**Marine Science Center-University of Basrah**

**Mesopotamian Journal of Marine Sciences**
**Print ISSN: 2073-6428**
**E- ISSN: 2708-6097**
www.mjms.uobasrah.edu.iq/index.php/mms

# Sedimentary and Environmental Properties of Selected Areas in the Southern Marine Environment of Iraq

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**Article info.**
- ✓ *Received: 8 March 2026*
- ✓ *Accepted: 14 April 2026*
- ✓ *Published: 29 June2026*

**Key Words:**
Cumulative Curves
Environmental Parameters
Grain Size
Statistical Size Parameters
TOC%

**Abstract** - The southern coast of Iraq features a diverse environment composed of Khors, deltas, and gulfs. Studying the characteristics of sediments in these regions is essential. A study was conducted on the characteristics and sources of sediments and the environmental factors affecting them in seven selected locations in the marine environment of southern Iraq. The sedimentary analysis indicates that there are four textures: sand, silt, mud, and sandy silt. Silt was the dominant component in all samples, reaching 88% except for Khor Shytianah, where sand reaching 90%. Additionally, the sediments were transported over long distances, resulting in a decrease in grain size as they moved away from their source. The cumulative frequency curves further indicate similar depositional processes across the region, with the appearance of the size range (Ø) 1) suggesting that grains are transported by suspension. It was found that the percentages of total organic carbon (TOC %) were highest in the Shatt Al- Basrah region at 2.5%, and lowest in sand at Khor Shytianah at 0.0.4 %. The results of the acidity function pH reveal that the studied region has an alkaline environment pH reached to 8.85. Moreover, there is an inverse relationship with particle size and salinity and conductivity. The results indicate that the area is a regressive deltaic estuary system. This study enhances understanding of the region's geology and the current environmental conditions of this ecologically sensitive area in southern Iraq, especially considering recent climate and urban changes. It provides essential baseline information for future environmental management and monitoring efforts.

# الخصائص الرسوبية والبيئية لمناطق مختارة في البيئة البحرية جنوب العراق

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**المستخلص** - يتميز الساحل الجنوبي للعراق بتنوع بيئي يشمل الخيران والدلتا والخلجان. لذا، تُعد دراسة خصائص الرواسب في هذه المناطق ضرورية. أُجريت دراسة حول خصائص ومصادر الرواسب والعوامل البيئية المؤثرة عليها في سبعة مواقع مختارة ضمن البيئة البحرية لجنوب العراق. يُشير تحليل الرواسب إلى وجود أربعة أنواع من النسيج هي الرمل، والغرين، والطين، والغرين الرملي. كان الغرين هو المكون السائد في جميع العينات، حيث بلغت نسبته 88% باستثناء خور شيطانة، حيث بلغت نسبة الرمل 90%. بالإضافة إلى ذلك، نُقلت الرواسب لمسافات طويلة، مما أدى إلى انخفاض حجم الحبيبات كلما ابتعدت عن مصدرها. تُشير منحنيات التكرار التراكمي إلى عمليات ترسيب متشابهة في جميع أنحاء المنطقة، مع ظهور نطاق الحجم

DOI:https://doi.org/10.58629/mjms.v41i1.433 , 

(Ø 1) الذي يشير بأن الحبيبات تُنقل عن طريق التعليق. وُجد أن أعلى نسبة للكربون العضوي الكلي (TOC%) كانت في منطقة شط البصرة 2.5%، بينما كانت أدنى نسبة في رمال خور شيطانة 0.04%. وتُشير نتائج قياس حموضة الرواسب pH إلى أن المنطقة المدروسة ذات بيئة قلوية، حيث بلغت درجة الحموضة 8.85. كما لوحظ وجود علاقة عكسية بين حموضة التربة وحجم الجسيمات والملوحة والتوصيل الكهربائي. وتُشير النتائج إلى أن المنطقة عبارة عن نظام دلتاوي متراجع. تُساهم هذه الدراسة في تعزيز فهم جيولوجيا المنطقة والظروف البيئية الراهنة لهذه المنطقة الحساسة بيئيًا في جنوب العراق، لا سيما في ضوء التغيرات المناخية والحضرية الحديثة. كما تُوفر معلومات أساسية ضرورية لإدارة البيئة ورصدها في المستقبل.
**الكلمات المفتاحية:** المنحنيات التراكمية، حجم الحبيبات، نسبة الكربون العضوي الكلي، المعاملات البيئية، ومعاملات الحجم الإحصائية

## Introduction

The Iraqi marine environment is important because of its complex nature, where salty seawaters mix with freshwater from rivers. This coastal area is known for its tidal flats, where various environmental and biological factors interact. Khor Al Zubair, located in the northwestern part of the Arabian Gulf, is one of the main tidal flats, with its processes largely influenced by the inflow of the Tigris and Euphrates rivers. Once a semi-enclosed body of marine water, Khor Al Zubair is now considered an estuary because of its connection to the Shatt Al Basra Canal.

These formations may include beach rocks from periods of regression. The sediments in Khor Al Zubair result from various transport factors and energy levels (ALDaood and Al Bidran, 2019). Issa *et al.,* (2009) pointed out that the Khor Al-Zubair tidal flats likely began as a lagoon at depths of 1-1.1 meters, transitioning to a shallow marine environment. Influenced by a river, it eventually became a brackish-marine area after the construction of the Shatt Al-Basrah canal.

The sediment composition in the northwestern Gulf is characterized by instability and variability, mainly due to numerous hydrological factors in the region (Muttashar *et al.,* 2024). Al-Humaidan *et al.,* 2023 noted that paleo-climatic changes caused by marine transgressions and regressions led to shifts in paleo-environments and the formation of ancient river courses at Al-Faw Port. The sediments consist of a silty clay loam texture. Illite, Kaolinite, palygorskite, and montmorillonite-chlorite (mixed layers) are the dominant clay minerals in the Shatt Al-Basrah River sediments, with a small amount of montmorillonite present (Al-Amery and Al-Saad, 2022).

Al-Manssory and Al-Ali, (2011) examined the sedimentology and mineralogy of the rocky island in the Khor Al Zubair area, northwest Arabian Gulf. Al-Marsoumi *et al.,* (2006) conducted a sedimentary, mineralogical, and geochemical analysis of selected sediments from the coast of Khor Abdullah, northwest of the Arabian Gulf. Al-Jabri and Al-Humaidan (2018): Al-Jabri *et al.,* (2018) indicated that the sediments in the Gulf region are rich in most trace elements. These results may be attributed to the adsorption of ions or ionic compounds onto the surfaces of particles, such as clay minerals and organic matter, with a direct relationship between CaCo3, Pb, and as minerals, as calcite provides areas with a higher pH. Contributing to these results is the fine texture of the subbottom in the region, which consists mostly of silt. Al-Humaidan *et al.,* (2019) highlighted the distribution of fauna in the Khor Shytianah area and the entrance to Khor Abdullah, two areas that differ in sedimentary energy, current speed, and fauna sizes and shapes, as they vary at the entrance to the khor.

Almahmood *et al.,* (2023) indicated that most water quality variables in the Shatt al-Basra are higher than permissible levels due to the deterioration of the Basra regulator, which weakens the movement of water masses and, in turn, reduces pollutant concentrations in the Shatt al-Basra basin.The core sediments of Khor Abdullah are mainly composed of quartz, carbonate minerals, gypsum, and halite in high percentages, with minor amounts of clay minerals.

The presence of illite and kaolinite indicates significant input from terrestrial sediments in humid environments, such as fluvial or coastal areas. These variations reflect climate changes and marine transgressions or regressions.

Most minerals originate from marine or brackish waters, showing the strong influence of marine conditions on the paleo-environment (Al-Humaidan *et al,* 2025). Although many geological and environmental studies have been conducted, we chose to integrate sedimentary studies with various common environmental factors in the region. This paper aims to study and identify the sedimentary properties and environmental characteristics of sediments in selected regions of the Iraqi marine environment.

**Study Area:**

The study area is located in the northwest part of the Arabian Gulf, stretching from Ras al-Bisha to Shatt al-Basra in southern Iraq, as illustrated in Figure 1. This region is characterized by a variety of Khors, including Khor Abdullah, known for its distinctive funnel shape at the entrance to the Arabian Gulf, and Khor al-Zubair. The western branch of the Khor al-Zubair channel connects to the main estuary through the Shatt al-Basra artificial canal, which was opened in 1983 and is 37 kilometers long. Additionally, the area features shallow islands and is influenced by tidal currents and the Coriolis effect.

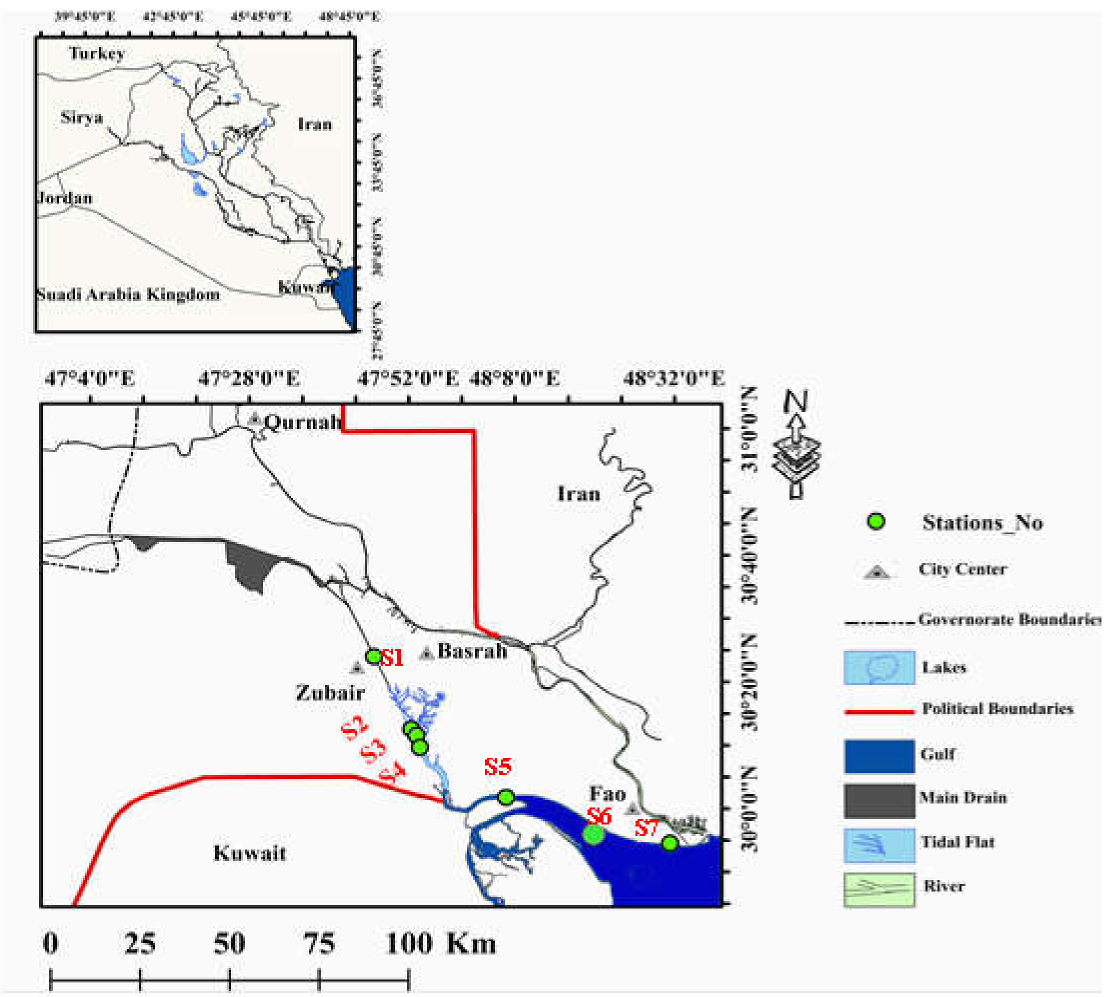


Figure 1. The location of samples in map of the study area.

**Geological Situation of the Region:**

**Geomorphology of the Region:**

The Mesopotamian plain is located in the unstable shelf area of the Arabian plate. The Pleistocene and Holocene sediments are represented by the aeolian, fluvial and marine sediments of the Dibdibah and Hammar formations, respectively (Al-Moussawi, 1993). The Zubair sub-region covers most of southern Mesopotamia, characterized by a uniform structural pattern dominated by faults and high basement rocks (Jassim and Goff, 2006). The source of Khor Al Zubair and Khor Abdullah is the Dabdaba Formation located in the north of the region (Al-Jibri, *et al.,* 1986). The thickness of the alluvial deposits in the northwestern part of the Arabian Gulf during the Holocene period is estimated at about 100 m. About 9000 years BP, the area near the Faw-Abadan cities experienced marine transgression, extending northward to the Basrah area around 8000 years BP. It then further advanced north to Nasiriyya–Amarah approximately 6000 years BP. This occurred due to marine transgression, leading to the dominance of brackish-marine conditions. During this time, brackish-water marine sedimentary sub-units were deposited over the previous fluvial plain deposits. The mid-Holocene marine invasion also coincided with a wetter climate (Aqrawi, 1993, 1995a,b, 2001). Ras Al-Bisha is located in southeastern Iraq at the mouth of the Shatt al-Arab River, which flows into the Arabian Gulf. The geological formations around Ras Al-Bisha mainly consist of Quaternary and Neogene sediments influenced by the river and sea-level changes (Jassim and Goff, 2006). The geological map of the study area as shown in Figure 2.

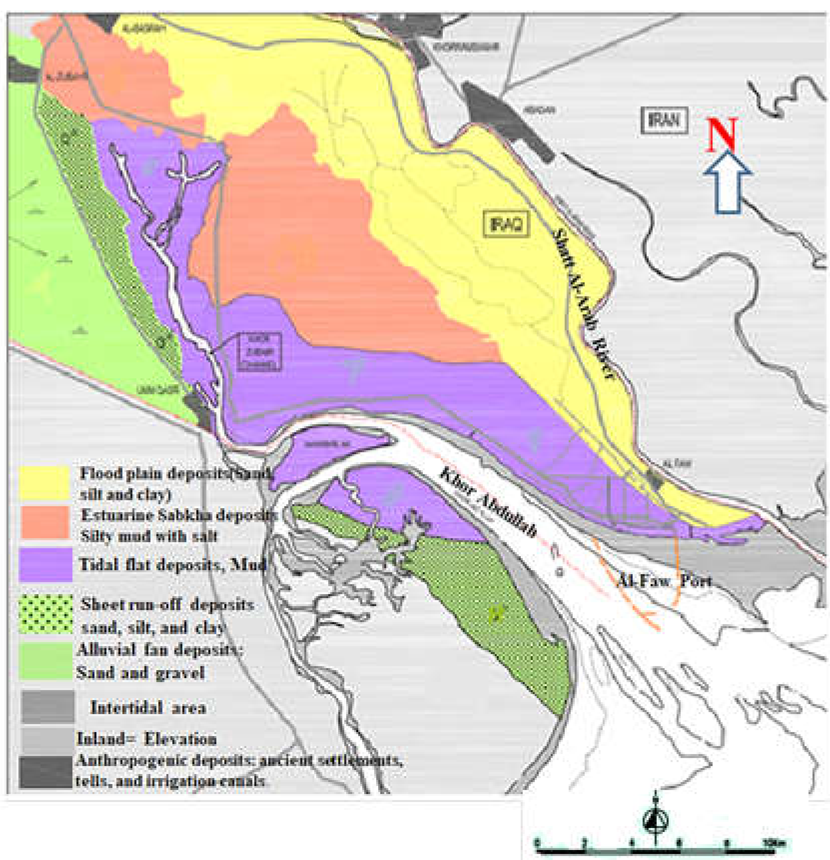


Figure 2. Geological map of the studied area according General Company for Ports of Iraq (2012).

## Hydrological Situation of the Region:

The hydrology of the Arabian Gulf is characterized by unstable water currents, high temperatures and salinity, and is affected by tidal currents. Water currents also have a important effect on the distribution of temperature and salinity, the movement of aquatic organisms, nutrients, and sediments, and their distribution (Karim and Salman, 1988). The water resources in the Basra Shatt suffer from pollution from many sources, especially agricultural, industrial, and sanitary drainage water.

The Basra Shatt is the main drain for sewage and salty general estuary water, and it is also affected by salty seawater coming from the Arabian Gulf (Yaseen *et al.,* 2016). Overall, the water quality is unsuitable for human consumption and agricultural use but can be utilized for animal consumption. It suffers from high salinity due to tidal influences from the Arabian Gulf and low water discharge (Al-Asad and Alhello, 2019).

The hydrology of the Arabian Gulf is characterized by unstable water currents, high temperatures and salinity, and the influence of tidal currents. These currents have a significant impact on the distribution of temperature and salinity, the movement of aquatic organisms, and the distribution of elements and sediments (Karim and Salman, 1988). The most important causes of these currents are winds, tides, the exchange of water masses, the ingress of Shatt al-Arab waters into the Gulf, and the Coriolis effect. The waters of the Gulf are warm due to their location within hot, shallow regions.

## Materials and Methods:

The samples represent seven sites distributed in a way that covers the entire area of the studied region, collected by the Grab Sampler device. Table 1 shows the coordinates of the study area for seven regions.

Table 1. Longitude and Latitude of samples in the study area.

| Station | Name | Longitude | Latitude |
|---|---|---|---|
| S1 | Shatt al-Basrah | 47° 53' 41.9851" E | 30° 9' 39.7968" N |
| S2 | Khor al-Zubair | 47° 53' 10.6585" E | 30° 11' 32.660" N |
| S3 | Khor al-Zubair | 47° 52' 24.3063" E | 30° 12' 33.2907" N |
| S4 | Khor al-Zubair | 47° 46' 47.4313" E | 30° 24' 0.0167" N |
| S5 | Khor Shytianah | ***48° 06' 41.92" E*** | ***30° 01' 44.7" N*** |
| S6 | Khor Abdullah | ***48° ٢١' 13.33" E*** | ***٣٠° ٠٥' 11.3" N*** |
| S7 | Ras al-Bisha | 48° 31' 20.313" E | 29° 54' 30.927" N |

Several analyses of environmental and sedimentary aspects were performed, along with desk research and statistical analysis. These included the following:

### Grain size analysis:

By using the wet sieving method, seven sediment samples from the study area were collected to separate the coarse fraction, represented by sand, from the fine fraction, represented by silt and clay, using a sieve with a mesh size of 0.063 mm. The pipette method was used, as described by Folk (1974).

**Total organic carbon TOC%:**

The percentage of total organic carbon (TOC%) in sediments depends on the amount of organic carbon produced by organisms in the area or transported to the sea by nearby rivers (Fleming and Barnes, 1967). Total organic carbon assays were conducted using the loss-on-ignition (LOI) method described by Nelson and Sommers (1996).

**EC and PH acidity:**

Examining the environmental specifications of the study area is essential, as these factors have a significant impact on the region. The interaction of these elements creates an environmental system that fosters the emergence and deposition of specific components and minerals, which in turn influences the presence of living organisms that produce these minerals. Key properties to consider include salinity, electrical conductivity (EC) and acidity (pH). These properties were measured using an EC and pH meter after creating a sediment filtrate at a ratio of 1:1.

**Office work:**

The office work consisted of processing the data obtained from laboratory analyses using the Excel Worksheet program and drawing charts. The GRAPHER program was also used to draw cumulative size curves in addition to calculating Statistical Size Parameters.

**Results and Discussion:**

**Grain Size Analysis:**

The study of size properties is important, as determining the size of sediment grains and knowing the percentage distribution of different sizes in them is of utmost importance. Sediment properties are fundamental for determining their origin, transport patterns, and directions (Gucciene, 2009). However, interpreting this information can be challenging due to the random variables involved in transport processes. The grain size analysis was conducted according to what was indicated by Folk (1974), and the percentages of the sediments of the study area were found as shown in Table 2, which shows the values of the results of the percentages of the three main components: sand, silt, and clay. These results indicate the dominance of silt in the sediments of the study area reaches 88% in site S4 Khor Al-Zubair, and the percentages for clay range from 1 to 25%. Also, the presence of sand ranges from 0.5 to 90% as shown in Figure 3.

Table 2. Percentages of sand, silt, and clay in the study area.

| NO. | Sample name | Station | Sand% | Silt% | Clay% | Texture |
|---|---|---|---|---|---|---|
| 1 | Shatt al-Basra | S1 | 0.5 | 75 | 24.5 | Mud |
| 2 | Khor al-Zubair | S2 | 14 | 76 | 10 | Sandy silt |
| 3 | Khor al-Zubair | S3 | 8 | 83 | 9 | Silt |
| 4 | Khor al-Zubair | S4 | 1 | 88 | 11 | Silt |
| 5 | Khor Shytianah | S5 | 90 | 9 | 1 | Sand |
| 6 | Khor Abdullah | S6 | 5 | 70 | 25 | Silt |
| 7 | Ras al-Bisha | S7 | 1 | 79 | 20 | Silt |

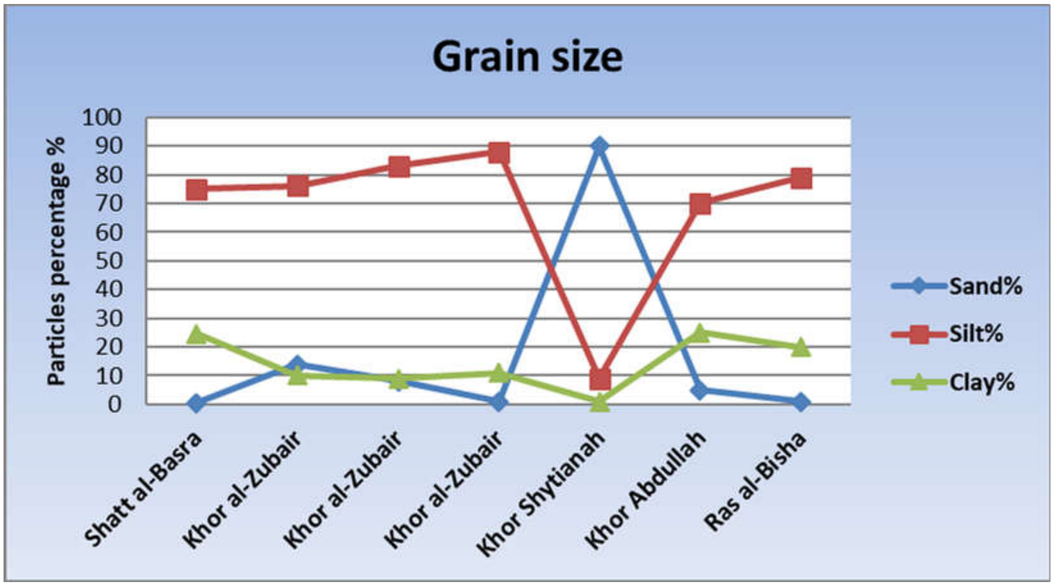


Figure 3. A chart showing the percentages of sand, silt, and clay in the study area.

The results indicated that the sediments in the region consisted of silt, sandy silt, sand, and mud, with a high content of silt dominating most areas. The percentage of silt reached a maximum of 88%, as shown in Table 2.

The increase in silt deposits can be attributed to water currents that transport silt from the Tigris and Euphrates rivers, which have high silt levels in their sediments. Most of the suspended materials from these rivers settle in Iraq, while an estimated 10% passes through Baghdad before ultimately reaching the Arabian Gulf (Emery, 1956; Khalaf, 1980; Elhabab and Adsani, 2013).

For classification, Folk's method (1974) has been used to analyze the basic components of the sediments in the study area: sand, silt, and clay. After calculating the percentages of these three components for each location, we found that the sediment textures in the study area were primarily silty and muddy, with a minor presence of sandy silt. However, at site S5 (Khor Shytianah), the sand percentage reached 90% due to its location, which is characterized by high wave activity, as shown in Figure 3. The sand percent was abundant in Khor Shytainah, comprising 95% representing a high-energy sedimentary environment (Al-Humaidan *et al.,* 2019). This phenomenon could be attributed to two factors. The first might be influenced by the Kuwait marine current during high tide. The second factor may relate to the bent shape of Warbah Island, which is caused by the narrow navigation channel in the area, as noted by Darmoian and Lindqvist (1988). The characteristics of sediments and their size variations are influenced by several factors, including the energy of sedimentary environments, which is affected by currents or sea waves, as well as environmental aspects like pH and water temperature (AL-Yamani, 2008). Figures 4, 5 and 6 provide close-up images of the study areas from Google Earth, illustrating the nature of the sediments.

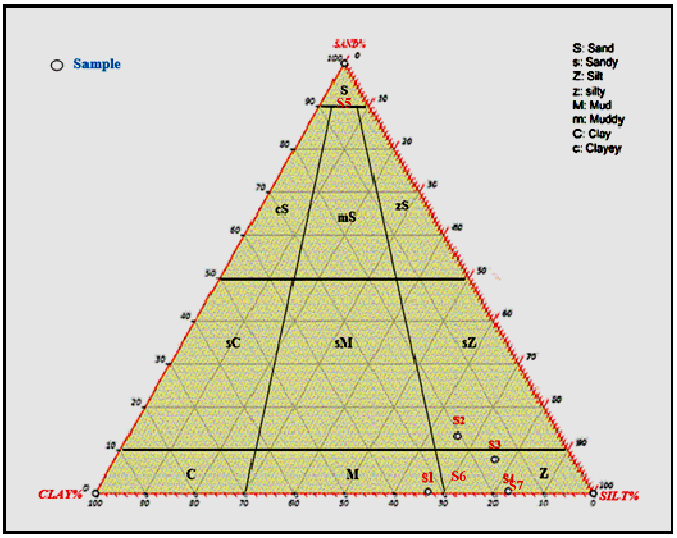


Figure 4. Classification of sediments according to the Folk (1974) diagram.

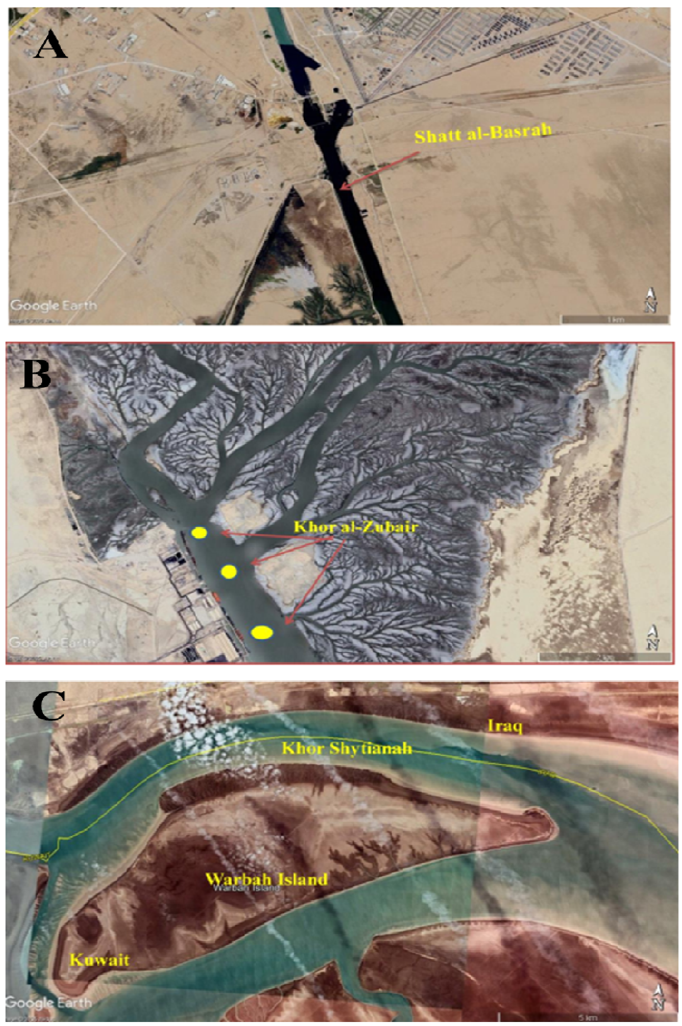


Figure 5. Images provide close-up A-Shatt al-Basrah, B- Khor al-Zubair and C-Khor Shytianah from Google Earth, illustrating the nature of the sediments.

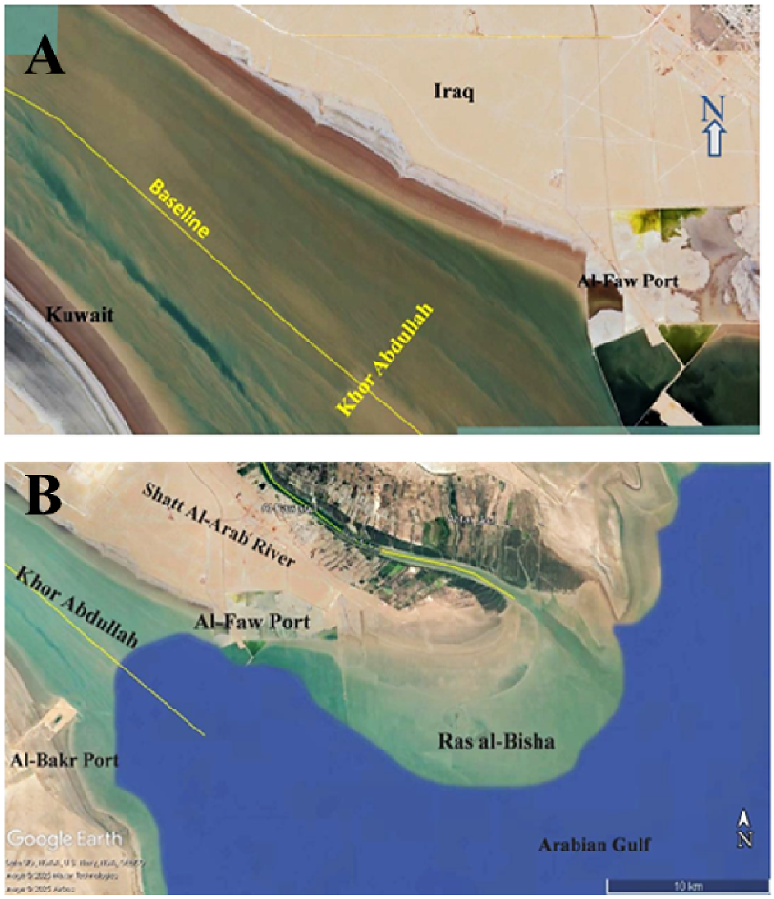


Figure 6. Images provide close-up, A- Khor Abdullah and B-Ras al-Bisha from Google Earth, illustrating the nature of the sediments.

The sediments are mainly derived from the Shatt al-Arab River system and the Tigris-Euphrates Valley Plain, which transport enormous quantities of suspended material and streambed debris towards the mouth. Erosion and deposition processes are influenced by natural factors such as water flow velocity and energy, and the deposition of different particle sizes (where fine particles are carried in the suspension, while heavier particles roll along the streambed) (Al-Humaidan, 2024). In addition, tectonic activities, which have historically affected ancient river courses through subsurface faults and structural uplift, continue to influence the current sedimentary situation and coastal changes (Al-Humaidan *et al.,* 2023; Mahdi *et al.,* 2025; Muttashar *et al.,* 2024).

Cumulative frequency curves were drawn using grain size analysis data and are of essential importance in many aspects, the most important of which is determining the type of transport processes for sediment grains, the energy of the current, and the type of depositional processes, and then determining the depositional environment (Boggs, 2006), as shown in Figure 7, which shows the cumulative curves between weight percentages and grain sizes in the unit of phi Ø.

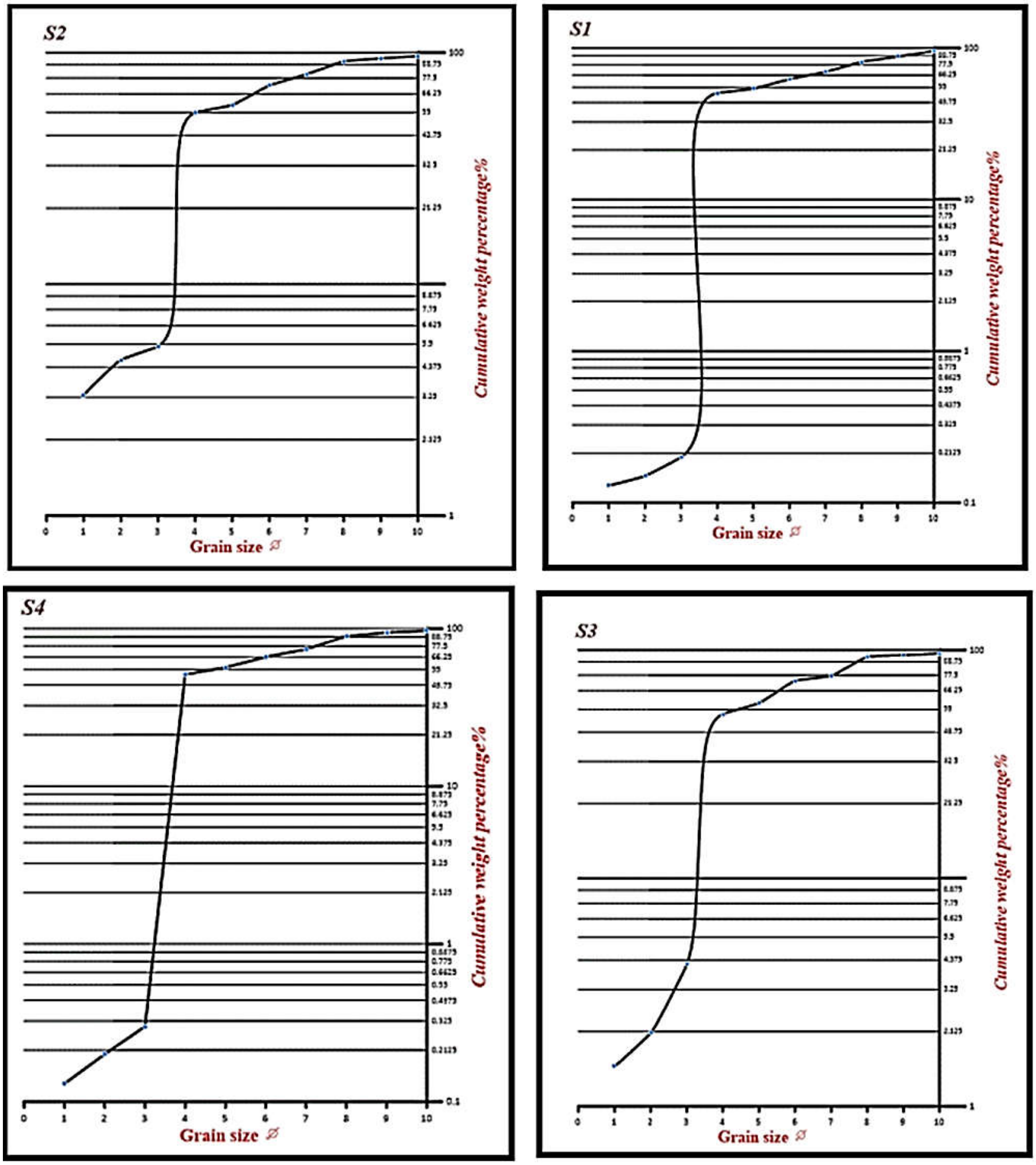


Figure 7. Cumulative curves of selected samples in the study area.

**Statistical Size Parameters:**

The graphic method was adopted to calculate the statistical parameters of (Folk, 1974) because it is considered the most accurate method for completing and extrapolating the results.The statistical Parameters that were calculated for the study area are the mean, median, sorting criteria, skewness, and kurtosis, which facilitated obtaining relationships between these criteria and then interpreting them , as shown in Table 3, which shows the values of the parameters for samples.

Table 3. The statistical parameters values.

| NO. | Sample name | Median Ø | ***Mean Size Ø*** | ***Sorting Ø*** | ***Skewness SkØ*** | ***kurtosis KGØ*** |
|---|---|---|---|---|---|---|
| 1 | S1 | 4.1 | 5.4 | 2.4 | 0.8 | 0.6 |
| 2 | S2 | 3.7 | 4.9 | 2.1 | 0.8 | 1.0 |
| 3 | S3 | 3.8 | 4.9 | 2.0 | 0.8 | 0.8 |
| 4 | S4 | 4.0 | 5.2 | 1.95 | 0.9 | 0.7 |
| 5 | S5 | ***3.2*** | ***4*** | ***1.28*** | ***0.64*** | ***1.06*** |
| 6 | S6 | ***3.9*** | ***5.06*** | ***2.32*** | ***0.69*** | ***0.91*** |
| 7 | S5 | ***3.9*** | ***5.3*** | ***2.4*** | ***0.7٩*** | ***0.6*** |

**Median:**

The median is the size value separating the smooth part from the rough part in the model, and it is of relative value as it changes from one model to another (Folk and Word, 1957).

$$\textbf{Median (Mds)} = Ø50 \qquad \text{------------1}$$

**Graphic Mean Size (Mz):**

This measure reflects the total volume of all sediments included in the frequency curve and is an indicator of the initial volume of the source rocks and the capacity of the sediment-depositing medium (Pettijohn *et al.,* 1973), as well as being an important and sensitive factor to the depositional environment (Friedman, 1967). The Mean Size value in the study area ranged from 4 – 5.4, this range would represent particle sizes from coarse sand (4 ϕ) to fine sand (5.4 ϕ) or very fine sand. The arithmetic mean was calculated according to Folk (1974) using the equation below:

$$\textbf{Mean size (Mz)} = (Ø16 + Ø50 + Ø84)/3 \qquad \text{---------2}$$

**Standard Deviation (Sorting) (Ϭ):**

Sorting is a function of the range of sand sediment grain sizes and reflects the type of deposition and the degree of uniformity in the energy and speed of the current. Good sorting is the result of stable current energy levels to some extent (Greenwood, 1969) and is also the degree of similarity in the size distribution of the sediments (Folk, 1974). Sorting values were calculated from the equation below:

$$(Ϭ) = (Ø84 - Ø16)/4 + (Ø95 - Ø5)/6.6 \qquad \text{----------3}$$

The sorting values of the sediments in the study area ranged from 1.28 to 2.4 Ø.

**Skewness (Sk):**

Folk (1974) explained that the skewness coefficient is the most effective statistical measure, capturing 90% of the cumulative curve. He also acknowledged the potential for symmetrical or nearly symmetrical models in the areas where different environments mix, which allows for the possibility of distinguishing between these environments.

$$(SK) = \frac{Ø16 + Ø84 - 2(Ø50)}{2(Ø84 - Ø16)} + \frac{Ø5 + Ø95 - 2(Ø50)}{2(Ø95 - Ø5)} \qquad \text{--------------- 4}$$

The Skewness values of the sediments of the study area ranged from 0.64 to 0.9 Ø..

**Kurtosis (KG):**

Kurtosis is defined as a measure of the proportion of the distribution's dispersion at the two ends compared to the dispersion at the central part. It is a sensitive and valuable measure of the nature of the distribution (Folk and Ward, 1957). The kurtosis values were extracted from the equation below according to Folk (1974).

$$\mathbf{KG = (Ø95 - Ø5) / 2.44(Ø75 - Ø25) \quad ----------------5}$$

The Kurtosis values of the sediments of the study area ranged from 0.6 to 1.06 Ø. The results of the region showed that the kurtosis values ranged from very platykurtosis to mesokurtosis. Median, mean, sorting, kurtosis, and skewness are several important measures used in statistical analysis to describe the shape of a distribution of data (Cooksey, 2020), which are used in many geological applications, including sedimentary environments.

The statistical parameters of the sediments in this area indicate relatively low volume ranges, as represented by the median and arithmetic mean. This suggests that the majority of the samples consist of fine silt, indicating that the sediments were transported over a relatively long distance. This distance has contributed to a decrease in their grain size, moving them away from their source.

Additionally, the sediments exhibit poor to very poor consistency, with only slight variations in sorting. This similarity reflects that most of the sediments in the study area are indeed silt. The skewness coefficient values show a significant positive skew (+SKI), signifying that the grain size distribution leans towards finer particles and demonstrates a very smooth skewness. The flatness values from the results range from flat to very flat, further confirming that fine sediments, such as silt and clay, dominate over coarser sediments like sand. Therefore, the variations in flatness values are largely influenced by the source of the sediments (Agwan and Al-Fattah, 2005).

Thus, we can conclude that most sediments in the region have been transported. The accumulation curves indicate similarities in the sedimentary processes within the region, and the size range (Ø1>) suggests that the grains are transported by suspension. According to Boggs (2006), fine sediments are indeed carried by suspension. The sorting values of the sediments in the study area indicate poor to very poor sorting, which suggests a depositional environment with limited energy, time, or reworking, resulting in a heterogeneous mixture of grain sizes. Mulder and Alexander (2001) noted that a short transport distance or an ineffective transporting medium can lead to poor sorting of grains.

The Skewness results show that most of the models of the studied region have very positive symmetry, and the type of Skewness is very smooth. This indicates the sediments are dominated by an excess of fine-grained particles relative to the mean, which strongly points to depositional processes where fine sediment was able to settle and accumulate. Fine sediment is building up in environments where there is a higher proportion of fine material in the tail of the distribution, such as in a sheltered lagoon where the skewness is positive (fine-skewed) (Duane, 1964).

Sample results of kurtosis indicate a consistent deposition process, leading to a more uniform or nearly normal distribution of grain sizes. A CM plot was created following Passega (1957), plotting the values of the coarsest size (1%) in microns (C) against the median size in microns (M) as described by Passega (1957), as shown in Figure 8. This relationship indicates that the sorting of bottom-moving sediments results in the concentration of speckled samples in the RS and T sectors. It suggests that the particle transport mechanism was solely uniform suspension, which explains why the transport current was steady and quiet.

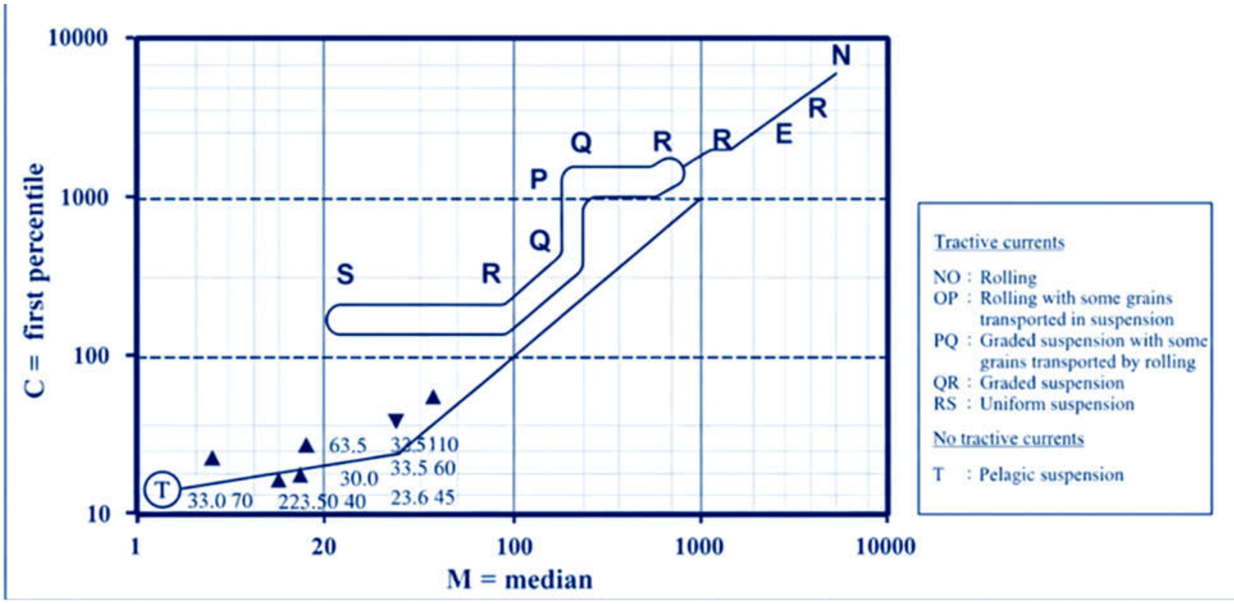


Figure 8. CM plot after Passega 1957

Deepthi *et al.,* (2018) and Pradhan *et al.,* (2020) confirmed that the grain size data in this diagram are used to calculate the forces generated by hydrodynamics during sediment transport path and their accumulation.

**Environmental Characteristics in the Region:**

Examining the physical and chemical characteristics of the study area is crucial, as these specifications significantly influence the environment. This results in an ecological system that fosters the formation and deposition of various components. Below is a simplified overview of these characteristics and their impacts:

**Acidity PH, Conductivity EC and Salinity:**

The acidity function can increase when $CO_2$ is decreased or removed through photosynthesis in some organisms, such as algae, which reduces acidity and also influences $CaCO_3$ deposition (Boggs, 2006). The results in Table 4 show that the acidity function values in the area are high, indicating an alkaline environment, as shown in Table 4 and Figure 9, which depicts the environmental properties of the study area.

Table 4. Environmental properties and total organic carbon.

| Station | Sample name | Texture | Conductivity (EC) (ms/cm) | Acidity PH | Salinity (‰) | TOC% |
|---|---|---|---|---|---|---|
| S1 | Shatt al-Basra | Mud | 23.42 | 7.7 | 14.98 | 2.5 |
| S2 | Khor al-Zubair | Sandy silt | 25.26 | 8.61 | 16.16 | 1.6 |
| S3 | Khor al-Zubair | Silt | 26.4 | 8.85 | 16.89 | 1.3 |
| S4 | Khor al-Zubair | Silt | 28.01 | 8.81 | 17.93 | 1.4 |
| S5 | Khor Shytianah | Sand | 29.62 | 8.1 | 16.85 | 0.4 |
| S6 | Khor Abdullah | Silt | 25.55 | 7.9 | 15.96 | 1.5 |
| S7 | Ras al-Bisha | Silt | 24 | 8.14 | 15.3 | 1.9 |

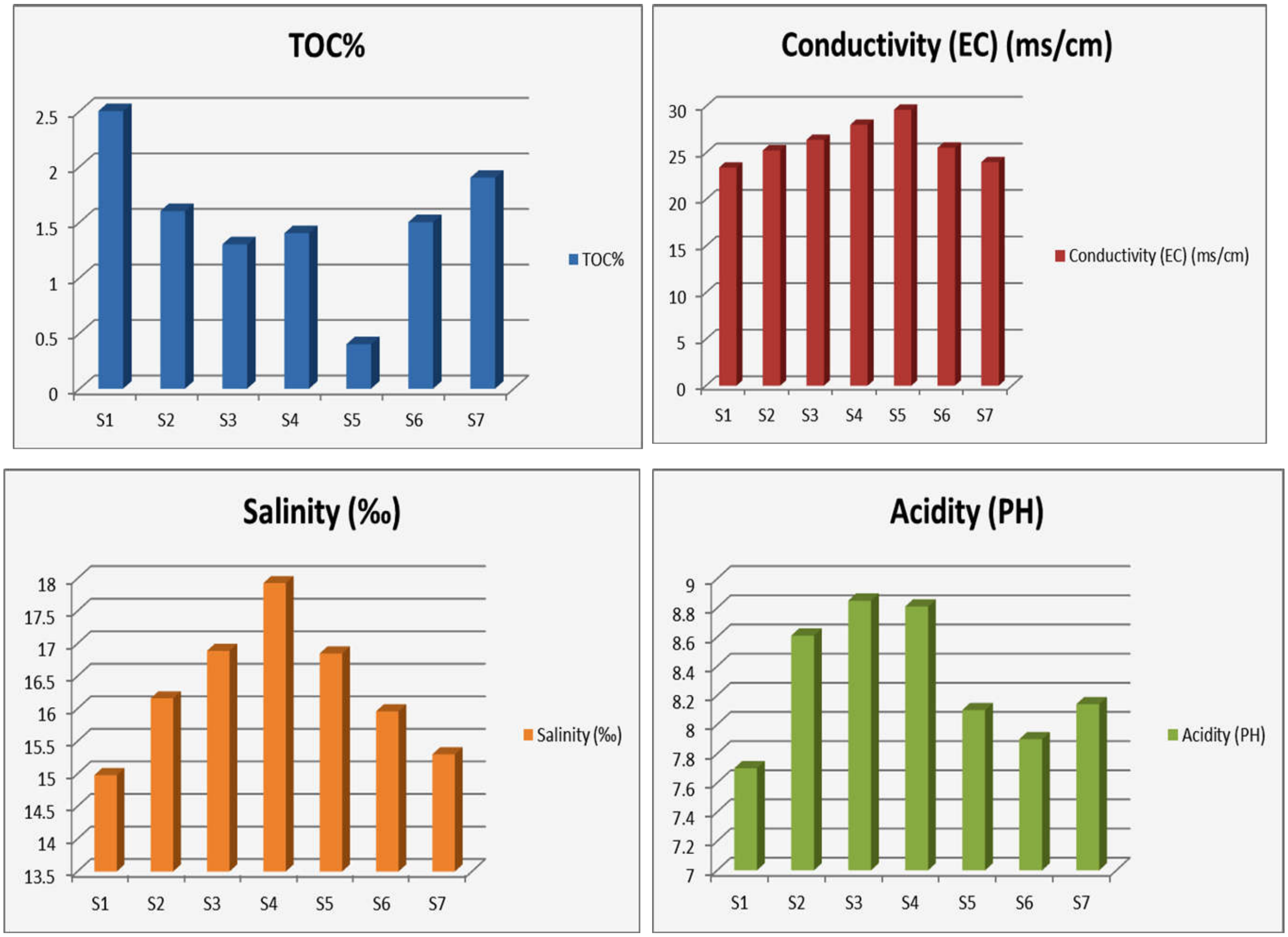


Figure 9. Diagrams illustrating the proportions of environmental factors in the study area

The pH factor is crucial because the waters of Shatt al-Basra and Khor al-Zubair are characterized by high alkalinity, confirmed by field measurements of the region's sediment soils. The measurements indicated increased pH values, with the highest reaching 8.61, signifying a shift toward a basic medium. According to Boggs (2006), increasing pH results in $CaCO_3$ precipitation in such areas. Awadh and Ahmed (2013); Awadh and Al-Qhani (2014) confirmed that high pH values indicate sediment that is rich in carbonates, which depends on the concentration of $CaCO_3$. Higher values may result from shallow water levels, increasing salinity and pH, which in turn raise the levels of carbonates and bicarbonates (Al-Khuzaie, 2020). The results also showed soil electrical conductivity, which was highest in alluvial soils at 29.62 ms/cm in Khor Shytianah, along with salinity, which peaked at 17.93 in Khor al-Zubair S4. There appears to be an inverse relationship between electrical conductivity, salinity, and the acidity function with particle size, as the values increased as particle sizes decreased. Generally, the pH of sediments remains alkaline, though it is influenced by organic matter and mineral composition, sometimes acting as a buffer against high salinity (Sameh and Almahasheer, 2022). Furthermore, a positive correlation was found between salinity and conductivity, as illustrated in the Figure 10.

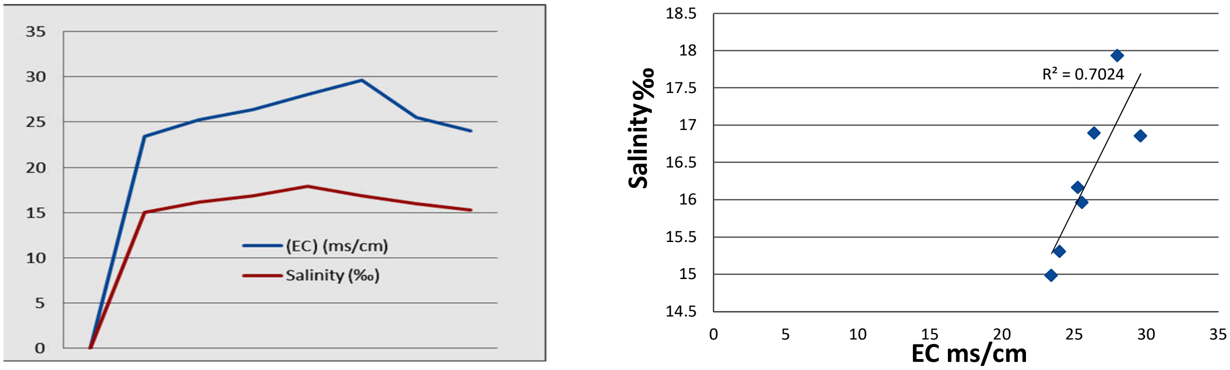


Figure 10. The strong correlation between salinity and electrical conductivity.

Sameh and Almahasheer (2022) pointed out that the sediments in the northwestern Arabian Gulf have a strong positive correlation between increased electrical conductivity and high salinity. This occurred when the evaporation rates increasing shallow, tidal environments.

**Total Organic Carbon (TOC%):**

Total organic carbon is widely distributed in soils and sediments over the Earth's surface and in almost all aquatic and terrestrial environments (Schnitzer, 1978). Trask (1955) confirmed that the percentage of total organic carbon increases in the sediments of rivers and bays. In this study, fluctuations in the rates of the values of (%TOC) measurements were observed, as the values ranged from (0.4) to (2.5), as shown in Table 4. An increase in organic carbon was clearly observed, accompanied by a decrease in the proportions of grain sizes.

The results of (TOC) showed an inverse relationship with the particle size. This result is consistent with the study of Al-Humaidan (2018), which concluded that total organic carbon is generally transferred and deposited with fine particles or silt and clay and decreases in coarse-grained sediments such as sand, as shown in Figure 11. This is consistent with the study of (Huon, 2000), which concluded that organic carbon ratios increase with decreasing particle size because organic carbon is adsorbed on mineral surfaces and has an infinitely high affinity for fine-grained sediments. In contrast, Figure 12 shows the inverse relationship between sand grains and organic carbon.

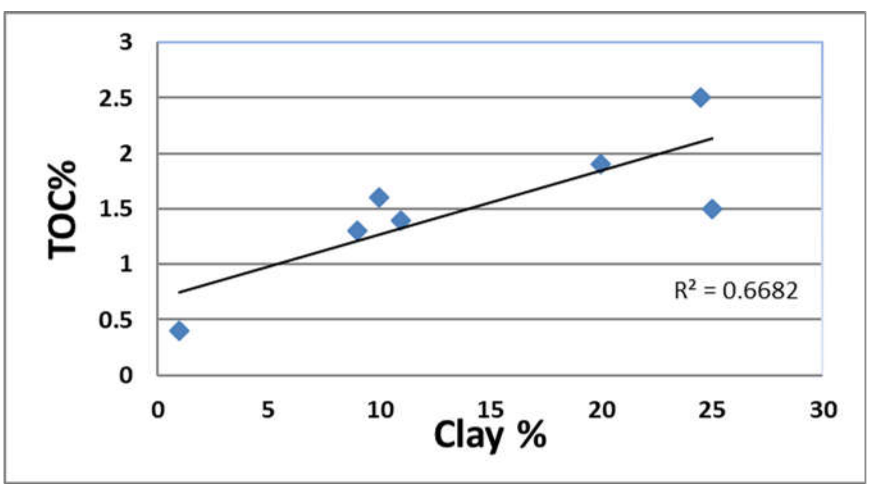


Figure11. The positive relationship between Clay grains and TOC%

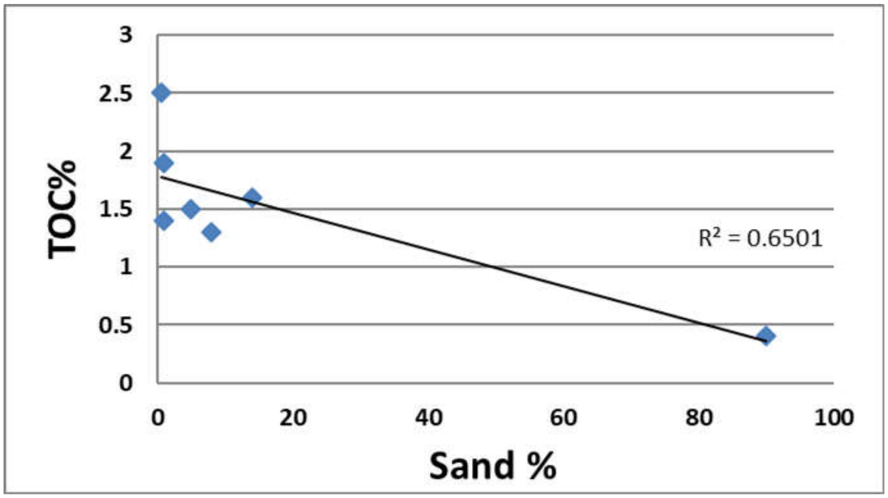


Figure12. The Nagative relationship between sand grains and TOC%.

The concentration of TOC is generally highest in sediments composed of fine grains (clay and fine silt) in both marine and transition zones ( estuaries and deltas), because fine grains have a much higher specific surface area compared to coarser grains (sand). This large surface area supplies more places for adsorption, allowing organic molecules to chemically or physically bind to the mineral surfaces (Dan and Gheorghe, 2009). Salinity has a significant impact on the size of biological communities, as well as their quantitative and qualitative representation (Power *et al.,* 2000). Additionally, the strong tidal currents flowing from the Gulf increase the salinity concentrations in the water of the Shatt al-Basra Canal (Galo *et al.,* 2022).

The salinity of 14.98‰ at Shatt al-Basra indicates brackish water, typical of an estuary in the Shatt al-Arab system where fresh water mixes with marine water from the Arabian Gulf. High TOC% as an Indicator of Organic Pollution: The value of TOC% in the Shatt al-Basra sediments is 2.5%, generally a high level of TOC, primarily from sewage discharge from Basra city into the canal (Galo and Resen, 2024). The presence of 2.5% Total Organic Carbon (TOC) alongside this salinity suggests significant organic matter deposition influenced by marine tides and salinity intrusion. This organic enrichment likely results from both natural river input and human nutrient loading, contributing to eutrophication (Hyland *et al.,* 2005; Al-Asadi *et al.,* 2022; Al-Asadi and Alhello, 2019 ) .

The values of 1.9% Total Organic Carbon (TOC) and 15.3‰ salinity at Ras al-Bisha indicate that it is located in an active estuarine or deltaic depositional environment. This area is characterized as a brackish water zone, highlighting its transitional nature between the freshwater of the Shatt al-Arab and the marine waters of the Arabian Gulf. Additionally, the fine-grained sediments, often consisting of silt, frequently found in Ras al-Bisha can contribute to lower oxygen conditions. This reduced oxygen level slows down the decomposition of organic matter, allowing for its effective preservation within the sediment. Ras Al-Besha has brackish water (mesohaline value) and notes the influence of salinity and sediment texture on the environment of the area (Shareef *et al.,* 2015). The sediment pH range in the study area ranges from 7.7 to 8.84, which is considered alkaline or slightly basic. This is typical for marine and estuarine environments in this region and is primarily influenced by the presence of carbonate minerals, such as calcite and aragonite. These minerals help preserve an alkaline environment, particularly in the presence of dissolved ions from seawater.

Research on water quality in the Shatt Al-Arab and nearby coastal waters indicates that pH values tend to increase as one approaches the sea, with values commonly ranging from 7.6 to 8.5 in the water column (Abbas *et al.,* 2020).

## Conclusions

The Iraqi marine environment is complex, mainly because of its location in the northwestern Arabian Gulf. Sedimentary analysis shows a relatively calm setting, marked by a dominance of silt and poor sediment sorting. This indicates that the area experiences weak tidal currents at the ends of the channels, where sedimentation occurs quickly, preventing grain size separation except in Khor Shytianah, which has a sandy texture due to its unique topography. Additionally, positive Kurtosis values point to an abundance of fine grains transported by uniform suspension. Results related to sediment flattening confirm a transitional environment between river and sea, highlighting two types of fine grains. High total organic carbon (TOC) levels generally imply a calm environment, especially in the Shatt al-Basra area, where sewage pollutants are common. In addition to the effect of salinity on organic carbon. These pollutants cause sediments to retain organic matter before oxidation. The region is also affected by Gulf waters, which are characterized by high alkalinity and a significant precipitation of calcium carbonate.

## Acknowledgements:

The authors would like to thank Dr. Milad Ali Hussein at the College of Marine Sciences, Applied Dep., for his cooperation in mapping the region.

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