Malaysian Journal of Chemistry, 2021, Vol. 23(4), 77-88
(Special Issue: 3rd Virtual Symposium on Multidisciplinary Science 2021 (V-SMS2021))

Grain Size Analysis of Sand Fractions and the Sedimentary Environment of Selected Soil Samples from Southern and Northern Iraq

Saraa Noori Shaker Al baghdady[1], Luma Abdalalah Sagban Alabadi[2]
[1]Department of Soil Science and Water Resources, University of Al-Qadisiyah
[2]Department of Horticulture and Garden Engineering, College of Agriculture, University of Al-Qadisiyah
*Correspondence author (e-mail: luma.al-abadi@qu.edu.iq)

Soil particle size analysis is a vital sedimentological tool used to determine hydraulic conditions, transport methods, and sedimentation. In this study, 4 soil sampling sites were selected within the Erbil governorate in northern Iraq: Shaqlawa, Salah al-Din Resort, Kouri, and Harir. In addition, 4 soil sampling sites chosen in the Maysan governorate in southern Iraq were Ali al-Gharbi, al-Batira, al-Maimuna, and al-Tayyib. Statistical criteria for particle sizes and binomial distributions were used to reveal the sedimentation processes and sedimentation environments. It was observed from the particle size distribution that loam alluvial clay and alluvial clay predominated in the Maysan soil samples, while alluvial loam textures predominated in the Erbil soils. The fine sand particles were predominant, followed by the medium, and then the very fine sand particles; also there was a decline in the coarse and very coarse sand particles in all studied soil samples from Maysan. However, the fine and medium sand particles were predominant, with similar proportions to the very fine, coarse, and very coarse sand particles in the soil samples from Erbil.

There was a variation in the volume distributions of the sediments of these northern soils, which could be observed through the relative change in the values of Phi compared to the soils located in southern Iraq. Therefore, the volume distribution of the sediments in most of them tended towards that of medium sands, while for Erbil soils they tended towards medium and fine sands. The results provided interesting data on the nature of the sedimentary environment.

The standard deviation values ranged between 0.98 - 1.10, indicating a good to a poor sorting degree in the soils of southern Iraq. In northern Iraq, the standard deviation values ranged between 1.42 - 1.185, indicating a poor sorting degree. The poor sorting could be explained by the proximity of the soil to the sedimentation source and the low momentum of the carrier factor. The results also showed a strong deviation towards fine particles in Maysan soil samples while Erbil soils had soft diffraction values. These results confirmed kurtosis (KG) values, which indicated that the degree of kurtosis was of the medium and pointed type in Maysan soils, while in Erbil soils it was of the flat to medium kurtosis type. The results of the sedimentary environment profiles also showed that the samples from the Maysan governorate fell within a riverine environment. In contrast, the samples from the Erbil governorate were located outside the scope of the riverine processes and were attributed to the nature and topography of the land in northern Iraq which is rugged and mountainous, unlike southern Iraq.

Key words: Sedimentary environment; sand fraction; statistical parameters of particles sizes

Received: June 2021; Accepted: October 2021

Sediment refers to any solid material suspended, precipitated and then accumulated in a sedimentation basin after sufficient time. Sediments result from weathering, erosion, transport, and then deposition by wind, water and snow. The environment is that part of the Earth's surface that can be distinguished from other parts of its surroundings based on natural, chemical, and biological processes, thus influencing and controlling the nature of the deposited sediments. Because of the diversity of the factors and natural conditions that characterize each environment, the sedimentary environments are classified **[17,20,23]** as the surface region of the lithosphere, which lies above or below sea level. These can be distinguished by a set of chemical, physical and biological characteristics and classified as erosion environments, non-sedimentation environments, or sedimentary environments based on physical and chemical processes **[23]**.

†Paper presented at the 3rd Virtual Symposium on Multidisciplinary Science 2021 (V-SMS2021)

There are groups of influencing factors such as the source of the rocks, the nature of the original material, and physical sorting**.** These factors are determined by the hydrodynamic conditions and transport factors, which have an essential role in the sedimentation process, and the mechanical abrasion that is formed during the transport process, which has a distinct role in changing the size and shape of the granules in terms of fracture, spherification, and rotation **[8,15]**. Sedimentation varies along the course of a river **[25]**. When there is a flow of high-density current, it carries gravel, coarse sand, and all that is in the suspension. However, deposits of medium size sands are transferred if there are low-density currents. These deposits range from mature and immature to super mature, depending on climate action and transportation distance. In general, the size of the sedimentary particles is reduced, and their sorting is improved by moving away from the course of the transporting river.

Transport of sediments depends on how the energy reaches the particles, which in turn affects the type of transport. There are two types of sediment transporters **[6]**. The sediments are either suspended or basal, forming a thin layer with a thickness of a few grains. The climate has a significant role in forming these soils, and this role is determined by the floods that are affected by cycles of humidification and drought, as climate changes and fluctuations impact the succession of sedimentation processes. Also, long periods have an essential role in increasing sedimentation. At the end of the sedimentation cycle, radical changes appear in the Earth's landscape.

A study of sediments begins in the field and requires an understanding of basic concepts and definitions of their components. It is also essential to know how to obtain the relevant information: firstly, what can measured in the field, and secondly, what can be expressed by quantitative curves. It is necessary to diagnose and estimate the sedimentary characteristics used in the environmental diagnosis and then analyze the environments and their contributing processes **[1]**. Since the sedimentary environments have variables, some of which are physical and chemical, they must belong to a specific geomorphological unit of shape and size. Therefore, there is a correlation between sedimentary conditions, the nature of the sedimentation, its characteristics, and the nature of the sedimentation medium, whether it is watery or airy, in addition to the study of sediment analysis and classification into volumetric groups, reflecting the nature and direction of the currents that deposited them. Therefore, our current study aimed to determine the sedimentary environment (whether riverine or coastal), and its sedimentary characteristics using statistical parameters, and to find the relationship between those environments in the sampling sites of soils from the Maysan and Erbil governorates, the distribution of sediments in them, and suitable environmental models for them.

MATERIALS AND WORKING METHODS

Field Procedures

We aimed to achieve the research objectives of determining the sedimentation environment of soils from four sites in the Erbil Governorate located in the north of Iraq: Shaqlawa, Salah al-Din Resort, Kouri, and Harir. Four sites were also selected in the Maysan Governorate of southern Iraq: Ali Al-Gharbi, Al-Batyra, Al-Maimuna, and Al-Tayyib. Surface samples were taken at a depth of 0 - 30 cm at all study sites.

Laboratory Procedures

- Soil samples were extracted and then transferred to the laboratory, where they were air dried, and broken up manually using a polyethylene hammer to preserve their morphology. Finally, they were passed through a 2 mm sieve and kept in plastic containers.

- The particle volumes were measured for the mechanical analysis of soil separation according to the pipetting method in a previous study **[10]**.

- Sedimentary Statistical Standards:

To calculate these parameters, the cumulative curves and the accuracy of these curves extracted depend on the mechanical analysis of soil separation or particle sizes and their texture. Therefore, volumetric analysis was carried out using sieves according to a previously published method **[11]**. First, 100 g of the sample was taken and washed using a 63-micron sieve. The clay and silt went through the sieve while the sandy part was separated and dried. The separated sand from each sample was divided into five classes: very coarse (V.C), coarse (C), medium (M), fine (F), and very fine (V.F) sand, according to the volumetric scale **[27]**.

The sifting process was carried out by taking 50 grams of sand and placing it in the sieve which was then covered with a lid, and then regulating the vibrating device. After 15 minutes, the device was turned on, and at the end of the sifting time, each sifter was emptied of its contents, and accurately weighed with a sensitive scale, and then the particle volumes of each type of the sand was measured, with the results shown in Figure 1.

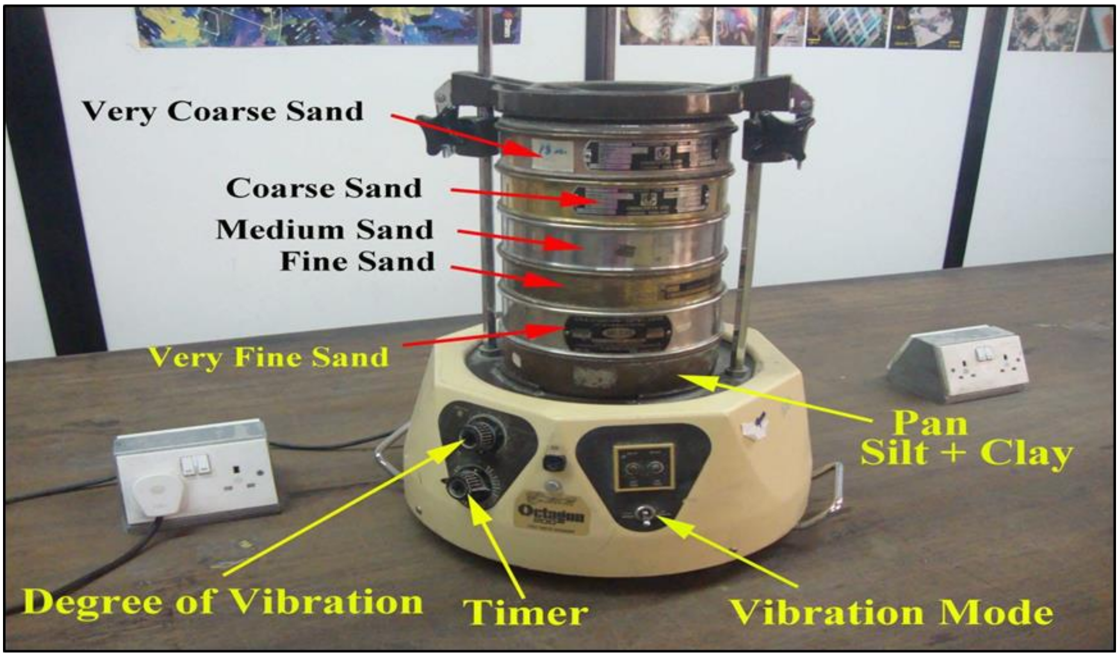

Figure 1. Sieves used for volumetric analysis with a vibrating device.

The sedimentary statistical parameters were calculated, and the units of Phi (φ) obtained **[26, 12, 22]** as follows:

$$\varphi = -\log 2\, d(mm) \qquad (1)$$

where:

φ = The diameter of the particles in Phi units.

d = The diameter of the particles in millimeters.

The sedimentary statistical criteria measured included the median size, the values of the standard deviation or the degree of sorting, the standardized skewness of the particles, and the kurtosis, each according to its equations as follows:

Median diameter Md (Ø50)

This is calculated from the cumulative aggregate curve of the volumes of particles by adopting the value central to the curve and then comparing it with the following (see Table 1) to know the type of deposited particles.

Mean Size, Mz

This is calculated by using the previous table to determine the type of deposited particle and according to the following equation:

$$MZ = (\varphi\, 16 + \varphi\, 50 + \varphi\, 84) / 3 \qquad (2)$$

where:

16φ = The Particle size at 16% of the cumulative aggregation curve.

50φ = Particle size at 50% of the cumulative aggregation curve.

84φ = Particle size at 84% of the cumulative aggregation curve.

Standard deviation values or the degree of sediment sorting, Iσ:

This is calculated using the following equation (3):

$$\sigma I = [(\varphi\, 84 - \varphi\, 16) / 4] + [(\varphi\, 95 - \varphi\, 5) / 6.6] \qquad (3)$$

Table 1

The type of precipitated particles	Particle Volume Average φ Md
Sand	4-1
Rough green	5-4
Medium and soft green	8-5
Clay	8-11

Table 2

Sediment sorting degree	Iσ . value
V.Well Sorted	0.35 >
Well Sorted	0.50 – 0.35
Moderately Well Sorted	0.71 – 0.50
Moderately Sorted	1.00 – 0.71
Poorly Sorted	2.00 – 1.00
V.Poorly Sorted	4.00 – 2.00
Extremely Poorly Sorted	4.0 <

From Table 2, determine the type of sediment sorting degree.

The values of the skew rate (skew), SKI

This is calculated using the following equation (4):

SKI = [(φ 16 + φ 84 +2 φ 50) / 2* (φ 84- φ 16)] + [(φ 5 + φ 95 -2 φ 50) / 2 * (φ 95 - φ 5)]   (4)

Table 3 was used to determine the diffraction of the precipitated particles.

Values of the kurtosis standards, *KG:*

This is calculated with the following equation (5):

KG = [(φ 95 -φ 5) / 2.44] * (φ 75 - φ 25)   (5)

Table 3

SKI deviation criteria value	Diffraction degree
Very Fine	(0.3 +) – (1.0 +)
Fine	(0.1 +) – (0.3 +)
Near Symmetrical	(0.1-) – (0.1+)
Coarse	(0.3-) – (0.1-)
Strongly Coarse	(1.0-) – (0.3-)

Table 4

Kurtosis quality	The value of the kurtosis standers KG
Very Platykurtic	< 0.67
Platykurtic	0.90 – 0.67
Mesokurtic	1.11 – 0.90
Leptokurtic	1.50 – 1.11
Very Leptokurtic	3.00 – 1.50
Extremely Leptokurtic	>3.00

Table 4 was used to determine the degree of kurtosis of the sedimentary particles.

RESULTS AND DISCUSSION

Volumetric analysis of soil particles

Volumetric analysis is of paramount importance in identifying the method of formation and origin of rocks, and it provides a clear picture of the nature of the conditions in which they were deposited **[5].** The accuracy of the statistical criteria used in determining the sedimentary environments depends on the results of the soil separation analysis and the determination of their textures. The validity, accuracy, and acceptance of the work increases statistically with the increase in the number of classes, so the sands of each sample were divided into five classes: very coarse (VC), coarse (C), medium (M), fine (F) and very fine (VF).

Table 5 shows the relative distribution of the soil samples separated into sand, silt, and clay, and their texture types, which were distributed throughout the classes, among them the moderately fine textures (silty clay loam (SiCL)) in soils (Al-Batira and Al-Tayyib) from Maysan Governorate. This is attributed to the effect of large quantities of soft materials due to the low velocity and intensity of the transporting water and its load capacity. Soft, silty clay (SiC), was identified in the soils of Al-Maimuna and Ali Al-Gharbi located in the Maysan Governorate. These textures were due to their location within transitional sedimentation zones between the slow and intense sedimentation zone. The texture became smoother further away from the source because fine sediments need a greater distance for sedimentation, unlike coarse sediments that deposit close to the source that transports them **[3].**

A similar distribution of soil texture types were observed in samples from Erbil governorate with its silt loam (SIL) texture, where the predominance of the silt was clear in all soil samples. This was due to their location within transitional sedimentation zones in topographically elevated areas.

Table 6 shows the results of the volumetric analysis of the separated sand. The dominance of the fine sand separated from all study soils located in Maysan governorate was 40.8 - 48.7mm, followed by the medium sand in terms of dominance 29.7 - 37.5mm, then the very fine sand 8.9 - 14.3mm and coarse sand 3.3-7.4mm and finally very coarse sand that was between non-existent to very few. 0.0-4.7mm. Figure 2 shows the volumetric analysis of these separations within the histogram of soil samples located in Maysan Governorate.

Table 5. Soil granular volumetric analysis by Pipette method

Sample Number	Sand %	Silt %	Clay
Al-Batira	12.5	55.6	31.9
Al-Maimuna	9.4	50.2	40.4
Al-Tayyib	10.7	52.8	36.5
Ali Al-Gharbi	8.5	49.2	42.3
Korean	17.5	62.7	19.8
Harier	14.4	58.6	27.0
Shaqlawa	16.8	64.1	19.1
Salahaddin	17.2	65.3	17.5

Table 6. Volumetric analysis of sandy fraction by sieves

Sample numbers	very coar sand 2-1 mm	coarse sand 1-0.5 mm	medium sand 0.5-0.25 mm	fine sand 0.25-0.125 mm	very fine sand 0.125-0.0625 mm
Al-Batira	0.0	3.3	36.7	48.7	12.9
Al-maimona	0.0	4.4	29.7	40.8	14.3
Al-tyyeb	4.7	6.5	30.9	44.7	13.4
Ali Al-Gharbi	0.0	7.4	37.5	46.2	8.9
Korean	6.9	7.3	34.9	38.2	12.7
Harier	4.5	7.2	38.2	35.6	14.5
Shaqlawa	5.2	8.4	39.1	31.9	15.4
Salahaddin	6.8	10.8	30.1	38.4	13.9

For the soil samples from Erbil governorate, the results showed the dominance of fine sand separated 31.9-38.4 mm, followed by medium sand 30.1-39.1 mm, then very fine sand 12.7-15.4 mm and coarse sand 7.2-10.8 mm, and finally very coarse sand 4.5 - 6.9 mm. However, the results for soil samples in Erbil Governorate are given in Table 2 and Figure 3, which show the distribution of the sand classes within the histogram, indicating the predominance of medium sand in the soils of Shaqlawa and Harir. In contrast, fine sand was predominant in the soils of Salah Al-Din and Kouri.

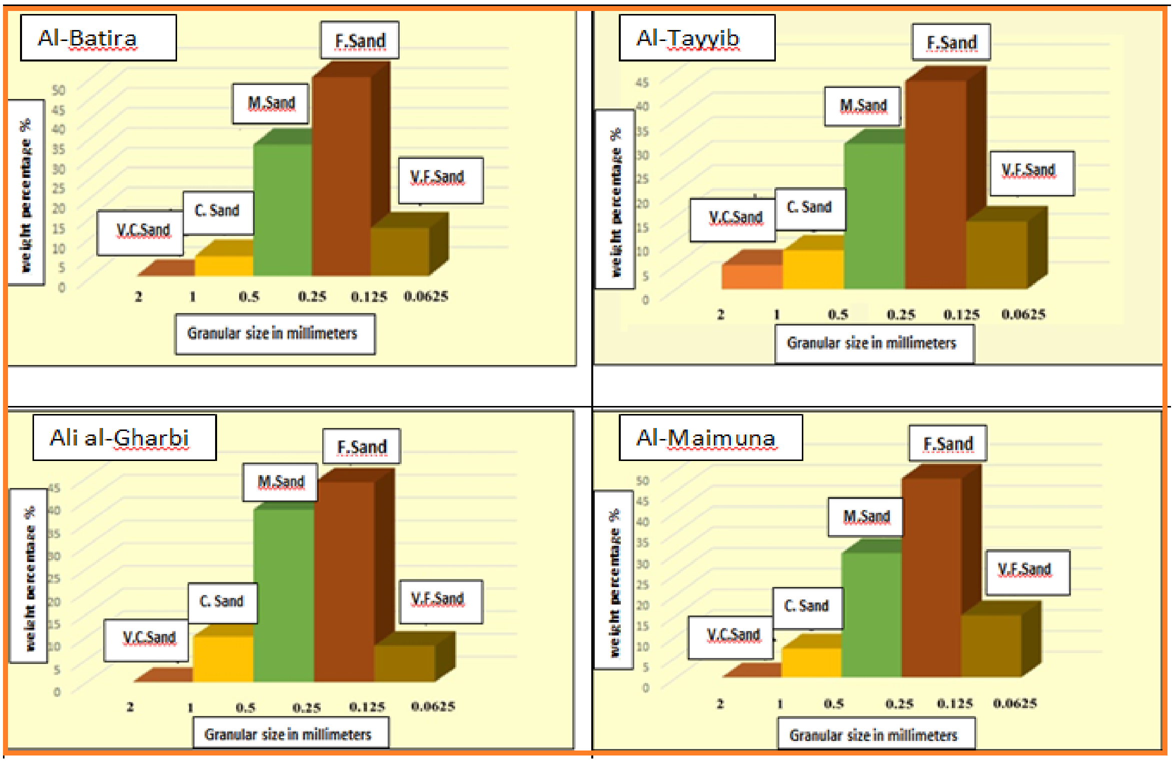

Figure 2. Histograms of the samples from the Maysan Governorate

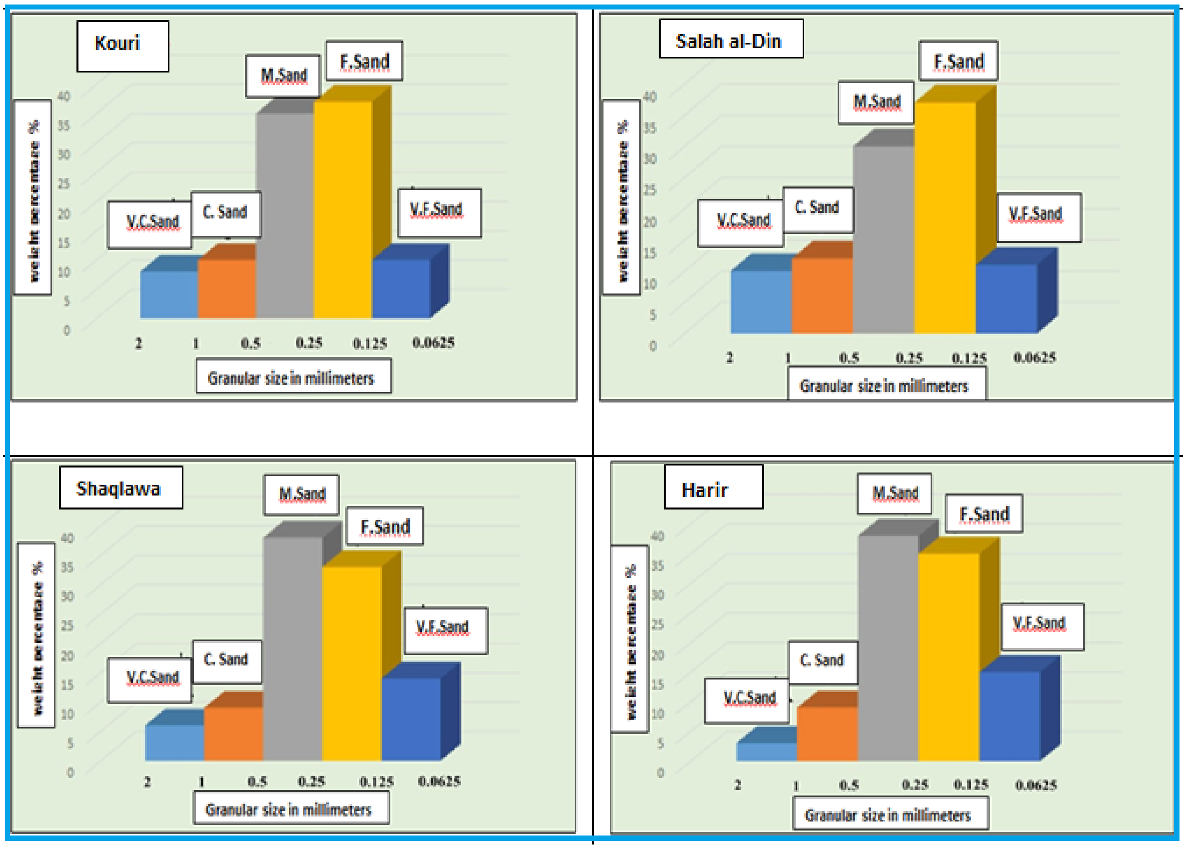

Figure 3. Histograms of the studied samples from Erbil governorate

There was an apparent discrepancy in the ratios of these classes, due to the discrepancy in the energy and momentum of the carrier factor for these separators, between the strong momentum that leads to the deposition of coarse particles, and the lower energy of the transmission factor and a decrease in its intensity, which leads to the transfer of fine particles, such as clay and silt **[3].** This is in addition to the distance of the vector factor from the site of sedimentation of the soil particles **[1].**

Cumulative Curves

Volumetric analysis in mm and phi units is one of the winter worth size classes. The results are more straightforward using phi units **[16].** Although the coarse particles were fewer and often negative, the finer particles were more significant in number **[19].**

Cumulative weight curves are critical in studying sediments as statistical parameters can be extracted from this data. Figure 4 presents the cumulative weighted curves of the separated sand classes in the soil samples from the Maysan Governorate, which showed a high percentage of fine sands, which fell within the category (φ2 - φ3) 48.7, 46.2, 44.7, and 40.8% for each of Al-Batirah, Ali Al-Gharbi and Al- Tayyib, respectively. This was followed by the medium sands, which fell within the category (φ1 - φ2) with 37.5, 36.7, 30.9, and 29.7 % in each of Ali Al-Gharbi, Al-Batira, Al-Tayyib and Al-Maimuna, respectively. The percentages of very fine sand fell in the category (φ3 - φ4) with 14.3, 13.4, 12.9, and 8.9% for Al-Maimuna, Al-Tayyib, Al-Batira and Ali Al-Gharbi, respectively. The lowest percentages were recorded in the coarse and very coarse sediments category (φ0 - φ1) and (φ1 - φ0), with 7.4, 6.5, 4.4, and 3.3% in Ali Al-Gharbi, Al-Tayyib, Al-Maimuna, Al-Batira and 4.7, 0.0, 0.0 and 0.0% in Al-Tayeb, Al-Batira, Al-Maimuna, Ali Al-Gharbi, respectively.

Table 7. The normal progression of sediment – grain sizes in mm and phi units using the Wentworth scale.

mm	2	1	0.5	0.25	0.125	0.064	0.032	0.016	0.008
Phi (φ)	–1	0	1	2	3	4	5	6	7

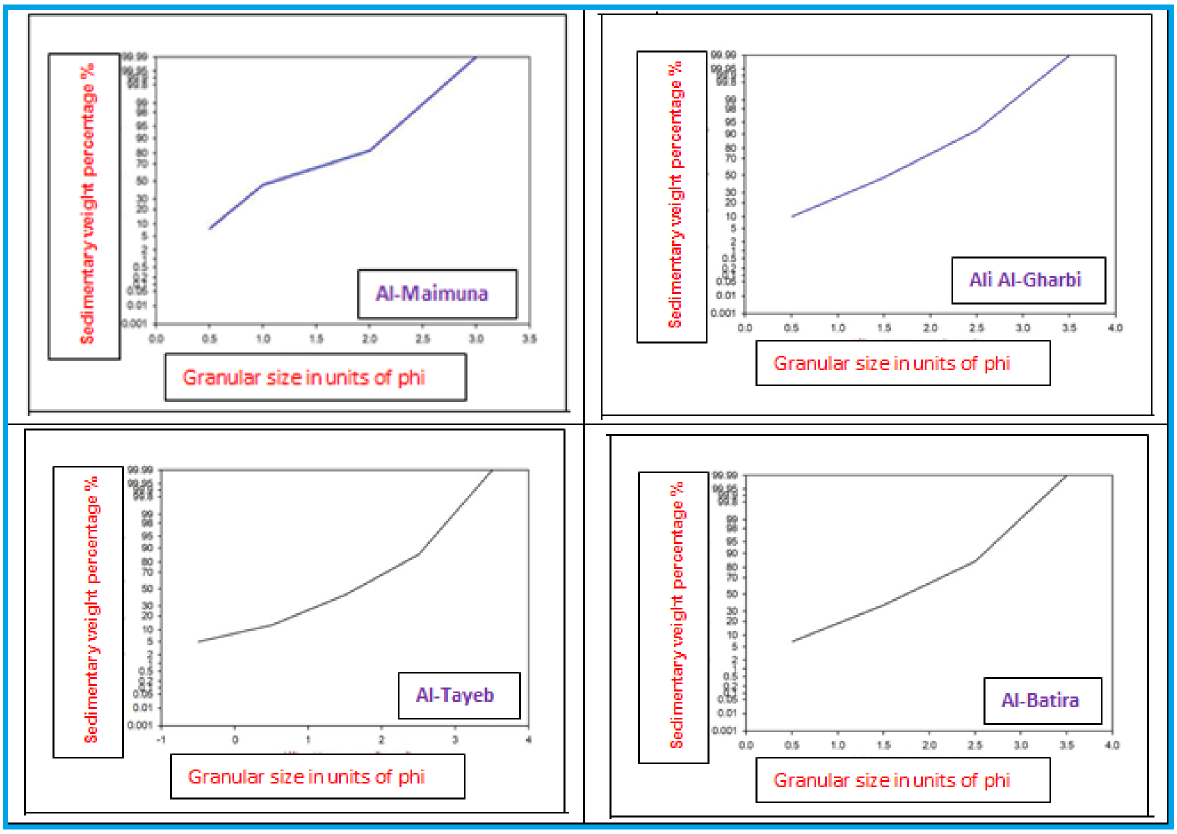

Figure 4. Cumulative weight curves of the samples from the Maysan Governorate

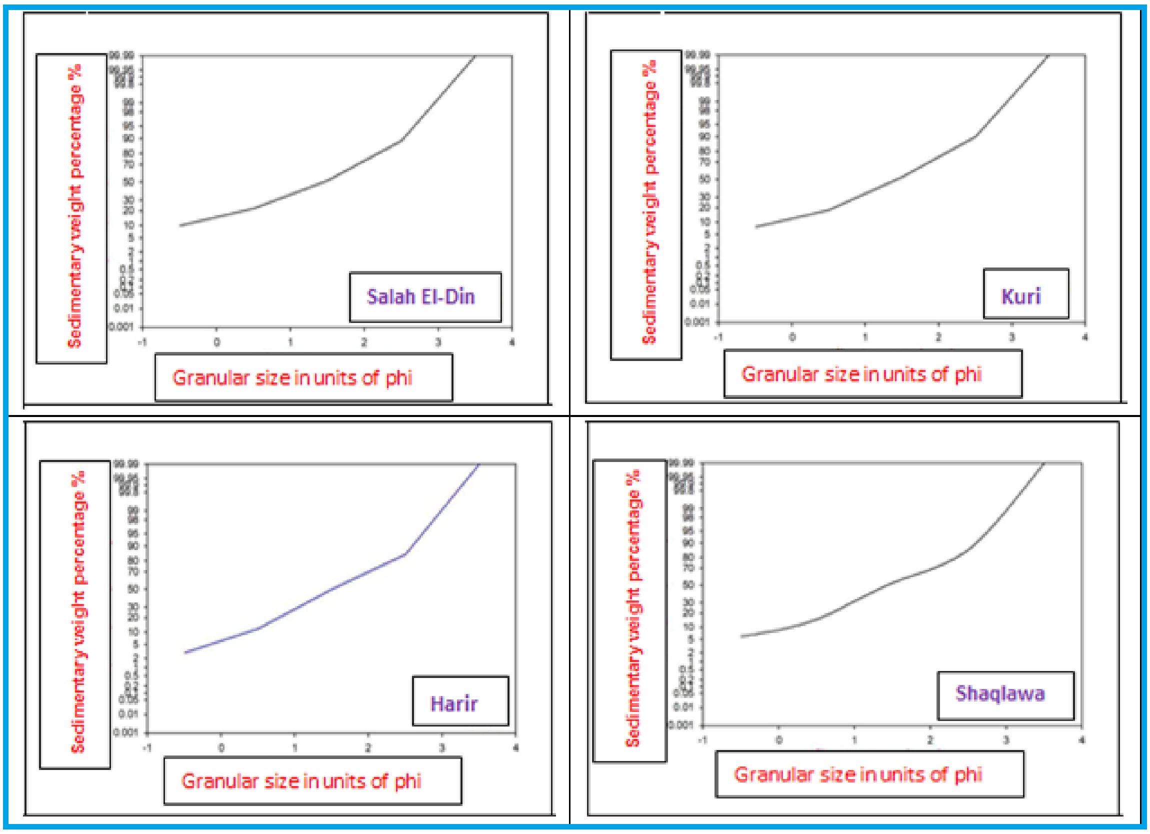

Figure 5. Cumulative weight curves of samples from Erbil governorate

Figure 5 presents the cumulative weight curves of the separated sand classes for soil samples from Erbil Governorate. The results showed a convergence in the proportions of the fine sand particles within the category (φ2 - φ3) and the medium sand in the sedimentation category (φ1 - φ2) with 38.4, 38.2, 35.6, and 31.9% in the soils from Salah al-Din, Kouri, Harir and Shaqlawa and 39.1, 38.2, 34.9, and 30.1% in soils from Shaqlawa, Harir, Kouri and Salah al-Din, respectively. The proportions of fine sand which fell within the sedimentation category (φ3 – φ4) were 15.4, 14.5, 13.9, and 12.7% in soils Shaqlawa, Harir, Salah al-Din and Kouri, respectively. The lowest percentages were recorded in coarse and very coarse sands (φ0 – φ1) and (φ1 – φ0), with 10.8, 8.4, 7.3, and 7.2% in Salah al-Din, Shaqlawa, Kouri and Harir and 6.9, 6.8, 5.2, and 4.5% in soils of Kuri, Salah El-Din, Shaqlawa and Harir, respectively.

There was an apparent discrepancy in the characteristics of the distribution of the volumes of the separated sand classes for the soil samples in this study. This discrepancy may be attributed to the characteristics of the sediment flow process, the length of the distance during transportation, and the climatic conditions. However, there was a general trend towards an increase in the fine and medium sand classes in all soil samples. This increase was attributed to the regularity of the slope and the flow speed at the sites of the sedimentary phenomena **[4].**

Statistical Parameters

Statistical constants or parameters are essential mathematics tools used in many applications, for organizing data and for various other uses. Many scholars have proposed different sediment criteria. One study **[13]** suggested a series of statistical criteria in close agreement with those proposed by another **[16].** The former used all volume analyses regardless of their method; this was more practical and representative because they were based on more detailed cumulative curves. Inman's parameters were insufficient because they are based on two or three points in the cumulative curve. The measured statistical criteria included median MDZ, mean size MZ, standard deviation or sorting, skewness SKI, and kurtosis KG.

Table 8 shows the mean granular size (MDZ) values for the soil samples in this study. The averages of those values in the separated sand classes were between 1.49 - 1.75 φ, which indicated that the median size was within the range of the medium sand located in the Maysan Governorate. For the soil samples from Erbil Governorate, values were between 1.48 - 1.65 φ, which indicate that its volumes were within the fine and medium sand range. This was confirmed by the values of the average total particle size MZ, which also fell within the range of 1.31 - 1.71 φ for the soils located in Maysan and between 1.25 - 1.63 φ for the Erbil soil samples.

Table 8. Values of the statistical criteria for the soil samples

Sample numbers	Statistical criteria				
	Mediator MDZ	Arithmetic mean MZ	standard deviation σ I	Skewness (SKI)	Kurtosis (KG)
Al-Batira	1.49	1.71	1.10	0.32	1.12
Al-Maimuna	1.75	1.31	0.98	0.34	1.14
Al-Tayyib	1.55	1.70	1.01	0.35	1.17
Ali Al-Gharbi	1.60	1.53	1.00	0.33	1.08
Korean	1.65	1.26	1.45	0.19	1.03
Harier	1.58	1.63	1.55	0.27	0.88
Shaqlawa	1.55	1.45	1.58	0.30	0.79
Salahaddin	1.48	1.25	1.42	0.29	1.01

The degree of standard deviation σI refers to the degree of sediment sorting. The kinetic energy of sedimentation factors of 0.98 - 1.10 φ for the Maysan soil samples, indicating that the degree of sorting was between good to poor. As for the Erbil soils, the degree of sorting (standard deviation) was 1.42 - 1.58 φ, which indicated poor sorting, attributed to the variable current speeds and disturbances during sedimentation. A good sorting degree is due to a smooth and stable stream **[7].** These sorting values were inversely proportional to the degree of improvement in their sorting, as confirmed by a previous study **[1].** Jassim **[18]** also attributed the inadequate screening to its proximity to sedimentation sources and the low momentum of the carrier factor. It was also an indication of a mixture of sedimentary particles resulting from more than one process and a vector for these sediments **[2].**

Table 8 showed the values of the deflection criteria (skewness, SKI), which represents the majority of particles in the sample in terms of roughness and smoothness **[2,4,21].** There was a strong skew towards fine particles, which ranged between 0.32-0.35 φ for soils in the Maysan Governorate. On the other hand, the values for Erbil soil samples were 0.19-0.30 φ, indicating fine diffraction values, which reflect the lack of phenomena related to scratching and evaporation processes, despite exposure to mechanical weathering processes during their movement from the source to the deposition site. This was confirmed by the kurtosis (KG) values, which indicate the degree of curvature of the kurtosis curve caused by the majority of the sample sizes, which is usually related to some form of dispersion and the nature of the distribution **[4].** These values ranged between 1.08 - 1.17 φ, which indicated that the degree of swelling of the sand particles was between the medium Mesokurtic type to the pointed Leptokurtic type.

Furthermore, the sediments that consisted of coarse and fine sands were the ones that had a very tapered bulge, indicating that there were two different sedimentation conditions in their environments, one an environment of calm water sedimentation, and the other an environment with a higher momentum and speed that allowed the transfer of coarser and larger particles **[1].** The kurtosis values for the soil samples from Erbil ranged between 0.79 and 1.03 φ, and these values indicated the degree of kurtosis of sand particles from the flat Platykurtic type to the average Mesokurtic type. The degree of flat kurtosis indicated that the samples had been exposed to the same depositional environment conditions.

Bivariate Diagrams

Several researchers have observed relationships between statistical parameters and the type of depositional environment. Therefore, two common sedimentary environments were chosen, reflecting two worlds **[14,24].** The results shown in Figure 6 were obtained by applying the environment profiles of the Maysan soil samples, and using a Stewart diagram, it was found that they had occurred within riverine sedimentation processes, that is, the action of riverine processes deposited them **[9].** Furthermore, the fact that all the samples were located within floodplains, which were formed by floods from river basins within Maysan province, was also evident from Friedman's diagram in Figure 8.

Figure 7 shows that according to the Stewart chart, the Erbil soil samples occurred in an area outside the scope of the riverine operations, but not far away. This was due to the topographical and geographic nature of the land in northern Iraq, which is different from the south. In the north, the lands are rugged and represent mountainous areas, so sediments accumulate due to torrential rain and within the environment of alluvial fans, which are considered calm torrents or very high speed, followed by sudden precipitation. This is also clear in the Friedman scheme, as we find that soil samples in Erbil were collected from locations far from the border between the riverine and coastal environments.

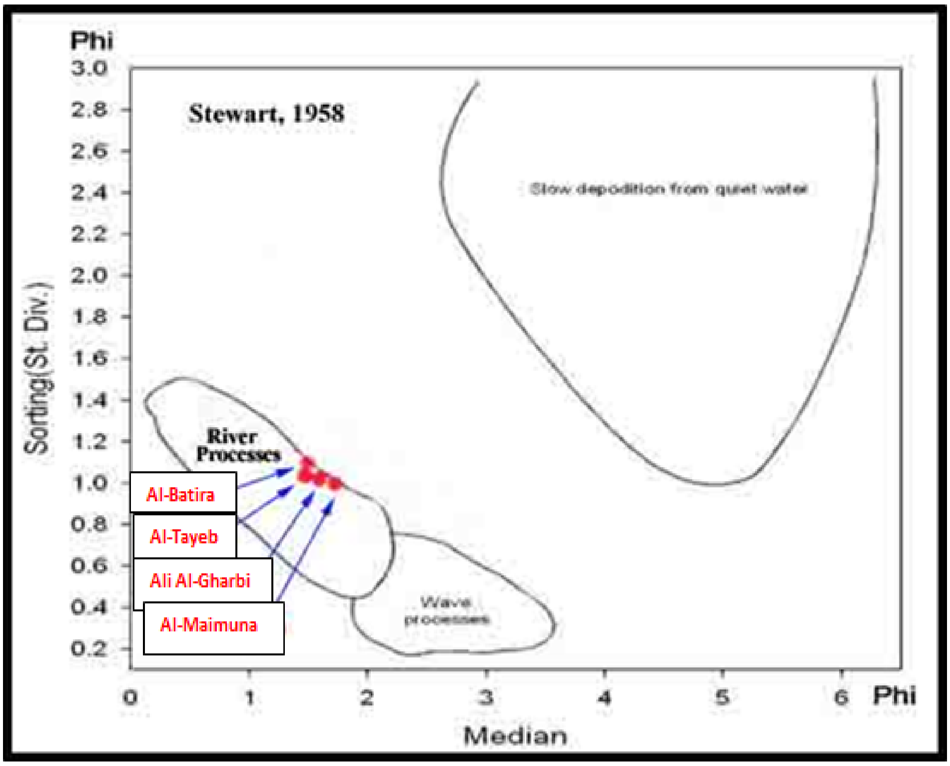

Figure 6. The Stewart chart and its statistical criteria for samples from the Maysan Governorate

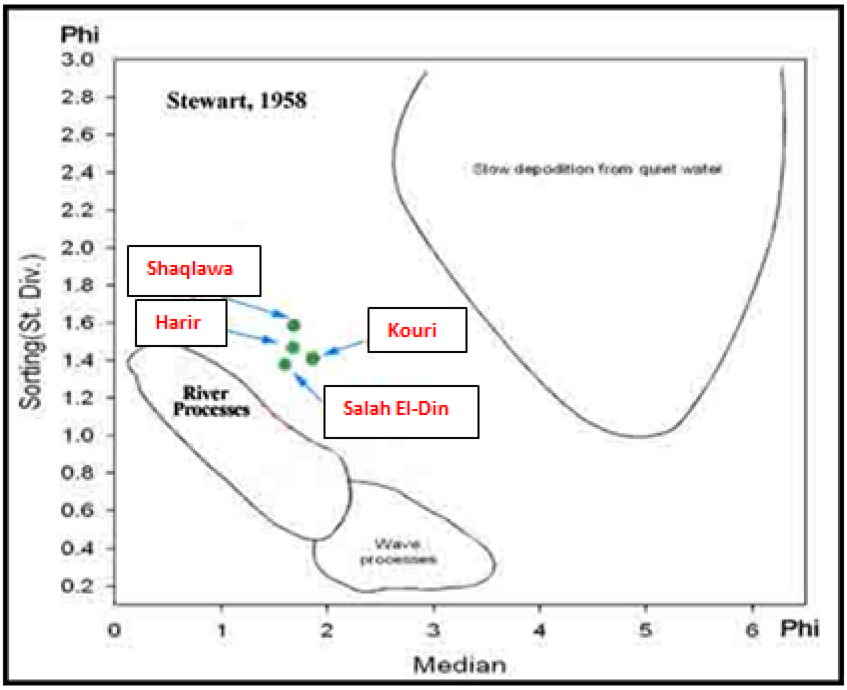

Figure 7. Stewart chart and its statistical criteria for samples from the Erbil Governorate

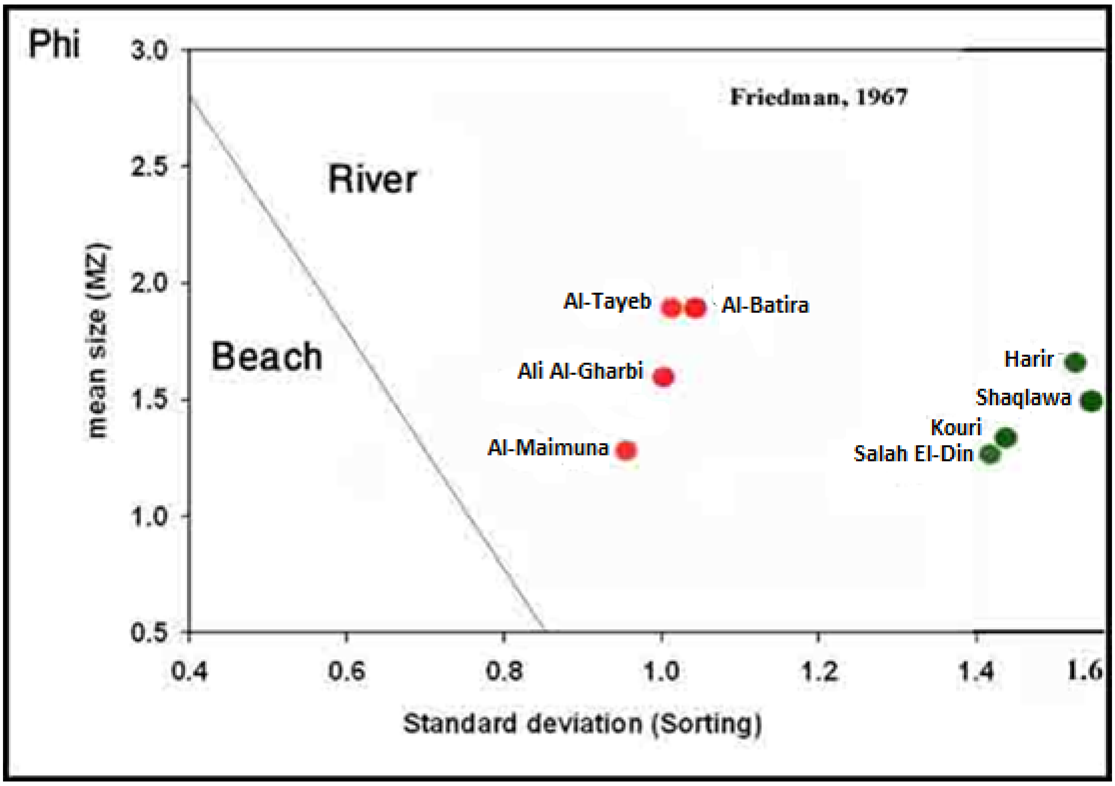

Figure 8. Friedman's world chart and its statistical criteria for the samples from the Maysan and Erbil governorates

CONCLUSIONS

There was a diversity in the studied soils, which ranged between silty clay loam (SiCL) and silty clay (SiC) with a predominance of fine sand classes, and the degree of sorting ranged between good to poor for Maysan soils. However, Erbil soil samples were categorized as silt loam (SIL), and the fine and medium sand classes were dominant, with a poor sorting degree. Furthermore, there was a substantial deviation of the Maysan soils towards fine particles, with a degree of kurtosis ranging from the medium type (Mesokurtic) to the pointed type (Leptokurtic), while the Erbil soils were within the values of fine diffraction and the degree of kurtosis ranged between the flat type (Platykurtic) to the medium type (Mesokurtic). The environmental profiles also showed that the Maysan soils fell within riverine sedimentation processes. In contrast, the Erbil soils occurred outside the riverine processes and were collected by torrential rains but within the environments of alluvial fans and in locations far from riverine and coastal environments.

REFERENCES

1. Abbas, Janan Abd al-Amir (2007) Determining the sedimentation environment of the Kut-Batira project from the south of the Iraqi alluvial plain. *Journal of the College of Education for Girls / University of Baghdad*, **18(1)**, 105–118.

2. Abd al-Amir, Hamid Kazem and Jihan Jamal Juma (2020) Patterns and Distribution of Map Units and Sedimentation Environment of Some Soil Chains of the Great Musayyib Project in Iraq. *Syrian Journal of Agricultural Research*, **7(4)**, 296–310.

3. Abd al-Amir, Hamid Kazem (2017) Biological analysis and statistical constants of the soil units map for the Great Musayyib Project / Babil Governorate. *Karbala Journal of Agricultural Sciences*, **4(4)**, 203–217.

4. Al-Jilani, Al Sayed Salih Al-Sadiq (2017) Volumetric (mechanical) analysis of alluvial sediments in some valleys of Al-Jabal Al-Akhdar. Morphological study. Department of Geography / College of Arts and Sciences of the Meadow / University of Benghazi. **18**, 4.

5. Al-Khalidi, Munther Ali Taha and Aws jumhur Hassan Al-Askari (2015) Analysis of the physical characteristics of river sediments in the central Diyala Basin. *Diyala Magazine*. **604–583**, 66.

6. Al-Masoudi, Istbraq Kazem Shayout (2013) Environmental characteristics of the waters of the Tigris River in Wasit Governorate. PhD thesis. Faculty of Education. Mustansiriya University

7. Amaral, E.J. and Pryor, W.A. (1977) Depositional environment of the St. Peter sandstone deduced by textural analysis. *Journal of Sedimentary Research*, **47(1)**, 32–52.

8. Daoud, Naqli Zarzis (2002) Applied geomorphology. Ministry of Higher Education and Scientific Research. Basra branch. *University House for printing, publishing and translation*, **4**, 210

9. Dathan, Ayad Muhammad (2020) Sedimentary and mineral sedimentation sequences of Anjana formation in selected areas north of Salah El-Din Governorate Master Thesis. College of Science. University of Tikrit Ayad Muhammad Gower

10. Day, P. R. (1965) Particle fractionation and particle-size analysis. Methods of Soil Analysis: Part 1 Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling. **9**, 545–567.

11. Folk, R. (1974) Petrology of Sedimentary Rocks: Austin, Texas, Hemphill Pub. Co, **182**.

12. Folk, R. L. (1980) Petrology of Sedimentary Rocks: Austin, Texas, U.S.A., Hemphill Publishing Co., 2nd edition, **184**.

13. Folk, R. L. and Ward, W. C. (1957) Brazos River Bar--a study in the significance of grain size parameters: *Jour. Seal. Petrology*, **27**, 3–26.

14. Friedman, G. M. (1967) Dynamic processes and statistical parameters compared for size frequency distribution of beach and river sands. *Journal of Sedimentary Research*, **37(2)**, 327–354.

15. Hou, B. and Frakes, L. (2004) Tertiary Sea levels and heavy mineral deposition in the eastern Eucla Basin, SA. in Regolith.

16. Inmann, D. L. (1982) Measures for describing the size distribution of sediments. *Journal of Sedimentary Petrology*, **22**, 125–145.

17. Jassim, Ali Al-Jassem and Saad Sami Al-Sheikhly (1997) General Geology, College of Science, University of Baghdad

18. Jassim, Hassan Katouf (2009) Sakharit, its sedimentation and the formation of Miqdadiyah in Badra region, eastern Iraq. Master's thesis, College of Science, University of Baghdad.

19. Khalid F. Hassan (2012) Size Distribution and Sorting Degree of the Recent Sediments of Al-Khazer River/ Northern Iraq. *Mesoptamia J. of Agri.*, **40(4)**, 1–10.

20. Mamita, Bassam (2006) Sedimentation science. Syrian Arab Republic - Tishreen University - Faculty of Science.

21. Musharraf, Mohamed Abdel Ghani (1987) The foundations of sedimentology, 1st ed. Deanship of Library Affairs, Riyadh, 30–40.

22. Román-Sierra, J., Muñoz-perez, J. J. and Navarro-Pons, M. (2013) Influence of sieving time on the efficiency and accuracy of grain-size analysis of beach and dune sands. Sedimentology, **60(6)**, 1484–1497.

23. Sabah, Norst (2013) Sedimentology concept. Mesopotamia Geology Channel. Earth Science / College of Science / University of Basra Sabah sediments: *Jour. Geology*, **30**, 377–392.

24. Stewart Jr, H. B. (1958) Sedimentary reflections of depositional environment in San Miguel lagoon, Baja California, Mexico. *AAPG bulletin*, **42(11)**, 2567–2618.

25. Tucker, M. E. (1991) sedimentary petrology. An introduction to the science of rocks. London. Methuen and company.

26. W. C. Krumbein (1934) Size Frequency Distributions of Sediments. *SPEM J. of Sedimentary*, **4(2)**, 65–77.

27. Wentworth, C. K. (1922) A scale of grade and class term for classic