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Geotechnical and Geochemical Study of Shatt Al-Hilla Banks' Soil in Babylon Governorate, Middle of Iraq

Haider A. AlAmar [1*]

[1] *Department of Applied Geology, College of Science, University of Babylon, Babylon, Iraq.*

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Correspondence:
Name: Haider A. AlAmar

E-mail
haider_abaid73@yahoo.com

ABSTRACT

This research deals with the engineering and geochemical features of Shatt Al-Hilla banks' soil. Six samples are collected to study the chemical properties of the banks' soil such as pH, Gypsum, EC, SO_3, and heavy metals. As well as physical and engineering properties of PI, LL, MC, dry and saturated density, and trace elements in the soil of the Shatt Al-Hilla banks provide a clear view of the geotechnical properties of the Shatt Al-Hilla banks. According to the study's findings, the LL percentage ranges from 20.0 to 18.7% with an average of 19.46%. All of the soil samples are classified as having poor plasticity. The PI percentage ranges from 21.0 to 16.0 with an average of 18.88% indicating that the banks' soils in Shatt Al-Hilla are classified as having low plasticity throughout the research region. The banks' soils in the research region are characterized as having low swelling capability in all stations along the Shatt Al-Hilla Banks. The values of dry density range from 1.684 g/cm^3 to 1.433 g/cm3 with an average of 1.522 g/cm3, and the EC ranges from 0.75 to 1.13 with an average of 0.97 indicating that the soil of Shatt Al-Hilla banks has very low salinity. The pH ranges from 8.6 to 9 with an average of 8.76, the gypsum ranges from 1.92 to 1.09% with an average of 1.36%, and the sulfate percentages vary from 3.75 to 0.99% with an average of 2.25%.

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دراسة جيوتقنية وجيوكيميائية لتربة ضفاف شط الحلة في محافظة بابل، وسط العراق

حيدر العمار [1*]

[1]قسم علوم الأرض التطبيقية، كلية العلوم، جامعة بابل، بابل، العراق.

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المراسلة:
الاسم: حيدر العمار

E-mail haider_abaid73@yahoo.com

الملخص

يتناول هذا البحث الخصائص الهندسية والجيوكيميائية لتربة ضفتي شط الحلة. تم جمع ستة عينات لمنطقة الدراسة لدراسة الخواص الكيميائية لتربة الضفاف مثل pH، الجبس، EC، SO_3، والمعادن الثقيلة للعينات المختارة. وكذلك الخصائص الفيزيائية والهندسية PI, LL, MC والكثافة الجافة والمشبعة والعناصر النزرة في تربة ضفاف شط الحلة من أجل تقديم رؤية واضحة للخصائص الجيوتقنية لضفاف شط الحلة. وبحسب نتائج الدراسة، تراوحت نسبة LL من 20.0 إلى 18.7% بمتوسط 19.46%. تم تصنيف جميع عينات التربة على أنها ذات مرونة ضعيفة. وتراوحت نسبة PI من 21.0 إلى 16.0 بمتوسط 18.88% مما يشير إلى أن الترب الضفة في شط الحلة تصنف على أنها منخفضة اللدونة في جميع أنحاء منطقة البحث. تتميز الترب في منطقة البحث بانخفاض قابليتها للانتفاخ في جميع المحطات على طول تربة ضفاف شط الحلة. وتتراوح قيم الكثافة الجافة من 1.684 غم/سم^3 إلى 1.433 غم/سم^3 بمتوسط 1.522 غم/سم^3، وتتراوح التوصيلية الكهربائية من 0.75 إلى 1.13 بمتوسط 0.97، مما يدل على أن تربة ضفاف شط الحلة منخفضة الملوحة جدا. ويتراوح الرقم الهيدروجيني من 8.6 إلى 9 بمتوسط 8.76، والجبس من 1.92 إلى 1.09 % بمتوسط 1.36%، والكبريتات من 3.75 إلى 0.99 % بمتوسط 2.25%.

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Introduction

Shatt Al-Hilla course penetrates Hilla City (100 km south of Baghdad), where its waters flow from north to south of the city of Hilla. Shatt Al-Hilla River located in the sedimentary plain of Babylon faces challenges such as collapse and erosion of banks, reducing traffic efficiency and causing damage to agricultural areas (Al-Sultani *et al.*, 2023). The river has relatively gentle slope and oscillating water flow system contribute to its issues (Al-Ameri and Al-Khafaji, 2014; Al-Turaihi *et al.*,2023). Heavy metals contaminate the river sediments in Shatt Al-Hillah and nearby areas from a variety of sources including the use of fossil fuels, municipal garbage, sewage, pesticides, and fertilizers. Because of the growing population, urbanization, and vast agricultural regions, these pollutants are considered a major environmental problem (Al-Khafaji *et al.*, 2014; Al-Turaihi *et al.*, 2022). The growing use of fertilizers and pesticides has resulted in increased pollutant emissions and waste deposition, particularly in urban and agricultural regions, which serve as metal sinks (Manea *et al.*, 2019).
The result indicates that soil and sediments exhibit a degree of pollution with no significant pollution detected in any water sample; as this water has a major role in influencing the engineering properties of the soil of Shatt Al-Hilla including the ability of the soil to bear the loads placed on it, which leads to a differential settlement on the bank river (Asd *et al.*, 2022). The composition and quality of TDS and EC of Shatt Al-Hilla banks' water as well as the soil have a significant impact on the erosion of structures, whether concrete or iron, but their impact goes beyond the non-engineering aspects of the soil such as agriculture in general.

Trace elements are considered dangerous contaminants that enter the freshwater environment and cause disturbances to the ecological balance (Canli *et al.,* 1988). Hameed et al. (2023) reported that minerals undergo sedimentation processes influenced by conveyor speed, load capacity, particle size, and specific gravity, leading to varying horizontal distribution due to the specific gravity ranges (Al-Amar and Al-Khalidi, 2018; Al-Amar et al. 2018). Manii and Saud (2019) studied Shatt Al-Hilla soil and their results indicate that soil and sediments exhibit a degree of pollution with no significant dangerous pollution detected in any sample. A wide range of contaminants including several heavy elements such as zinc, copper, cadmium, and lead as a result of the disposal of industrial waste therein, as well as the types of chemical fertilizers used in agriculture, all enhance the levels of pollution in rivers (Faraj *et al.,* 2007). Kindi et al. (2022) studied heavy metals in Shatt Al-Hilla water, and they found them to be within the acceptable limits; however, the lack of special cages for fish growth led to recommendations for building floating cages out of plant protein rather than animal protein. Al-Turaihi et al. (2023) studied the hydrochemistry of the artesian wells in the Babylon Governorate.

Aim of study

The study aims to conduct a geotechnical evaluation of selected soils from Shatt Al-Hilla and to find out their engineering and chemical characteristics, their relationship and their impact on engineering facilities, studying some engineering problems of the chosen soil of the study area, study some chemical properties same like the TDS, EC and some heavy metals in Shatt Al-Hilla Banks in the city of Hilla.

The Justifications for Study

This study is selected for Shatt Al-Hilla because of the great significance of the plans for developing the banks for engineering uses, service and recreational facilities along the soil of the banks of Shatt Al-Hilla.

Geological Setting and Climate

The surface of the examined area is covered by a recent Euphrates River floodplain (alluvial environment). The new sediments accumulated in the east is silt with clay and some fine sand. The flood plain, on the other hand, is buried under Quaternary sediments ranging in age from the Pleistocene to the Holocene and with thicknesses ranging from a few meters to 180 meters. They are reflected in the fluvial deposits of the Tigris and Euphrates rivers, as well as their tributaries (Jassim and Goff, 2006). The Mesopotamian Plain has no apparent pre-Quaternary bedrock since it has been submerged by Quaternary deposits (Abed, 2022). The flood plain Quaternary sediments gradually thickens from northwest to southeast. The climate of Iraq varies dramatically from summer to winter and from south to north. Southern summers are long, hot, and dry. Temperatures have risen beyond 50°C. Winter in the south is brief and pleasant. The average precipitation in Mesopotamia is 178 mm (Mohammed *et al.,* 2022). The Babylon Governorate has a hot and arid climate. Winters are bitterly cold, and summers are scorchingly hot and dry. Despite monthly rain, the majority of rain comes between January and April.

Materials and Methods

The location of the study area is at the banks of Shatt Al-Hilla within Hilla City. Table (1) includes the station coordinates, and Fig. (1) depicts the site plan for the station's location. Six stations along Shatt al-Hilla banks are selected to sampling soil in January 2021. Samples were taken to a depth of 1 m from the LS with a clean stainless steel scroop. Samples are collected and stored in polyethylene bags with a weight of 1 kg for each sample. The samples then analyzed in the consultative bureau lab. at Babylon University, College of Science to determine the chemical properties (pH, EC, TDS, SO_3 and heavy metals) for the selected samples and physical and engineering properties such as Atterberg limits, moisture content, specific gravity, dry and saturated density).

Table 1: The station coordinates of the investigated area

Station	Latitude	Longitude
1	32 45 43.22	44 43 12.43
2	32 45 23.55	44 43 45.71
3	32 45 48.39	44 33 43.97
4	32 45 43.03	44 36 44.02
5	32 47 16.67	44 36 12.07
6	32 46 08.81	44 36 19.17

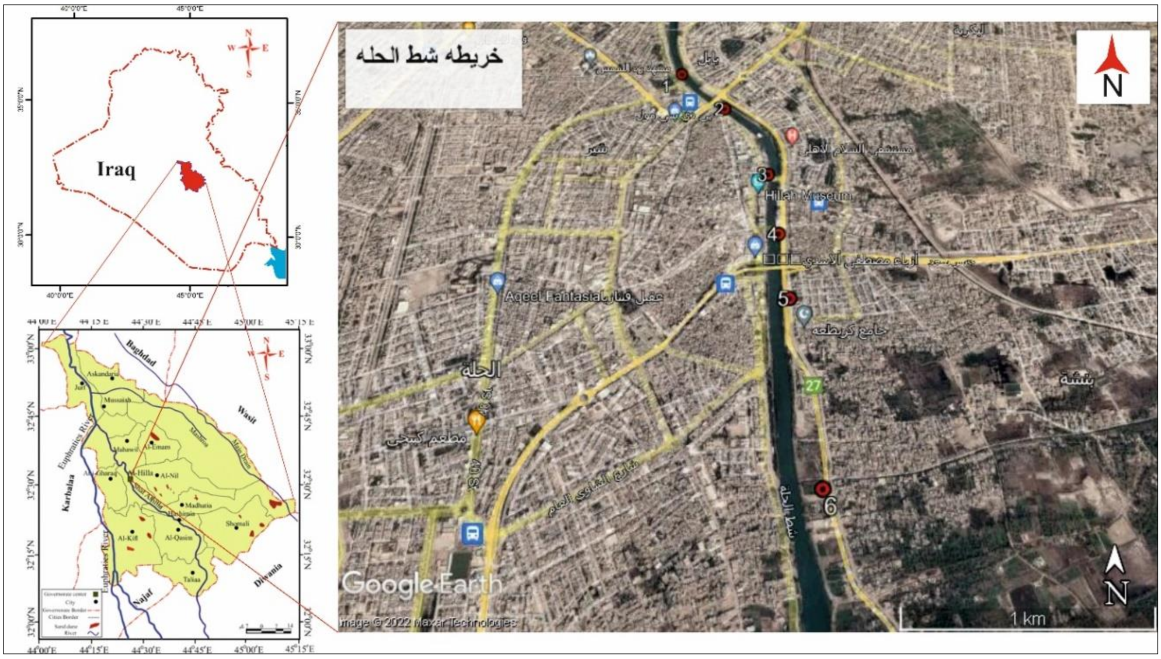

Fig. 1. Satellite map of the station of the study area in Babylon Governorate.

Results and Discussion

The physical tests are shown in the Table (2) below. The liquid limit may be (LL) test is specified by ASTM D ASTMD 424 - 59 standard test method. The test method also allows the test to be performed at MC as 20 to 30 strokes. In the soil bank, the LL is the percentage of the maximum value of LL, which is 20.0% in St. no.1, whereas the minimum value is 18.7% in St. no.4 and the average is 19.46%. All the soil stations have LL less than 50%, thus the soil is classified as having low plasticity because of LL<50%.

Table 2: The results of some physical tests of the study soils.

St	LL%	PI%	M.C%	Specific Gravity	Sat. density g/cm^3	Dry Density g/cm^3
1	20.0	8.1	20	2.66	1.754	1.433
2	19.4	9.0	16.0	2.66	1.781	1.522
3	19.2	8.2	19	2.67	1.705	1.444
4	18.7	7.4	21	2.63	1.890	1.684
5	19.8	9.2	18	2.69	1.730	1.501
6	19.7	10.4	19.3	2.64	1.800	1.551
Average	19.46	8.71	18.88	2.658	1.775	1.522

The plasticity index (PI) is a measure of the plasticity of soils. The plasticity index is the range of water contents, in which the soil exhibits plastic properties. PI is calculated from the equation below:

$$PI = LL - PL \text{ ---------- } (1)$$

In Shatt Al-Hilla bank soil, the PI percentage has the maximum value of LL, which is 21.0% in St. no.1, and the minimum is 16.0% in St. no. 4 with an average of18.88% as given in Table (2). The bank soils in Shatt Al-Hilla are classified as having low plasticity (Table 2) along the study area. The relationship between plasticity index and swelling capability is shown in Table (3).

Table 3: Swelling Capability and plasticity index after (Saeedy, 1997)

Plasticity Index	Swelling Capability
0-15	Low
15-35	Medium
35-55	High
>50	Very high

The bank soils in the study area are classified depending on the data listed in Tables (2 and 3) as having low swelling capability in all stations along Shatt Al-Hilla banks soil.

Specific gravity is defined as the ratio of the weight of soil solids to the weight of water. The specific gravity in sandy soils is estimated to be about 2.65, while for clay soils it may vary from 2.35 to 2.70. The specific gravity (S.G) for Shatt Al-Hilla banks soil (Table 2) has the maximum value of 2.69% in St. no.5, and the minimum is 2.63 in St. no.4 with an average of 2.658.

Also called the water or moisture content (*MC*), which is the percentage of the weight of the water as moisture (*mw*) to the weight of solid particles (*md*) in a particular sample of soil. It is calculated from:

$$MC = (mw / md) * 100) \text{ ---------- } (2)$$

The moisture content of Shatt Al-Hilla banks soil (Table 2) ranges from the maximum value of 21% in St. no.4 and the minimum value of 16% in St. no. 2 with an average of 18.88%.

The values of the saturated density for the soil of the bank slopes in the study area in Table (2) range from the maximum value of 1.89 g/cm^3 in St. no. 4 and the minimum value of 1.705 g/cm^3 in St. no. 3 with an average of 1.775 g/cm^3. While the maximum dry density is 1.684 g/cm^3 in St. no. 4, and the minimun is 1.433 g/cm^3 in St. no.1 with an average of 1.522 g/cm^3.

The results of the chemical analysis and properties of Shatt Al-Hilla banks soil are shown in Table (4).

Table 4: The chemical concentration and properties of Shatt Al-Hilla banks soil.

Sta.	Cu	Pb	Cd	Zn	Ni	SO_3	EC	Gypsum	pH
	ppb						ms/ cm	%	
1	0.003	0.0080	0.0023	NIL	0.0053	2.44	0.97	1.22	8.6
2	0.011	0.0043	0.0081	0.023	0.0021	2.87	1.13	1.09	8.9
3	0.003	0.0042	0.0078	0.011	NIL	1.98	0.98	1.23	8.7
4	0.006	0.0048	NIL	0.0302	0.0105	3.75	1.12	1.42	8.7
5	0.004	NIL	0.0076	0.0291	0.0139	0.99	0.75	1.92	9
6	NIL	0.0043	0.0051	0.0076	0.0092	1.49	0.89	1.32	8.7
Average	0.0045	0.0042	0.0051	0.0168	0.0068	2.25	0.97	1.36	8.76

Lead can be found in various igneous rock minerals, including pyroxene, olivine, alkali-feldspar, and amphiboles (Ameen, 2020).

Many factors influence lead content include changes in the pH and parameters of the basin, the conductivity of the source water, and the acidic conditions in the oxidizing environment (Matthess, 1982). High lead concentrations may cause cancer and mental disease, kidney and other infections. The lead (Pb) concentration in Shatt Al-Hilla banks as shown in Table (4) ranges between 0.008 ppb and Nil with an average of 0.0045 ppb in soil samples will be neither dangerous nor toxic.

Copper (Cu) concentration in water increases with temperature and the acidic solution that frequently coexists with sulfur generating copper sulfate in most rocks. When the quantity of copper (Cu) in water is 1.5 ppb, it is deemed poisonous and causes a variety of ailments that are fatal to humans. If the quantities exceed 2 ppm, the water is hazardous and produces a variety of diseases that can lead to death (WHO, 1996). Because clay minerals and illite absorbed copper from the aquatic environment, producing a drop in its concentration, there is little copper in the studied area (Al-Hiti, 1985). Table (2) exhibits the copper (Cu) concentration of the Shatt Al-Hilla banks ranging from 0.0061 ppb to NIL with an average of 0.0042 ppb. Table (4) reveals that the soil sample's copper concentration is never hazardous

Zinc concentrations in crustal rock minerals including sphalerite, smithsonite, willemite, and hemimorphite are 75 ppm; other sources include animal biological remnants and industrial operations like metallurgy (Hem, 1991). Under low temperatures and pressures, zinc is among the elements found in the mineral’s calcite, dolomite, and clay. Zinc do not change in the existence of dolomite and calcite indicating that digenesis activities on the rocks affect it (Al-Shammary, 2008; Weber, 1964). As indicated in Table (4), the zinc concentration of Shatt Al-Hilla banks ranges from 0.011 ppb to NIL with an average of 0.0168 ppb implying that the soil samples are neither harmful nor toxic.

Numerous minerals including carniorite, millerite, nicolite, and pentlandite contain nickel. By eroding and dissolving rocks and soils, through biological cycles, and industrial processes, nickel enters groundwater and surface water. Ni will be hazardous to people if the content is higher than the acceptable limit in drinking water (WHO, 1999). As indicated in Table (4), the nickel concentration of Shatt Al-Hilla banks ranges from 0.0139 ppb to NIL with an average of 0.0068 ppb implying that nickel concentration in soil samples is neither harmful nor toxic.

Hodges (1976) reported that cadmium (Cd) is a very poisonous element that is not beneficial to human life, and it accumulates in the human body throughout life, particularly in the kidney and liver, and causes kidney problems in humans (so the designation is Itai-I). Weathering of Cd minerals such as cadmoselite, olarite, and greenockite, as well as the earth's crustal rocks, such as clay, which has 19 ppm Cd adsorbed, leached into natural streams. Cd and Zn have similar geochemical features; however, Cd is far less abundant in natural waters (Alloway and Ayers, 1997; Hem, 1991). As indicated in Table (4), the cadmium concentration of Shatt Al-Hilla banks ranges from 0.00023 ppb to NIL with an average of 0.00551 ppb implying that cadmium concentration in soil samples is neither harmful nor toxic.

The electrical conductivity (EC) of the soil is defined as the ability of 1 cm^3 of water to conduct electric current at a temperature of 25 °C (Todd, 1980). It is usually measured in units of (microhms), which is mhos x 10-6 or as used s/cm, and this susceptibility increases with the increase in temperature and is a function of the temperature and the type of ions present in the water and their concentrations. To measure the electrical conductivity of the soil, the soil samples are dried and ground, then sieved in a sieve (2 mm), after that they are mixed with a proportion of water at a ratio of 1:1. The following table is used to determine the type of salinity:

Table 5: The type and degrees of salinity for soils according to Electrical Conductivity (FAO, 1996).

Salinity type	Salinity in ms/cm
Very low salinity	4 − 0
low salinity	8 − 4
Moderated salinity	16 − 8
High salinity	20 − 16
Very high salinity	> 20

As indicated in Table (4), the EC of Shatt Al-Hilla banks ranges from 0.75 in station no. (5) to 1.13 in station no. (2), with an average of 0.97. According to Tables (4 and 5), the soil of Shatt Al-Hilla banks is classified as having very low salinity.

The importance of measuring the pH of the soil lies in the process of erosion of concrete. The concentration of H_2S gas is related to the value of pH, and then a possible converting of this gas to sulfuric acid occurs. Hindi (1982) and Salman (1996) mentioned that hydrogen disulfide gas depends on the pH of groundwater. Where the pH tends to be acidic in the presence of plants and because of the organic acids expelled from the stony neighborhoods and the change in the level of groundwater in the soil, which leads to a change in soil conditions between aerobic and anaerobic, in addition to climate changes. As indicated in Table (4), the EC of Shatt Al-Hilla banks ranges from 8.6 in station no. (1) to 9 in station no. (5), with an average of 8.76.

The presence of gypsum in the soil of the study area is due to its sedimentation and its first formation in the holes and transported by the Tigris and Euphrates rivers. Gypsum deposits are present in the study area in the form of granules of different sizes, lenses or thin layers of different extensions, or the form of crystals. The gypsum content is studied in the study area because of the dangers. Also, it affects concrete because the sulphate ion reacts with lime (slacked lime, $Ca\ (OH)_2$) present in Portland cement to be crystalline gypsum, and the volumetric expansion of gypsum exerts a cracking effect on the concrete (Kezdi, 1974). As indicated in Table (4), the gypsum of Shatt Al-Hilla banks ranges from 1.92 % in station no. (5) to 1.09 % in a station no. (2), with an average of 1.36 %. The permissible limit for gypsum is 2 % in the soil of the study area.

The percentage of sulfate in the soil of the study area is examined. This is to show the extent of this percentage and the possibility of its impact on future projects on the banks of Shatt al-Hilla. Sulfates (soluble) are usually found in the soil as salts of calcium, sodium and magnesium, as the dissolution of sulfates in soil water leads to attacking and eroding concrete. As indicated in Table (4), the Sulphates in the soil of Shatt Al-Hilla banks range from 3.75 % in station no. (4) to 0.99 % in station no. (5), with an average of 2.25 %. The permissible limit for sulfates is 2 % in the soil of the study area.

Conclusions

After studying some physical and chemical properties and trace element concentrations in Shatt Al-Hilla banks soil, the field observations found the following:

Maximum LL percentage is (20.0%) in St. no.1, and the minimum value is (18.7%) in St. No.4 with an average of 19.46%. All the soil stations have LL less than 50, thus the soil is classifies as having low plasticity. The PI percentage is the maximum value of LL as 21.0% in St. no.1, and the minimum value is (16.0%) in St. no.4 with an average of 18.88%. The bank soils in Shatt Al-Hilla are classified as having low plasticity. The bank soils in the study area are classified as having low swelling capability in all stations along Shatt Al-Hilla banks soil. The maximum value of the specific gravity (S.G) is 2.69% in St. no. 5, and the minimum value is 2.63 in St. no. 4 with an average of 2.658%. The maximum moisture content is (21%) in St. no. 4, and the minimum value is 16% in St. no. 2 with an average of 18.88%. The maximum value of saturate density is 1.89 g/cm^3 in St. no. 4, and the minimum value is 1.705

g/cm^3 in St. no. 3 with an average of 1.775 g/cm^3. While the maximum value of dry density is 1.684 g/cm^3 in St. No. 4, and the minimum value is (1.433 g/cm$_3$) in St. no.1 with an average of 1.522 g/cm^3.

The lead (Pb) concentration in Shatt Al-Hilla banks ranges between 0.008 ppb and Nil with an average of 0.0045 ppb. The copper (Cu) concentration of the Shatt Al-Hilla banks ranges from 0.0061 ppb to NIL with an average of 0.0042 ppb. The soil sample's copper concentration is neither hazardous nor poisonous. The zinc concentration of Shatt Al-Hilla banks ranges from 0.011 ppb to NIL with an average of 0.0168 ppb. The zinc concentration in soil samples is neither harmful nor toxic. The nickel concentration of Shatt Al-Hilla banks ranges from 0.0139 ppb to NIL with an average of 0.0068 ppb implying that nickel concentration in soil samples is neither harmful nor toxic. The nickel concentration of Shatt Al-Hilla banks ranges from 0.0139 ppb to NIL with an average of 0.0068 ppb. The nickel concentration in soil samples is neither harmful nor toxic. The cadmium concentration of Shatt Al-Hilla banks ranges from 0.00023 ppb to NIL with an average of 0.00551 ppb. The cadmium concentration in soil samples is neither harmful nor toxic. From the study of the concentration of the heavy metals above, we found that all the soil samples of Shatt Al-Hilla are neither toxic nor dangerous. The EC of Shatt Al-Hilla banks ranges from 0.75 in station no. (5) to 1.13 in station no. (2), with an average of 0.97. The soil of Shatt Al-Hilla banks is classified as having very low salinity. The pH concentration of Shatt Al-Hilla banks ranges from 8.6 in station no. (1) to 9 in station no. (5), with an average of 8.76. The Gypsum content in Shatt Al-Hilla banks ranges from 1.92% in station no. (5) to 1.09% in station no. (2), with an average of 1.36%. The Sulphates in the soil of Shatt Al-Hilla banks range from 3.75% in station no. (4) to 0.99% in station no. (5), with an average of 2.25%.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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