Sand Minerals in Soil of Gadwal Al-Garbi in Karbala Province

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Abstract

A field study was carried out in the year 2021 to find out some soil characteristics and mineral distribution of light and heavy sand minerals in the soil deposits of the Western Table Project in Karbala Governorate, within the coordinates of longitude (44.106° and 44.217° east) and latitudes (32.480° and 32.620° N), and 50 sites were chosen. It covers the surface layer of the project's soil and revealed the locations of the points, such as drill holes, with a depth of 0-30 cm. It analyzed the soil separations and some of its characteristics, as well as diagnosing the sand minerals of its light and heavy types. The results indicated that all sites were characterized by the predominance of sand separated and the average values of the degree of soil interaction were 7.6 and the average values of electrical conductivity 4.78 dSm-1 and the average values of the exchange capacity of soils are 22.83 cmol of charge. kg-1, and the average values of calcium carbonate were 23.75%, and the average values of gypsum were 0.198%, while the average values of the organic matter were 0.97%. As for the results of the mineral analysis of the fine sand separated, it showed the dominance of quartz minerals, then calcite and feldspar for the light minerals, while the dominance was for the dark minerals, pyroxene and amphibole for the heavy minerals, and the results of the weathering index showed low values to indicate a decrease in the rate of weathering in the soil.

Key word : Gadwal Al-Garbi , Mesopotamia Plain , Sand Minerals , Weathering index

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Introduction

The nature of the mineral composition of the sand particles in some soil sites in the middle of the Iraqi sedimentary plain indicates that the opaque minerals are the predominant minerals within the heavy sand particle and that they are distributed irregularly in the horizons of the soil and reflect the impact of geomorphological processes, especially the sedimentation processes that occurred in the region, and occupied a group of minerals The amphibole ranked the main in the distribution of minerals particle by heavy sand, as most of the results showed in those areas to the predominance of quartz mineral within the fine sand particle , due to its resistance to weathering processes due to its strong crystalline structure bonds as well as its inheritance from the original material. Al-Rawi (2003) indicated when studying one of the sedimentary soil series in the Saqlawiya region that the light minerals separated by very fine sand, showed the predominance of Quartz mineral and attributed the increase in its percentage to its resistance to weathering due to the nature of its chemical bonds and the degree of its hardness. As for the light minerals, the dominance was as follow by Muscovite, Biotite, Chlorite, Chert and Feldspar. As for the heavy minerals, the study showed the predominance of the Pyroxene group, followed by the Opaque minerals, Epidote , Amphibole group, the Garnet group, the Biotite and Chlorite minerals , with trace amounts of Zircon, Tourmaline, Rutile and Muscovite minerals.

Al-Ani (2006) mentioned in her study of the minerals of rivers shoulders that light minerals in the fine sand fraction constitute 81-96% of all study horizons in the middle of the Iraqi sedimentary plain, and also that these minerals did not have a vertical distribution taking a regular path and attributed this to the effect of the sedimentary condition of those The areas that are in line with the nature of the geomorphological processes affecting their formation in comparison to the pedogenic processes.

Al-Mukhtar (2015) showed, during its study of the sediments content of the Iraqi sedimentary plain, from heavy sand minerals to the predominance of Opaque minerals, followed by Pyroxene , Amphibole, Apidot, Chlorite, Biotite, Tourmaline, Zircon, Stuarolite, kyanite, and finally Rutile, respectively.

Al-Fatlawi (2016) indicated in her study of the mineral properties and heavy elements of the soil of the Iraqi sedimentary plain within the two sites of Wasit and Maysan governorates that the mineral composition of the fine and light sand fraction between the dominance of Rock fragments, followed by Quartz , flint, Mudstone and Feldspar, while heavy sand minerals were the dominant For Opaque minerals, low values of Staurolite, kyanite, Rutile and Tourmaline minerals with weak metal weathering processes due to low values of Zircon and Tourmaline compared to the higher content of pyroxenes and amphiboles.

Al-Salawi (2017) explained in the results of a study that the percentage of light sand minerals in the soils of Babylon is higher than it is in the Kut soils. On the contrary, the percentage of heavy sand minerals was lower in Babylon compared to the Kut soils, which was higher. At the Kut soil. It also led to the discrepancy in the weathering evidence of heavy sand minerals, which was higher in the soils of Babylon compared to the soils of Kut.

Materials and Methods

The study area is located in the Karbala governorate and within the geographical coordinates between longitudes (44.22° and 44.54° east) and latitudes (33.32° and 32.44° north) (Fig. 1) and it is part of the sedimentation of the floodplain which is known as the Iraqi alluvial plain (Abd al-Amir , 2016). 50 drill holes were selected representing the surface layer in the project, and using the GPS system with a UTM coordinate system, the location of the drilling was determined for the studied area, from which samples were extracted from the horizons and according to the Soil Survey Manual 1960, then the soil samples were dried, crushed and passed through a sieve with the diameter of its holes 2 mm for the purpose of measuring soil properties that represent some physical and chemical properties of soil, which included the volumetric distribution of soil particles by the method of density and soil interaction (pH) using a pH meter and electrical conductivity (ECe)) in the extract of saturated soil paste using the Electrical Conductivity Bridge and the exchange capacity of positive ions (CEC) using 1N ammonium acetate NH4OAc at (pH = 7.0) and soil content of calcium carbonate minerals ($CaCO_3$) using acid (HCl 1N) and scavenging of the remaining acid by NaOH (1N) and soil content of calcium sulfate minerals ($CaSO_4.2H_2O$) mediated by acetone precipitation and content Soil from organic matter (OM) by wet digestion method according to the methods mentioned in Jackson, 1958 and Black, 1965.

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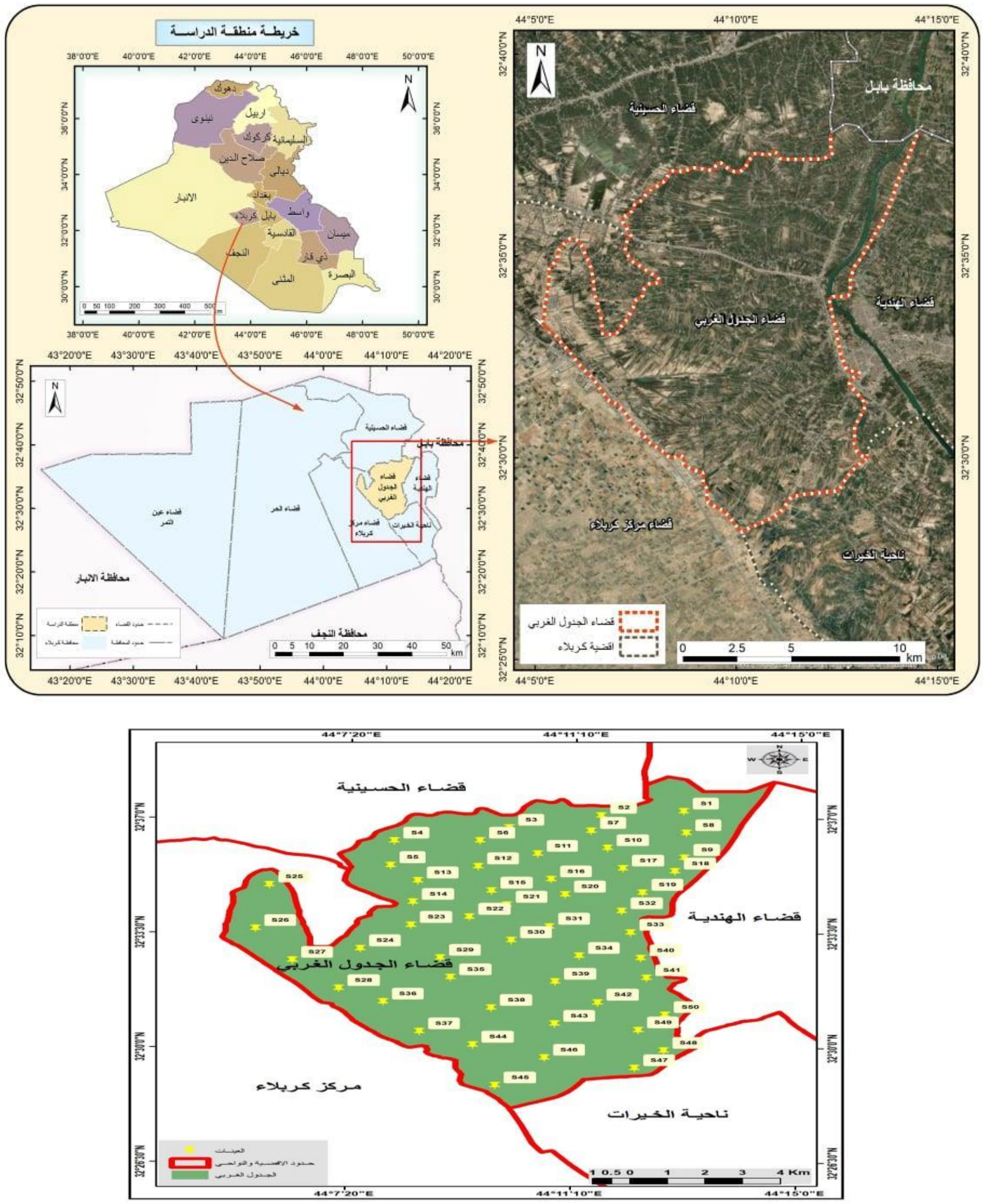

Fig. 1. Study area

The mineral analysis included the removal of binding materials and included removing salts from the samples by washing them with distilled water for three times, then calcium carbonate was removed using sodium acetate corrected at a reaction degree of 5 (Kunze, 1962) and the organic matter was removed using a 14% sodium hypochlorite solution (Anderson, 1963). Removal of free oxides by NA-citrate-bicarbonate-dithionite method according to (Mehra and Jackson, 1968), then the separation and fractionation process was carried out for sand minerals (53-100 microns) with its light and heavy types, using a bromoform solution with a specific weight of 2.89 (Folk, 1974) for the purpose of preparing slides Examination of minerals according to their optical qualities according to the method mentioned in Kerr, 1959 and Heinrich, 1965, and the use of Canada balm and the covers for the slide and by using a polarized microscope, then determining the percentage of each metal within the field of vision by diagnosing minerals and determining their percentages using the point-counting method and according to the method Suggested by the scientist Fleet and described in the book of the world (Carver, 1971) by adopting its optical qualities during the passage of light through it, which represents the color cracking, twinning, appearance, refractive index, number of axes, angle of extinction, and the phenomenon of color absorption. Then the weathering evidence was calculated for each of the light and heavy sand minerals, as follows:

1-Weathering ratio light minerals (Wrl) and my methods:

Wrl = (Quartz + Chert) / Feldspar + Rock Fragment)

2- Weathering ratio heavy minerals (Wrh) and my agencies:

Wrh = (Zircon + Tourmaline) / (Pyroxene + Amphibole)

Result and Discussion

1-Soil Characteristics

The results in Table 1 indicate that the sand fraction content ranged between 204.0 - 512.7 gm kg^{-1} and an average of 360.2 gm kg^{-1}, and the values of clay fraction ranged between 124.8 - 464.0 gm kg^{-1} and an average of 286.2 gm kg^{-1}, while the silt content ranged from between 236–440.4 g kg^{-1} and an average of 353.5 gm kg^{-1} at a depth of 0–30 cm, the values of the degree of soil pH ranged between 7.1–8.1 and an average of 7.6, and the electrical conductivity values ranged between 3.1–7.2 dSm^{-1} and an average of 4.78 dSm $^{-1}$ The values of the exchange capacity of soils ranged between 16.1 - 29.5 cmmol charge. kg^{-1} with an average charge of 22.83 cmol. kg^{-1}, soil calcium carbonate values ranged between 17.8-30.2% and an average of 23.75%, the values of gypsum content of soil ranged between 0.13-0.32% and an average of 0.198%, while the values of soil organic matter content ranged between 0.57-1.32% and an average of 0.97%.

Table 1. Soil Characteristics of study area

O.M	CaSO4	CaCO3	CEC	pH	Ece	Clay	Silt	Sand	Soil No.
%			Cmole		ds m^{-1}	gm kg^{-1}			
0.95	0.21	26.8	22.6	7.6	4.8	353.1	366.5	280.4	S1
1.12	0.15	22.4	22.1	7.4	5.3	329.6	390.0	280.4	S2
0.94	0.19	23.6	24.5	7.2	6.2	337.7	426.3	236.0	S3
0.68	0.16	22.7	18.4	7.8	3.7	180.4	407.2	412.4	S4
0.74	0.32	24.8	19.1	7.8	4.1	201.8	317.6	480.6	S5
0.82	0.14	30.2	20.5	7.9	3.5	249.6	261.6	488.8	S6
0.94	0.18	26.8	20.8	7.8	4.2	262.5	365.4	372.1	S7
0.57	0.17	28.5	16.4	7.7	3.8	149.5	373.1	477.4	S8
0.88	0.13	26.3	20.1	7.5	5.6	259.6	380.4	360.0	S9
1.15	0.15	24.2	26.8	7.3	6.4	372.0	296.0	332.0	S10
0.95	0.25	23.3	21.5	7.5	5.1	256.0	422.0	322.0	S11
0.87	0.21	24.4	18.2	7.6	4.8	161.6	380.4	458.0	S12
0.76	0.19	25.2	17.4	7.8	3.3	164.4	429.1	406.5	S13
0.61	0.21	23.6	16.1	7.8	3.7	124.8	380.8	494.4	S14
0.92	0.14	26.7	19.5	7.9	3.2	223.0	428.8	348.2	S15
0.87	0.18	24.8	18.4	7.4	4.6	209.5	378.0	412.5	S16
1.18	0.26	19.2	20.5	7.3	4.8	231.4	380.0	388.6	S17
0.91	0.22	17.8	22.4	7.2	5.3	246.9	430.4	322.7	S18

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1.23	0.18	20.3	27.2	7.2	5.8	392.0	388.0	220.0	S19
1.06	0.22	18.7	26.5	7.1	6.2	370.4	336.8	292.8	S20
0.94	0.15	21.1	23.1	7.5	4.7	253.7	358.0	388.3	S21
0.82	0.17	21.2	22.8	7.9	6.3	254.0	280.0	466.0	S22
1.02	0.13	20.1	23.4	7.9	6.2	269.6	320.8	409.6	S23
1.09	0.19	19.4	24.1	7.6	5.9	302.4	341.6	356.0	S24
1.07	0.25	18.2	26.5	7.5	4.7	376.0	342.0	282.0	S25
0.85	0.21	26.8	23.8	7.3	5.4	284.0	296.0	420.0	S26
0.76	0.19	22.4	22.9	7.4	5.1	270.1	257.6	472.3	S27
0.83	0.17	23.6	21.2	7.1	7.2	245.0	365.4	389.6	S28
0.64	0.15	22.7	16.3	7.2	6.8	150.0	438.0	412.0	S29
0.81	0.19	24.8	21.3	7.4	6.1	240.9	246.4	512.7	S30
0.73	0.24	30.2	17.8	7.4	5.7	174.4	410.0	415.6	S31
0.95	0.17	26.8	19.4	7.8	4.3	209.6	440.4	350.0	S32
0.81	0.22	28.5	20.1	7.8	3.8	224.6	359.8	415.6	S33
1.02	0.28	26.4	24.6	7.9	3.7	309.6	380.0	310.4	S34
0.92	0.32	24.2	19.5	8.1	3.1	212.0	348.0	440.0	S35
1.13	0.26	23.3	24.4	7.6	4.8	290.0	358.0	352.0	S36
1.09	0.19	24.4	25.9	7.4	5.3	319.6	310.8	369.6	S37
1.25	0.17	25.2	28.2	7.4	5.4	393.6	361.2	245.2	S38
1.18	0.16	23.6	28.7	7.3	5.9	397.5	307.8	294.7	S39
1.16	0.27	26.7	26.4	7.2	6.3	366.0	388.0	246.0	S40
1.32	0.24	24.8	29.5	7.5	4.6	448.0	348.0	204.0	S41
1.06	0.19	26.8	24.1	7.5	4.4	322.4	357.6	320.0	S42
1.24	0.18	21.9	28.2	7.7	3.8	436.0	342.0	222.0	S43
1.26	0.13	20.4	29.5	7.8	3.1	464.0	240.0	296.0	S44
1.06	0.15	18.5	25.4	7.8	3.4	318.4	267.6	414.0	S45
1.13	0.22	21.4	26.9	7.7	3.6	404.0	236.0	360.0	S46
1.02	0.25	23.2	25.1	7.5	4.1	314.0	428.4	257.6	S47
1.15	0.27	20.1	26.2	7.6	3.9	358.0	346.0	296.0	S48
0.91	0.19	24.6	20.3	7.8	3.6	230.4	349.2	420.4	S49
1.16	0.15	26.3	27.2	7.9	3.4	397.4	315.4	287.2	S50

2-Light Sand Minerals

The results shown in Table 3 show that the percentage of light minerals of sand fraction of the soils of the study area ranged between (87.2% - 93.5%), which is an indication of the weak weathering processes in these deposited materials. The predominance of the mineral was quartz, followed by calcite, feldspar group , calcite, mica, gypsum, and finally chlorite (Fig. 2).

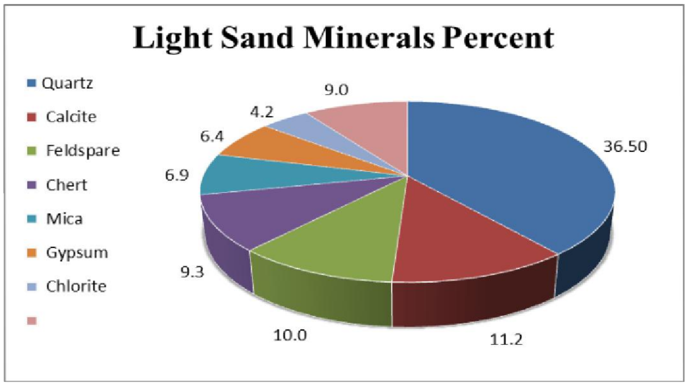

Fig 2. Light Sand Minerals Percent

The percentage of Quartz mineral ranged between (30.3-42.5%) and an average of (36.5%), and this could be due to its resistance to weathering due to the nature of its chemical bonds and its hardness of 7 on the Mohs scale of hardness and not containing cracks and its light weight. Long distances as it is deposited when the momentum of the transmission forces decreases. Therefore, it is the most stable mineral under depositional conditions, and it is usually from second and third sedimentation cycles (Tucker, 1991). It is followed by Calcite mineral in terms of dominance and is found in a percentage ranging between (6.7 - 15.4%) and an average of (11.2%), then the group of Feldspar minerals (orthoclase and plagioclase) with a percentage ranging between (6.3 - 12.4) and an average of (10.0%) and that the presence of feldspar in abundance is An excellent indicator of the existence of a dry climate in its environment, and it is used in explaining the existence of paleoclimates, (Folk, 1974). Also, its relationship with quartz is an important key to knowing the history of sediments. Whenever the size of feldspar decreases in relation to quartz, it indicates the effect of physical forces on its weathering (Ali and Saadallah, 1991), then Calcite with a percentage ranging between (4.1-12.8%) and an average of (9.3%), then the group of Mca minerals (muscovite and biotite). It appeared at a rate ranging between (3.7 - 9.7%) and an average of (6.9%), and this can be attributed to its weak resistance to weathering and weathering to smectite minerals under dry and semi-dry conditions. It is one of the Flaky Minerals, with a hardness of (2-3 mohs) and a parallel opacity. Because of its lamellar shape, it can be washed out of coarse sand and tends to collect and deposit in the size of a fine silt, then the Gypsum mineral, which appeared in a percentage that ranged Between (4.7 - 8.5%) and an average of (6.4%), and finally Chlorite, whose percentage ranged between (2.7 - 5.7%) and an average of (4.2%).

As for the group of weathered minerals (Rock Fragments), its percentage ranged between (4.3-12.8%) and an average of (9.0%). It is one of the common particles in coarse sand and can be found in fine sand. Despite its many types, the carbonate rock particles Rock Fragment is common in calcareous soils, which is indicative of its arid climate (Pettijohn, 1975). It was accompanied by crystals of feldspar and some ferromagnesian minerals. And rocky particles are soft and fragile particles that are most affected by weathering, so one of the characteristics of sand deposited in aqueous depositional conditions is that it is rich in quartz and rock pieces that do not last long in the sediments (Folk, 1974), and the increase in their ratio in the horizon materials of soil chains with The texture is of medium roughness, indicating its proximity to the sedimentation source and that it did not travel long distances. As the survival of the rock pieces during the transportation process by the river is not easy because the size of most of them is reduced to be the size of mud or silt. And its percentage can increase due to additions from the branches of the channels, which compensates for the

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deficiency resulting from the erosion process (Pettijohn et al., 1973).
And it may be due to mechanical erosion that dominates chemical weathering under rapid erosion conditions, which can transfer materials or particles quickly by water. Therefore, the unstable minerals do not have enough time to be exposed to the processes of weathering and erosion, so their proportions remain high in the sediments (Pettijohn, 1975). Irrigation and fertilization, in addition to the minerals carried by sediments during their deposition. The weathering that occurs in sedimentary soils includes the weathering of minerals at their original source as well as their mechanical weathering during transportation and then the weathering that can take place on them while they are stable. Therefore, it generally does not give a real value to each of these stages, which may have different values. As for the weathering index, it indicates weak weathering processes due to the high percentage of rock pieces and a decrease in the proportion of limestone, while quartz and feldspar minerals appeared within the specified levels of sedimentary soils, The highest value of the weathering index was 2.805 and the lowest value was 1.338, with an average of 1.852 for all the studied sites. This can be attributed to the fact that these horizons may have been geomorphological surfaces with humid environmental conditions that contributed to the weathering of their minerals and then were covered with recent sediments. And its decline in some horizons may be due to the fact that it is sediments that have not been subjected to weathering for a long period of time, or that they did not have enough time to weather their minerals (Al-Aqili, 2002).

Table 2. Light Sand Mineral Percent

WrL	Rock F.	Chlorite	Chert	Gypsum	Mica	Calcite	Feldspare	Quartz	Soil No.
1.556	11.9	4.8	6.1	7.5	9.7	16.4	12.2	31.4	S1
1.500	14.8	5.2	8.7	7.1	10.7	15.5	9.8	28.2	S2
1.897	12.9	4.7	9.4	8.2	9.2	19.1	7.4	29.1	S3
2.071	11.8	4.5	9.1	7.3	6.9	16.2	9.4	34.8	S4
1.872	12.1	5.1	9.5	7.5	6.2	16.3	10.5	32.8	S5
2.362	12.5	4.1	10.2	6.1	7.7	18.9	6.3	34.2	S6
1.582	14.4	5.2	8.7	6.3	4.8	16.3	11.7	32.6	S7
2.095	12.8	4.8	9.4	4.8	7.6	14.7	9.2	36.7	S8
1.500	20.6	3.6	10.1	6.2	4.1	14.1	8.2	33.1	S9
1.922	14.3	5.3	12.6	7.2	6.3	17.2	7.6	29.5	S10
1.586	18.2	5.6	11.2	6.5	4.7	18.3	6.9	28.6	S11
1.726	17.1	4.3	10.7	8.1	6.1	17.7	6.3	29.7	S12
1.764	14.7	3.5	11.9	7.3	6.9	16.8	9.0	29.9	S13
1.755	13.3	4.2	10.5	6.7	6.2	17.6	10.4	31.1	S14
1.633	16.1	5.7	9.8	6.1	6.7	16.2	8.7	30.7	S15
1.538	15.4	4.6	8.4	6.2	5.9	16.8	10.8	31.9	S16
2.054	10.5	5.1	11.9	7.5	6.2	19.2	9.8	29.8	S17
2.010	10.4	5.9	12.4	7.9	7.2	17.3	10.1	28.8	S18
2.143	10.5	4.2	13.6	7.5	6.1	18.4	9.8	29.9	S19

1.926	12.5	4.8	10.5	6.9	6.3	14.7	10.5	33.8	S20
1.921	13.6	5.2	11.1	5.7	5.7	16.5	9.3	32.9	S21
1.469	17.2	6.7	10.2	5.9	6.1	17.6	8.6	27.7	S22
1.556	11.9	4.8	6.1	7.5	9.7	16.4	12.2	31.4	S23
1.660	15.0	4.5	8.4	6.3	5.2	16.7	10.3	33.6	S24
1.897	12.5	5.1	11.9	4.8	6.8	15.5	10.9	32.5	S25
1.851	10.8	4.1	10.5	5.4	7.1	20.4	11.3	30.4	S26
1.672	12.0	5.2	9.4	6.9	5.8	18.5	11.8	30.4	S27
2.154	8.3	4.8	11.2	7.1	7.7	18.9	11.2	30.8	S28
1.460	15.4	4.0	10.2	7.4	6.1	17.8	10.9	28.2	S29
1.641	12.1	5.3	9.8	4.7	6.4	18.9	12.4	30.4	S30
1.695	12.7	4.6	8.7	6.8	5.4	17.7	11.6	32.5	S31
1.802	12.8	3.8	12.5	6.3	9.2	17.1	9.9	28.4	S32
1.712	12.3	4.6	10.3	6.9	6.6	17.9	11.3	30.1	S33
2.081	9.8	3.6	10.5	5.9	9.7	15.8	11.3	33.4	S34
1.713	13.3	3.2	9.4	4.8	9.1	17.8	10.7	31.7	S35
1.963	11.7	2.7	10.1	6.2	8.2	18.9	9.9	32.3	S36
2.275	6.9	3.4	12.7	6.3	8.4	18.7	12.4	31.2	S37
2.149	9.2	6.1	10.1	5.8	8.6	15.9	11.0	33.3	S38
1.838	12.9	2.7	11.8	6.7	8.7	15.5	10.5	31.2	S39
2.422	8.2	4.1	11.4	7.5	9.7	15.4	10.3	33.4	S40
1.607	12.9	5.2	9.4	8.5	9.1	16.2	10.5	28.2	S41
1.799	13.3	3.9	12.1	6.7	8.2	17.1	9.6	29.1	S42
1.990	9.7	6.4	13.7	6.3	8.4	18.5	10.5	26.5	S43
1.926	10.6	3.7	11.9	7.3	8.6	16.9	11.1	29.9	S44
1.338	17.2	5.7	10.3	7.5	8.7	15.9	9.4	25.3	S45
1.465	15.9	4.5	9.4	5.9	8.8	16.7	10.1	28.7	S46
2.466	7.9	2.9	12.8	7.1	6.9	16.2	11.4	34.8	S47
1.722	14.7	3.1	10.6	6.8	6.2	15.3	10.5	32.8	S48
2.062	14.4	2.8	12.6	6.9	6.7	14.1	8.3	34.2	S49
2.805	7.8	2.7	12.1	8.3	5.9	16.9	9.6	36.7	S50

WrL=(Quartz + Chert) / (Feldspar + Rock Fragment)

3-Heavy Sand Minerals

Heavy minerals are related to the geological components of the soil and clearly reflect the characteristics of the original source of the rocks. Which are usually derived from igneous and metamorphic rocks exposed in northeastern Iraq and the neighboring areas, the percentages of heavy metals in the fine sand fraction as indicated in Table (3), range between (6.3-12.8%) and at a average of 8.13% for all studied sites, and it shows Figure 3 Distribution of the average percentages of heavy metals in the studied soil sites.

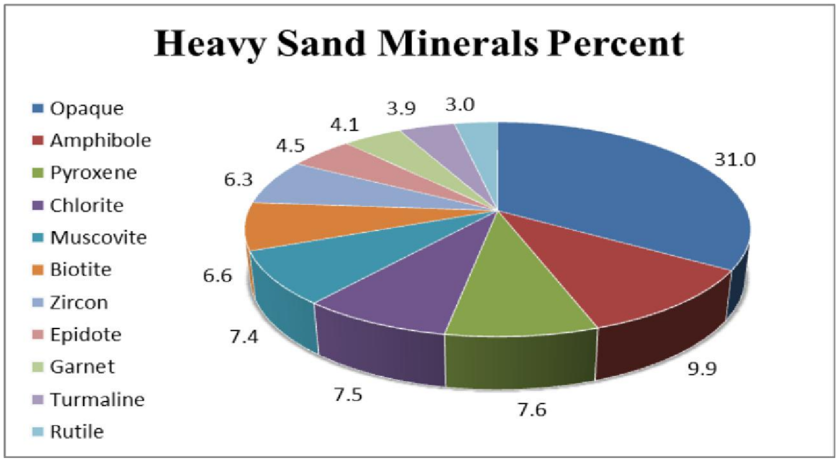

Fig 3. Heavy Sand Mineral Percent

The dominance was for opaque minerals, and their percentage ranged between (27.1 - 34.8%) and an average of (31.0%), followed by the amphibole minerals group, with a percentage ranging between (7.6 - 12.8%) and an average of (9.9%), followed by the pyroxene group with a percentage ranging between (5.5 - 9.7%). With an average of (7.6%), followed by chlorite with a rate that ranged between (4.3 - 9.6%) and an average of (7.5%), followed by muscovite with a rate that ranged between (5.8 - 8.6%) and an average of (7.4%), then biotite with a rate that ranged between (4.9 - 7.9). %) with an average of (6.6%), then zircon with an average of (4.2 - 9.3%) with an average of (6.3%), then apidot with a rate that ranged between (2.7 - 6.6%) and an average of (4.5%), then carnites at a rate that ranged between (2.9 - 5.8%), with an average of (4.3%) and tourmaline with a percentage that ranged between (2.1 - 6.3%) and an average of (4.2%) and finally rutile with a percentage that ranged between (1.7 - 5.9%) and an average of (3.3%), while the weathered minerals appeared by a percentage It ranged between (0.4 - 15.7%), while the weathering index values ranged between (0.367 - 0.921), with an average of (0.611). The results agreed with what was found by Al-Mashhadi, 2003 when studying the series of the Latifiya project.

Table 3. Heavy Sand Minerals Percent

WrH	Weatherd	Rutile	Epidote	Garnet	Turmaline	Zircon	Muscovite	Biotite	Chlorite	Amphibole	Pyroxene	Opaque M.	**Soil No.**
0.733	2.7	2.6	5.5	4.9	4.8	7.8	6.7	6.8	8.4	9.6	7.6	32.6	**S1**
0.591	6.4	4.5	4.7	2.9	4.2	6.8	7.2	5.2	8.2	9.7	8.9	31.3	S2
0.575	4.1	3.7	6.3	4.2	3.7	6.3	7.1	6.2	8.2	10.2	7.2	32.8	S3
0.521	4.1	2.9	6.4	4.2	3.2	6.7	6.5	5.6	7.5	11.5	7.5	33.9	S4
0.610	5.3	4.5	3.4	4.9	4.7	6.4	8.6	7.8	7.7	9.5	8.7	28.5	S5
0.921	5	3.8	5.2	4.6	6.1	6.7	7.4	7.5	8.3	7.6	6.3	31.5	S6
0.626	6.1	3.7	5.3	4.2	4.3	6.6	7.6	6.5	7.6	9.3	8.1	30.7	S7
0.697	6.5	4.5	5.7	5.3	2.1	8.5	8.6	6.2	7.7	9.6	5.6	29.7	S8
0.719	2	3.5	5.6	5.5	5.2	7.1	8.1	7.3	7.2	9.2	7.9	31.4	S9
0.850	7.1	4.1	4.6	4.7	4.3	9.3	7.8	5.7	6.9	9.7	6.3	29.5	S10
0.572	2.6	5.9	6.5	4.4	3.7	6.2	7.4	7.2	8.4	10.7	6.6	30.4	S11
0.495	8.5	3.4	3.9	3.6	2.5	6.9	5.9	6.3	8.7	10.3	8.7	31.3	S12
0.713	7.4	4.1	4.7	5.3	4.5	7.2	6.4	6.1	8.3	9.7	6.7	29.6	S13

0.675	4.8	3.8	5.5	4.6	3.1	7.5	7.7	6.3	7.9	8.9	6.8	33.1	S14
0.548	5	5.3	5.2	3.5	2.3	6.3	6.9	6.2	9.5	9.4	6.3	34.1	S15
0.566	2.6	2.2	6.6	4.9	2.3	7.1	7.9	7.7	8.3	10.1	6.5	33.8	S16
0.669	0.4	4.6	6.3	5.6	3.1	7.8	8.1	6.1	7.1	10.4	5.9	34.6	S17
0.781	3.1	2.9	6.6	4.1	4.3	7.5	7.5	6.4	7.8	8.9	6.2	34.7	S18
0.696	2.3	3.2	5.3	5.2	3.3	8.4	6.6	6.5	8.6	10.4	6.4	33.8	S19
0.679	7.6	3.1	4.9	5.8	4.1	7.1	7.3	4.9	6.9	10.2	6.3	31.8	S20
0.688	5.3	3.6	5.8	4.9	3.2	7.4	6.3	6.9	7.8	9.1	6.3	33.4	S21
0.886	0.7	3.7	6.2	4.5	5.9	7.3	6.8	7.5	9.3	9.4	5.5	33.2	S22
0.727	6.8	2.2	6.6	4.5	4.2	6.7	8.3	5.6	8.2	8.8	6.2	31.9	S23
0.658	9.3	3.1	4.8	5.3	4.3	5.9	6.3	6.9	8.4	9.2	6.3	30.2	S24
0.671	1.9	4.9	4.4	4.7	4.3	6.5	8.2	7.5	9.6	10.2	5.9	31.9	S25
0.676	3.9	5.6	6.2	4.7	5.1	4.5	7.5	6.2	8.6	8.6	5.6	33.5	S26
0.717	2.4	4.3	4.1	5.2	6.3	5.1	6.9	6.7	9.2	9.1	6.8	33.9	S27
0.791	2.4	3.8	5.4	4.8	5.3	6.4	7.2	6.2	8.9	8.7	6.1	34.8	S28
0.565	9.2	2.4	4.6	4.2	5.7	4.8	8.5	7.1	5.3	9.4	9.2	29.6	S29
0.442	8.7	3.1	3.4	3.5	4.3	4.8	7.9	6.2	6.7	11.8	8.8	30.8	S30
0.547	10.2	4.1	3.5	3.5	4.8	5.6	8.3	7.3	5.6	10.1	8.9	28.1	S31
0.424	9.6	3.6	3.9	4.1	3.7	4.9	8.1	6.2	4.9	11.1	9.2	30.7	S32
0.590	11.4	2.5	2.8	3.6	3.9	6.3	7.1	7.8	7.9	9.2	8.1	29.4	S33
0.495	12.9	3.4	3.4	2.9	3.2	6.8	7.1	6.7	5.6	10.7	9.5	27.8	S34
0.536	14.8	1.8	3.1	3.3	5.2	4.6	6.3	6.4	7.9	9.4	8.9	28.3	S35
0.367	11.5	2.6	3.1	3.5	3.1	4.2	8.4	6.3	6.2	10.5	9.4	31.2	S36
0.585	15.7	1.8	3.5	3.8	4.2	5.8	7.3	5.7	6.7	8.7	8.4	28.4	S37
0.524	11.9	2.4	3.3	3.6	4.7	6.2	6.8	6.3	4.3	12.1	8.7	29.7	S38
0.534	12.8	3	3.7	4.2	4.3	5.2	7.4	6.9	7.1	9.4	8.4	27.6	S39
0.505	9.7	3.6	2.7	4.3	3.9	5.6	5.8	6.7	6.8	10.9	7.9	32.1	S40
0.614	9.8	2.6	3.1	3.7	5.1	5.4	7.8	7.8	7.4	8.8	8.3	30.2	S41
0.429	8.4	1.9	3.2	3.9	3.9	5.1	7.6	6.9	8.2	12.5	8.5	29.9	S42
0.411	9.5	2.1	3.7	3.4	3.7	4.9	7.9	7.6	6.9	11.7	9.2	29.4	S43
0.458	9.3	2.3	4.2	3.9	4.5	4.7	6.3	6.8	7.2	10.4	9.7	30.7	S44
0.483	10.4	2.6	3.1	4.8	4.6	5.3	7.8	6.3	6.7	12.8	7.7	27.9	S45
0.567	11.5	1.7	3.3	3.7	3.8	6.3	8.4	7.1	6.8	9.7	8.1	29.6	S46
0.610	12.4	3.4	2.8	4.3	3.7	6.3	7.8	5.9	5.9	8.5	7.9	31.1	S47
0.665	14.2	3.7	3.4	3.6	5.1	5.8	7.4	7.2	6.1	8.9	7.5	27.1	S48
0.511	13.8	3	3.2	3.5	4.0	5.6	7.4	5.7	5.7	10.4	8.4	29.3	S49
0.644	9.8	2.1	2.9	3.5	4.3	7.3	7.1	7.9	7.7	9.2	8.8	29.4	S50

***Wrh = (Zircon + Taurmaline) / (Amphibole + Pyroxene)**

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