noticeable increase in salinity was recorded at the Hit station in 1975 when the filling of the upstream reservoirs (Tabqa and Keban) began. By 1989, the Euphrates' salinity at Al-Qaim reached 1,000 ppm. Further downstream, at Al-Hindia (532 km from the Syrian border), the TDS has increased to about 1,100 ppm as measured in 2002. At Al-Nassiriah, where the problem is the most acute, available records show that the TDS range from 1,300 to 4,500 ppm for the years of 1979 to 2001 (Fig. 4). Rahi and Halihan (2009) also referred to salinity values greater than 2,000 ppm at Al-Samawa and exceeded 3,500 ppm at Al-Nassiriah for period (1998–2002). This means that the Euphrates water has become unsafe for either domestic or irrigation purposes starting from Al-Samawa to its confluence with the Tigris at Al-Qurna. Al-Nassiriah since mid 1970s relied on Al-Gharraf River that branch from the Tigris River upstream from Al-Kut and flows into Al-Nassiriah Governorate.

The Euphrates and Tigris rivers also pick up a wide range of chemicals, including pesticides, herbicides and petroleum products, which are associated with agricultural practices as well as sewage (mostly untreated waste), disposed of directly into the water course. This alarming situation worsened after the complete collapse of the sewage system after the overthrow of the previous regime in 2003. Raw sewage began entering the Euphrates, Tigris and Shatt Al-Arab Rivers, unchecked and on continuing basis. The Euphrates is, literally, used as a drain carrying the irrigation return from several agricultural areas within Iraq. The quality of the receiving waters can be severely affected by these return waters (Klaas, 2003).

Iraq always worries about the continuity of the flow within both rivers (Euphrates and Tigris) throughout the Iraqi territories. The effect of the reduced flow will probably be greatest in the lower part of the basin in the marshes, the Shatt Al-Arab and the Northern Arabian Gulf, where the whole ecology of the marshes has evolved in response to the flow of these rivers. With the reduction of the peak flooding, together with the much lower overall flows, the impact on the natural environment will be considerable and also it reduces the flushing ability of these rivers to dispose of pollutant.

Iraq needs more water than what it gets now due to the increase in population (the average rate of increase in population in Iraq is about 3.0 % (Ali, 2004), reconstruction, and rebuilding of its industry and agriculture. The on-going decline in the quantity and quality of surface water, due to many local and regional causes, puts real constraints on the population growth rate, expansion in the industrial activities and in the agricultural practices, as well as in the domestic use of potable water. In recent years, the situation has reached critical point where people in most of the Basrah governorate depended on bottled/desalinised waters even for their animals stock let alone the domestic usage. Many farmers have deserted their lands due to the lack of fresh water especially in the Faw peninsula and on the banks of the Shatt Al-Arab estuary.

The Marshes:

The land between the Euphrates and Tigris (Mesopotamia) is the most fertile region that

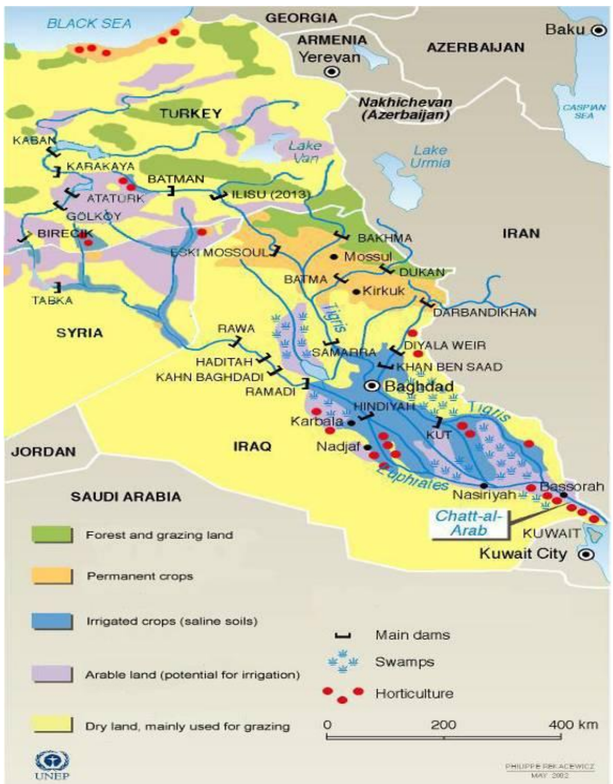

Fig1: Land use and the main dams in the Euphrates Tigris watershed. Source RCET

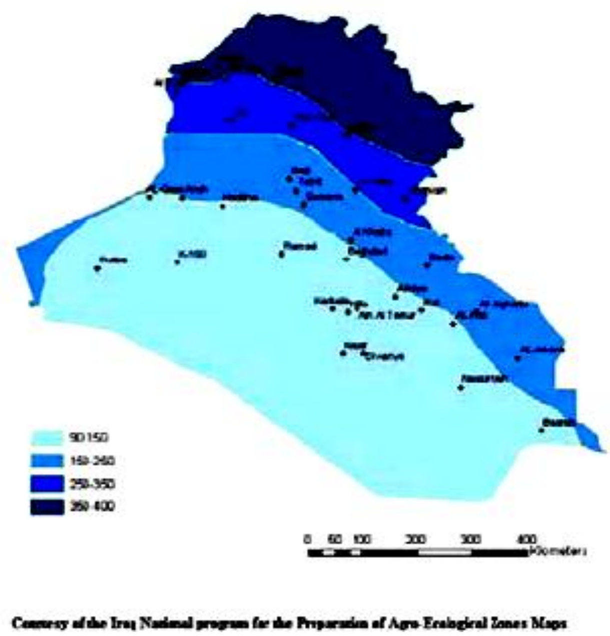

Fig 2: Annual rainfall (mm) in Iraq 2009, State Board of Agricultural Research, Ministry of Agriculture - Baghdad,

Table 1: Water analyses of irrigation supplies from the Euphrates and Tigris in Iraq (extracted from: Ayers and Westcot, (1994).

Sample Site	EC dS^w/m	pH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	$SO4^{2-}$	$HCO3^-$	Ca/Mg	Reference
				me/l							
Diyala River at The Diyala Weir	0.47~3ppt	8.0	3.3	1.5	0.7	0	0.5	1.9	2.8	2.2	MacDonald & Partners 1971
Euphrates River at Al Kaim	0.73~4ppt		2.8	2.3	2.0		1.8	2.8	3.1	1.2	Hanna & Al-Talbani 1970
Euphrates River at Samara	1.44~9ppt		3.3	3.5	4.3		4.9	3.0	4.2	0.9	Hanna & Al-Talbani 1970
Tigris River at Mosul	0.46~3ppt		2.7	1.8	0.5		0.7	1.4	3.2	1.5	Hanna & Al-Talbani 1970
Tigris River at Qurne	1.14~7ppt		3.8	3.2	2.9		3.0	3.1	3.7	1.2	Hanna & Al-Talbani 1970

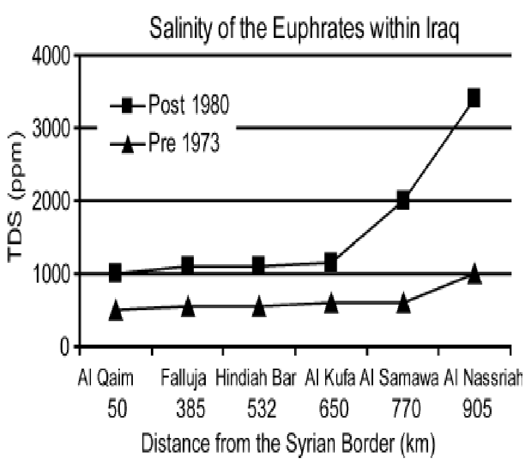

Fig 3: Salinity along the Euphrates river prior to 1973 and after 1980 (Rahi & Halihan 2009)

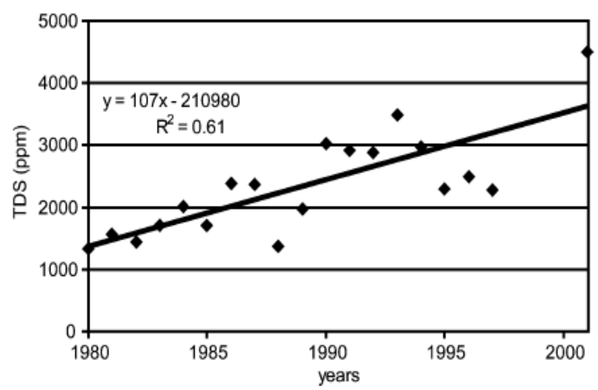

Fig 4: Euphrates TDS content at Al-Nassiriah, Southern Iraq (Rahi & Halihan 2009)

Comprises about 25% of Iraq's surface area. The whole area is very flat; the land expands among Basrah, Amara and Nasiriya used to completely submerge as one expanse of marshland during flood seasons. The wetlands once covered between 15,000 and 20,000 km^2 but covered less than 760 km^2 by 2000 (Fig. 5). There was an additional 30% decline from 2000-2002 (Richardson et al., 2005). Until recently, the average depth of water in the main marshes during the flood season was about 1.0-1.5 m and the maximum about 2.0-3.5 m, although a depth of approximately 6 m has been recorded in Haur Al-Hawizeh on the Iraqi Iranian boarders. Most of the lakes and marshes are fresh water, but Haur Al-Hammar, which is fed by the Euphrates, has higher salinity (Partow 2001). Water levels reach their maximum in early spring and then fall by as much as two meters during the hot dry summer. In recent years however seasonal flooding has rarely occurred because of reduced amount of water coming from upstream particularly on the Euphrates in Turkey and Syria (Partow, 2001).

The marshes used to be home to many species of birds and served as an important resting ground on the intercontinental flyway for migratory birds. In addition many fish fauna rely on the marshes as spawning grounds (Partow, 2001). These wetlands eventually drain southeast wards into the Gulf via the Shatt Al- Arab Estuary. Since 1970, the wetlands have been dramatically changed.

The most serious threat to wetlands in Iraq has been the drainage and diversion of water supplies for agricultural, the oil exploration and production purposes and in the early eighties of the last century, for military purpose. Dam-building on the Euphrates in Turkey and Syria and the increasing utilization of the waters of the Tigris and Euphrates for irrigation in upper and middle Iraq have greatly reduced the extent of seasonal flooding in the marshes.

Since 2001, there has been an international effort to restore the Mesopotamian Marshlands. Uncontrolled releases of Tigris and Euphrates River waters after the 2003 war have partially restored some former marsh areas, but restoration is failing in others because of high soil and water salinities. Nearly 20% of the original 15,000 square kilometre marsh area was re-flooded by March 2004 (Richardson, et al. 2005) and the marshland's area increasing from 760 km^2 in 2002 to 3980 km^2 in 2005. By December 2006, it was estimated that water once again covered 58% of the pre-drained wetland (IMOS/ UNEP, 2007). However; research conducted by the Marine Science Centre of Basrah University in recent years indicates that only small re-flooded area of Al-Hawizeh marsh on the Iraqi Iranian boarders has sustained its environment (MSC, 2005). Even though some of the marshes were re-flooded, the environmental conditions that developed were different from prior to drainage. Upstream dams now control the volume and timing of water coming into the marsh, and the total volume of incoming water has diminished and the spring flood pulse has almost disappeared.

Although the major destruction of the marshes could be related to the action of the previous regime in Iraq, the reduced flow due to damming in neighbouring countries presents the largest and more permanent threat that cannot be easily reversed (Jones et al., 2008). The attenuation of the flooding peaks that happens in the upper parts of the Euphrates Tigris watershed, together with the much lower overall flows, which the marshes is receiving will considerably impact on the natural environment of the marshes and have direct and indirect impacts on the biodiversity.

The future survival of the marshes must, therefore, be put in question as a result of the changes which have occurred, or are likely to occur, in the upper parts of the basin in Turkey, Syria and Iraq. Reduced sediment loads that used to be carried by the rivers will also have untold impacts on the natural development of the marshland and the coastal delta. A rehabilitation programme would therefore need to consider the significance of sediment retention by engineering structures and propose necessary remedial measures (Al-Mansurey, personal communication, Marine Science Centre).

Salinity in the Tigris and Euphrates Rivers near their discharge point at the marshes ranges from 0.5 to 2.00 ppt. The marshes are generally more saline than the rivers due to further evaporation and the input of agricultural runoff. Winter and spring floods used to lower the salinity of the lakes while high evaporation raises salinity during the summer season. The Central Marshes are typically fresh water, ranging from 1 up to 2 ppt. Al-Hammar Lake has higher salinity, ranging up to 10 to 15 ppt in some section, with salinity increasing to the south and east. South of Al-Hammar marsh is saline lakes and sabkhas with salinities up to 60 ppt (AMAR 2003).

During the 1980s, increasing salinity emerged as another serious threat to the marshes, particularly in the southeast portion of Haur Al-Hammar. One of the contributing factors is likely to be the linkage of the southern part of Haur Al-Hammar (at Qarmat Ali) to a new canal, the "Al Basrah Canal", which runs parallel to the western banks of the Shatt Al-Arab into the Gulf. This canal was constructed during the Iran/Iraq War to provide a safe shipping lane between Basrah and the Gulf. Another reason for the increase in salinity is the continuous flushing of salts from irrigated land via drainage canals into the wetlands. Much of the wastewater is discharged into the mouth of the Al Basrah Canal and thus enters Haur Al-Hammar (Al-haydarey, 2009). Salts that accumulated on the sediment surface during the decades of drying probably leached into the re-flooded water and increased concentrations of chloride and sodium; high evaporation rates and water stagnation also contributed further to high saline conditions especially in the Al-Hammar marsh area (Richardson et al. 2005).

Hamdan et al., (2009) attributed the delay in vegetation recovery post flooding in the Central marsh to the high salinity and bicarbonates in the surface water, and to reduced seasonal fluctuation in the quantity of water input and output.

In 2008-09, rainfall and runoff were 40% below average for Iraq, and the size of the Marshes was reduced almost to 2003 levels, future droughts is expected to be more frequent, longer, and more extreme. During the drought of 2009, water in the marshes became more saline, as salts remained on the soil surface or moved from below due to capillary action. In addition, there was an increase in the levels of chloride, magnesium, and calcium; the water became more acidic; the amount of dissolved oxygen in the water decreased; and plant diversity also decreased. Some of these changes have led to increased levels of illness in people and animals as well as negative impacts on economic activities like fishing (CIMI, 2010).

Studies and reports produced by organizations like the UNEP, UNDP, FAO, USAID, and Canada Iraq Marsh Initiative (CIMI) and others, shows that the marshes are still struggling to survive. Although the re-flooding of the Marshes after 2003 provided some optimism that at least a partial restoration was possible, the severe drought of 2009 and an increase in infrastructure projects along the Euphrates and Tigris (and their tributaries) the size of the Marshes approached the lowest levels of pre-2003. Adding up to that, the local and central government do not look like they are committed to benefit from the studies and recommendations proposed by the above mentioned initiatives and they are very slow in taking actions to restore the marshes.

Over the past few years, Iran has dammed up many of the small rivers that provided water to the Hawizeh Marsh on the Iraqi Iranian boarders (Fig 5). In a normal year, flow from Iran contributes roughly 25% of the water to Hawizeh marsh, however Iran construction of a six metre high dyke along the border with Iraq, effectively divided the Hawizeh Marsh into two. The dyke was completed in the spring of 2009, (Fig. 6) shows the dyke along the border.

As a result, the Marshes have become very fragmented. Ecological fragmentation has a negative impact on the survival of many species, on the health of the Marshes and on the people whose livelihoods depend on the environmental services provided by the Marshes. Even the Hawizeh Marsh, now a designated site under the Convention on Wetlands of International Importance (the Ramsar Convention), is being affected and this will worsen in response to the impact of the Iranian dyke along the border.

As the marshes acted as buffers for sediment and nutrient transport downstream, the draining of the marshes, expected to significantly increase the sedimentation and input of agricultural, industrial, and urban pollutants into the Gulf and change its hydrodynamic regime over the long-term with unknown ecological consequences. Although some scientists argue that less sedimentation is already happening due to the many dams on the headwaters, which is reducing the sediment discharge to the downstream, these conflicting opinions need to be taken into consideration and further studied need to be carried out to reach conclusions about the impact Shatt Al-Arab and ultimately the Arabian Gulf.

Shatt Al-Arab River

The Shatt Al-Arab River is considered as a major fresh water discharge into Arabian Gulf (Fig. 7), the 192 km long waterway which extends south-easterly from the joint point of Tigris and Euphrates north of Basrah to discharge its waters to the Arabian Gulf near Al-Faw city, about 116 km south of Basrah. Its depth varies from 8-15 m, and the width range between 0.5-2.0 km. The difference between high tide and low tide is about 1.5m in summer and drops to 0.25 m in flood season (March to May).

The Shatt Al-Arab River is the largest, and regionally the only important estuarine system entering the northern Gulf (Sheppard, et.al. 2010), with average outflow of 1200 m^3/sec. The annual discharge of Shatt Al-Arab River varies seasonally depending on the contribution of its tributary rivers (Fig. 6) CIMI, 2010. The freshwater noticeably dilutes the high salinity of the water in the northwestern Gulf, and the estuary is a strong connection between the marshes and northern Gulf from the point of view of species and nutrients (Al-Yamani et al., 2008).

The Shatt Al-Arab River delta is formed from the sediments of three rivers, the Euphrates the Tigris, and the Karun River which rises in west-central Iran and, like the Tigris, drains the Zagros Mountains of western Iran. The Karun is probably the primary contributor to the present delta. The drainage basin of these three rivers is about 792,000 km in area (Samajlov, 1956). Although much of the delta made up of broad marshes and associated lowlands that are valuable as agricultural lands, most coastal regions are tidal flats and sabkhas lacking of extensive vegetation where salts are deposited.

The amounts and quality of water and sediment delivered to the delta by the Shatt Al-Arab are largely dependent on conditions in the marsh both at and above the confluence of the Tigris and Euphrates Rivers. Mudflats and sandbars dissected by tidal channels dominate the delta front. Where seawater is trapped during storm tides, saltpans develop (Short & Blair, Jr.1986). The interaction between Shatt Al-Arab River and the Arabian Gulf form the Estuary water body called Shatt Al-Arab Estuary, which is considered as a part of Iraqi marine waters. The Shatt Al-Arab Estuary, which is approximately 40km long, flowing along the Iraqi coast down to the Kuwaiti coastal waters. This distance is decreasing due to a reduction in river discharge, which allowed a salt-water wedge to penetrate into the Shatt Al-Arab River (Partow, 2001).

The Shatt Al Arab River and the coastal Iraqi waters are characterised by tidal phenomena. The type of the tide is mixed semi-diurnal and the tidal range averages 3.0m near its mouth to 0.5m at Basrah (Rzoska, 1980). Due to the fresh-water discharge of the Karun River into the Shatt

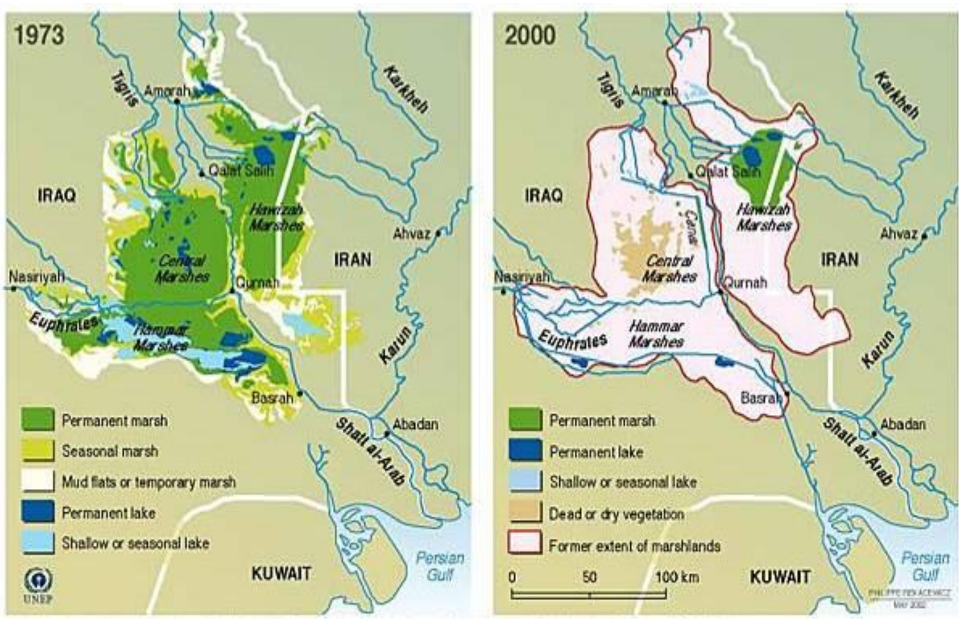

Fig 5: Map of the Marshes of southern Iraq 1973 compared to 2000 (from the United Nations Environmental Programme, Vital Water Graphics at (UNEP, 2001) http://www.unep.org/vitalwater/26.htm.

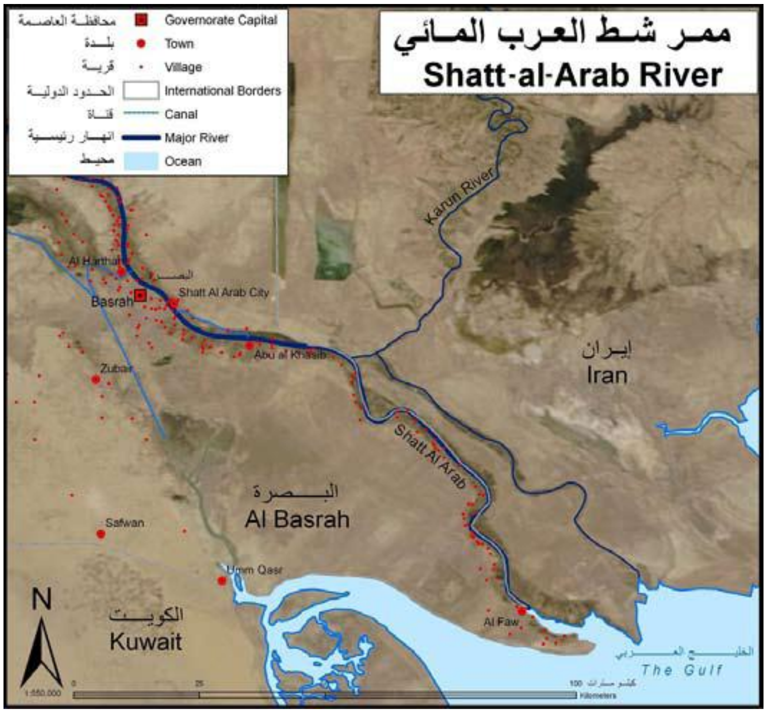

Fig 6: The Shatt Al-Arab River discharge into the Arabian Gulf. CIMI, 2010

Al-Arab, the saltwater does not penetrate further than Abadan (about 50 km inland, halfway to Basrah). However, the river water rises and falls as far north as Qurnah due to the dynamic tide influence (Sanlaville, 2003). This fluctuation of water levels is utilized to irrigate date palm and other farms that line the banks of the Shatt al-Arab River near Basrah. Saad & Antoine (1978) attributed the exceedingly high average values of salinity found at the lower reaches of Shatt Al-Arab River in January, August and October to the effect of the Gulf water, also reported that the water of Shatt Al-Arab River may be traced as far as about 5.0 km into the Arabian Gulf, and (Brewer et al., 1978) indicated that the discharge of this river reaches the waters off Kuwait bay during the flood season.

Much of the suspension load of the Tigris and Euphrates rivers is normally deposited in the marshes and the delta of Shatt Al-Arab River prior to the discharge into the Gulf. The minimum sediment accumulation in the lower part f the Shatt Al-Arab River is estimated to be 0.1 cm/year and around 1.0 cm/year in the marsh areas. It has been estimated that the net annual sediment discharge entering the Gulf amounted to 0.93 million tonnes (Al-Ghadban, et al 1999).

The Euphrates River historically carried an average silt content ranging from130 to 1800 grams per cubic meter in September, and for the Tigris, it varied from 170 to 2300 grams per cubic meter (AMAR 2003). Aqrawi, (1994) estimated the sediment load at 50-100 million tonnes per year of suspended sediment in the Tigris and Euphrates. Little of this sediment reaches the sea, however. Most of the material settles on the way and is responsible for the great deposit of alluvium that fills the Mesopotamian plain. Upstream damming of the rivers has greatly decreased their silt load, although recent figures are not available, Al-Mansoury (personal communication) has confirmed this statement. Water flowing into the dense-reed beds of the marshes drops their final load there. Water within the open lakes of the marshlands is clear, and the rivers past the interior deltas also have dramatically clearer water (AMAR 2003). The net result is that the marshlands as the final inland sink of the river system will be particularly hard-hit by the reduced water flow, which in turn will impact the productivity of the Northern Arabian Gulf.

Draining to the northern Arabian Gulf also Khor Al-Zubair estuary which is a semi-land locked tongue extending from Khor Abdullah northward (Fig. 6). It has length of 35 Km and a width of 1-2Km depending on the tidal situation. With the connection of the northern tail of this inlet to the Euphrates River by the Al-Basrah canal it has became the second most important source of freshwater, other than Shatt Al-Arab to the Gulf. The Canal is being used previously to drain the Al-Hammar marsh area. The building of the Al-Basrah canal and the physical manipulation of the marshlands has been reported to have caused a considerable impact on the environmental characteristics of the Khor such as temperature, salinity and dissolved solids and on the hydrodynamics of the northern Gulf (Al-Mussawi and Basi, 1993).

The average salt content of the Shatt AL-Arab River water passing through Basrah city was estimated to be about 0.7ppt in 1958 (Najarian et al, 1961). However decline in freshwater in the Shatt Al-Arab estuary has stimulated seawater intrusion and disrupted its complex ecology. In addition, the reduced amount of sediment reaching the sea has slowed the buildup of the Shatt Al-Arab coastal delta, and the whole geologic process may eventually be reversed through coastal erosion (Partow, 2001).

Salinity ranged from 1.3 to 2.1 ppt at lower regions of Shatt Al-Arab, which shows gradual estuarine characteristics caused, more or less, by gulf water. These differences are mainly due to the seasonal variations of Shatt Al-Arab River water discharge and the tidal currents. In spite of the dilution with fresh water which comes from Tigris, Euphrates and Karun Rivers, the salinity of Shatt Al-Arab shows higher values even in the upper parts. These higher values might be attributed to the agricultural runoff, industrial and other disposal. Arndt and Al-Saadi (1975) stated that, this part of the river act as drainage for the irrigation of the agricultural fields nearby, where the soil has high salt content. While Saad, (1978) argued that there is an increase in salinity values according to the decreasing in the water discharge from the Euphrates and Tigris, where the salinity reached about 10 ppt in Basrah and around 40 ppt in Al-Faw. On the other hand Al-Yamani (2008) stated that salinity at the lower reaches of the Shatt Al-Arab River 6.00 to 7.00 ppt under conditions of low river water volumes and the intrusion of marine waters.

The influence of the Shatt al-Arab River discharge on the northern Arabian Gulf results in a gradient of environmental conditions, which change according to river flow volume. As a result of this interaction, different locations and distinct periods may be identified in Kuwaiti waters. Polikarpov, et.al, (2009) show in their study that the northern zone of the Kuwaiti coasts is less saline, more dynamic, turbid and rich in nutrients. However the freshwater input into the Arabian Gulf has been considerably reduced due to dam construction upstream, frequent droughts, and the drying of the marshes. Hartman et al., (1971) estimated that Shatt Al-Arab supplies about 5 $x10^9$ m^3 nutrient rich fresh water into the basin each year.

Nezlin et al. (2007); Al-Yamani et al., 2007argued that because of the fresh water of Shatt Al-Arab River that entering the Gulf in summer, the northwest Gulf is rich in total chlorophyll (Fig. 7), were shallow waters influenced by the Shatt Al-Arab River discharge are more productive than open Gulf waters.

Decreased amounts of water from north of the Marshes coupled with less discharge from the Karun river in Iran have allowed salt water to move farther upstream on the Shatt Al-Arab River and without an increased flow of freshwater, this situation will worsen. Salt water has already polluted some of the Marshes especially Al-Hammar marsh, making the water unfit for human and animal consumption. Historically, the average flow in the rivers was 70 cubic metres per second. By 2009, the flow had decreased to 20 cubic metres due to the drought and upstream dams (CIMI, 2010).

All the above indicate that the water vulnerability and security in Iraq could be severe. The fragile water resources situation makes the whole region of the Euphrates Tigris watershed extremely sensitive to changes in rainfall or the availability of water in terms of quantity and quality. Adding to all the above complications, scientists in recent years started to look at the implications of the considerable uncertainties as to the impacts of global climate change on water quantity and quality. The sensitivity of river discharge to climate change is of significance to the Middle East region (Odemis and Evrendilek, 2007). Taking into account these statements, several renowned scientists highlighted the susceptibility of the two rivers to climate change.

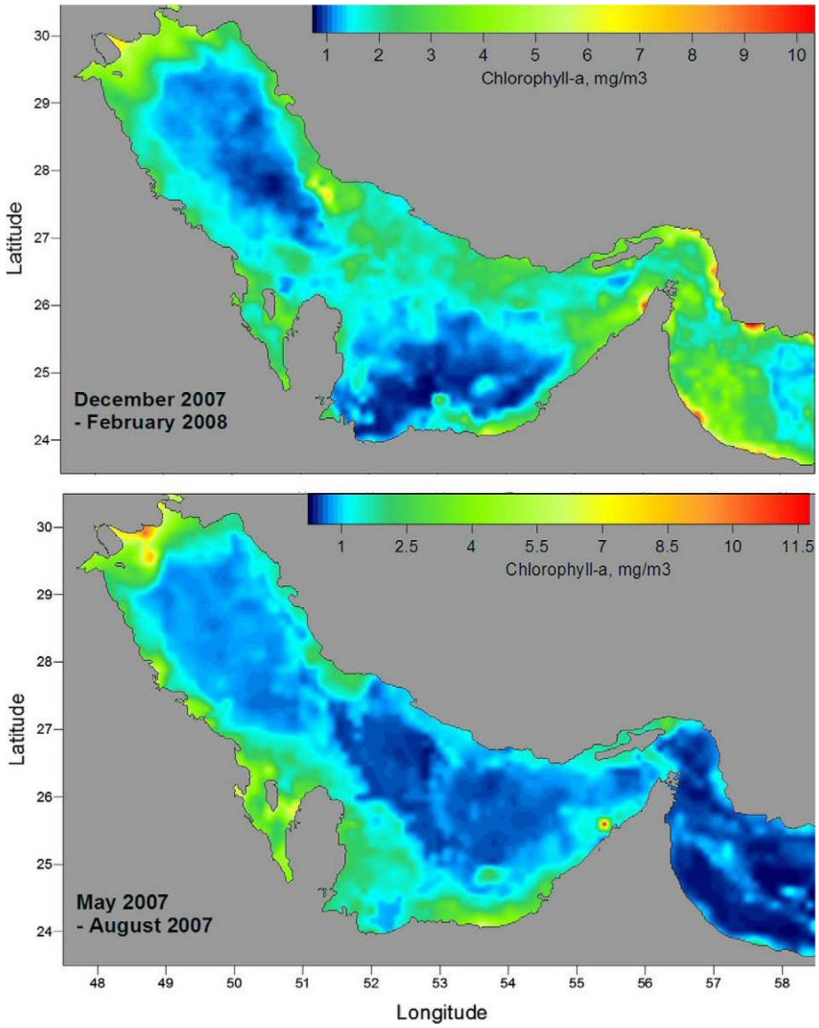

Fig 7: Winter and summer surface chlorophyll distribution in the Arabian Gulf, based on MODIS-aqua satellite (Sheppard *et al* 2010).

Conclusions:

The Euphrates and Tigris rivers make modern society possible in a geographic region that would otherwise be dominated by only a harsh desert climate. Iraq is almost totally dependent on its neighbours' water management practices because there are no permanent tributaries feeding the Euphrates River within Iraq and fifty percent of the water for the Tigris River comes from outside the country. The water quality issue is also a major problem between the upstream and downstream riparian countries of the Euphrates Tigris watershed. In the absence of meaningful regional oversight, decades of unsustainable damming, both within and outside Iraq, has weakened both rivers. Also Iraq has very limited access to the Arabian Gulf; this access is fundamental for industrial, economical, commercial, and military purposes as well as its biological importance to the Northern Arabian Gulf. If this ecological system is well managed, it can meet a broad range of economic, social, and cultural aspirations of all Iraqis. The system also provides a range of essential environmental services that would be extremely costly if not impossible to restore or replace if ecosystem functioning is further impaired.

For the time being the status of legislation, financial supports, and infrastructure impede the effective characterisation and management of water resources in Iraq. The environment is not a priority, and it has never been to any government of modern Iraq. The present situation put real pressure on the decision makers to start developing long-term strategies, defining Iraq's goals for its water policies, consolidate its negotiation powers with facts and figures before it starts any negotiation with the other riparian. This cannot happen without a solid development of a strong scientific base of local capabilities with the support of the international community. Although Iraq has a ministry for the environment working with International organizations as well as emerging community groups there are still no programmers to educate the community on best practices of conserving, managing, and protecting precious water resource, vulnerable environments including the marshes and the coastal areas.

The reduction in flow decreases each river's ability to flush pollutants. Euphrates, Tigris, and Shatt Al-Arab River are severely burdened by the direct, untreated discharge of industrial and sanitary waste into their waters. Discharge of these polluted waters to the marine environment will impact the whole productivity of the ecosystem. Reduction of wastewater and pollutants by constructing efficient sewage treatment facilities (or update existing ones), and the reduction of non-point source pollution such as agricultural runoff is urgently needed.

Finally, the authors have noticed that the Euphrates Tigris watershed issue has been a good case study for researchers of International and Environmental Law and Environmental Management practitioners particularly since the first Gulf War in 1991. Most of these studies and reports produced though depended on historical data, data from neighbouring countries, but very little and fragmented research done in Iraq. Thus, most of the reports and scientific papers published about the Euphrates Tigris watershed in Iraq consistently refer to earlier (before and around the 1980), data which inadequately characterises the current situation. With the exceptions of some international recent studies done for the marshes, (e.g. Partow 2001; Richardson et al., 2005; IMOS/ UNEP, ,2005, 2007; CRIM 2006; CIMI, 2010), there are limited comprehensive long term environmental studies and evaluations done for Shatt Al-Arab River , its tributaries and the Iraqi coastal area as an integrated system.

On the other hand there are numerous environmental and geochemical studies for the Tigris, Euphrates and Shatt Al-Arab River has been carried out, however far too many are either as MSc and PhD thesis from different Universities in Iraq with limited access to these data because they are mostly unpublished or published in local journals that are not accessible to the wider scientific community. While there is too little sharing of environmental information for this area within Iraq and amongst the watershed countries. This is, perhaps, one reason why the ecosystem is so poorly understood and managed, and why cumulative and trans-boundary impacts are rarely considered. That is why most of the time these studies and data may provide little useful information on how much more stress the environment of this watershed and its habitat might tolerate.

Iraq is specifically suffers from the lack of adequate legislation for sustainable water resource management in the context of wider river basin management. Investment in the capacity development of the scientific base is still not a priority in Iraq yet. Iraq also needs to work harder to effectively participate in international and regional environmental agreements and processes.

The upheaval in Iraq during the past two decades, the destruction of many national ministries during and after 2003 and the limited capacity to collect and manage information since then make working on the Euphrates Tigris and Shatt Al-Arab River watershed particularly difficult problems. It is also hard to identify the data set that most accurately represents reality among the series of available assessments, which have resulted in a number of inconstant conclusions. This poses considerable challenges. Therefore, we believe that the water quality, hydrology, as well as environmental assessments is urgently needed for the whole watershed, including the coastal area. Immediate and effective attention to rehabilitate the water ways, improve water management of the system through better coordination and cooperation between different government agencies, the academia, the community, and regional and international community to improve water management is required.

6. Recommendations:

As Iraq is building its new economic bases in the Gulf through the development of new ports installations for oil and commercial exports and imports, extreme environmental measures need to be taken in order to protect the marine environment for future generations.

Ecologically sustainable development by implementing integrated ecosystem-based planning and management for the rivers, the marshes, and marine areas is crucial for the recovery and survival of the whole ecosystem in Iraq.

Iraq needs to not only work closely and strategically with the Euphrates and Tigris transboundary riparian (i.e. Turkey, Syria, and Iran) but also need to work closely with Kuwait and Iran on the issues of the coastal ecosystem on the Arabian Gulf. Otherwise Iraq will be facing a difficult situation that affects its agricultural and economic development. Iraq also need water conservation programs, and effective regional cooperation, water resources data and experience exchange between the transboundary countries.

Internally, Iraq needs to enforce water and environmental conservation and protection laws. It is the role of the regional and local authorities supported by the national government to start an effective environmental community awareness and education campaigns on best environmental practices and environmental sustainability and managements.

On the technical side however there is an urgent need for a long term integrated monitoring plan, also Iraq needs automated monitoring stations along the two rivers, the Shatt Al-Arab River, at several strategic points in the marshes and on the coastal and territorial waters in the Arabian Gulf for continuous and regular readings of physical and chemical parameters, flow and other parameters. The data collected need to undergo an extensive and comprehensive management plan and compiling and analysing that requires coordination among all levels of government and other key sectors such as the universities.

Finally the Marine Science Centre (MSC) of Basrah University is working towards an integrated and comprehensive study of these important waterways. However, it needs the support of the international community similar to the effort put into the study of the marshes of southern Iraq.

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نوعية المياه الداخلية في العراق وتأثيرها على شمال غرب الخليج العربي

نادية المظفر و بيان مهدي

مركز علوم البحار- جامعة البصرة

المستخلص:

يتناول هذا الاستعراض التغيرات في نوعية المياه في الأنهار العراقية الرئيسية، دجلة والفرات وشط العرب على مدى العقود القليلة الماضية؛ وعلى وجه الخصوص من آثار الانخفاض في إمدادات المياه العذبة، وأثر ذلك على شمال غرب الخليج العربي.

ان التغير في كمية ونوعية المياه الواصلة من منابع نهري دجلة والفرات على مياة الانهار بسبب آثار بناء السدود في دول المنبع خفضت بشكل كبير من تدفق المياه الى الانهار في العراق. بالإضافة إلى ذلك، فأن نوعية المياه في تدهور مستمر في ظل غياب برامج إدارة أحواض الأنهار، والإلقاء المباشر للنفايات المنزلية والعامة غير المعالجة الصلبة والسائلة والكيمياويات الزراعية، والمواد الصناعية الخطرة مباشرة الي مجاري الانهار حيث ان مثل هذا السلوك ذو تأثير كبير على الصحة العامة والبيئة.

تشير الدلائل الرئيسية حتى الآن الى إجهاد بيئي واضح و توغل الجبهة المالحة في مصب شط العرب وروافده، والتي تؤثر بشكل كبير على الأنشطة الزراعية وسبل معيشة المزارعين الذين يقيمون في المنطقة المحيطة بالانهار الرئيسة في جنوب العراق بشكل خاض. وقد أدى توغل الجبهه المالحة في شط العرب الى ظهور بعض الأنواع البحرية في مياة شط العرب المويلحة. ومن الادلة الاخرى عن تلوث شط العرب هو وجود المخلفات الصلبة بما في ذلك قناني المياة البلاستيكية والاكياس والنفايات الصلبة الاخرى والصرف الصحي التي تطرح مباشرة الى مجاري الانهار. هناك حاجة لدراسات أخرى لهذه القضايا لتحديد الآثار البيئية قصيرة وطويلة الأمد على حد سواء على البيئات المختلفة والمعتمدة على هذة الانهار الرئيسية كلاهوار وشمال غرب الخليج العربي.