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# Sedimentation in Variation on Properties and Distribution of Sand Minerals in Some Soils of Iraq

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**KEY WORDS:**
*Morphological Properties; Heavy Minerals; Light Minerals; Soil composition; Weathering Index*

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**ABSTRACT**

The study was conducted to identify heavy and light sand minerals and to determine their morphological properties and distribution within the soils of some sites in Iraq (north, center, and south) And the extent of its impact on the structural composition of these soils to identify the appropriate methods for managing them and raising their production efficiency. The studied soil samples were obtained from depths of (0-30) cm and (30-60) cm. According to the mineral analyses of the sand particles, the analysis results showed that light minerals with a specific gravity of less than 2.89 largest part of the sand fraction. The carbonate rock minerals, which fall within the rock fragments, are dominated by Quartz, Feldspars, and the group of coated grains by clay. Results revealed clear differences in the proportions of light and heavy minerals and their morphological characteristics between the study areas, reflecting these regions' diverse geological and environmental characteristics. Study showed that the percentage of light minerals in the studied samples was much higher than that of heavy minerals in all the study soils. This shows the effect of different factors, such as weathering, transport, and sedimentation. Results showed that when studying the Weathering Index for light minerals, there was a slight variation between its values for all regions. it was also noted that the Weathering Index increased in the surface soil layer of the Tikrit site and the Qal'at Saleh and Al-Kahlaa sites, which indicates that these soils were exposed to and affected by weathering factors.

# تغاير صفات وتوزيع معادن مفصول الرمل في بعض ترب العراق

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**الخلاصة**

أجريت هذه الدراسة بهدف تشخيص معادن الرمل الثقيلة والخفيفة ومعرفة صفاتها الشكلية وتوزيعها ضمن ترب بعض مواقع العراق الواقعه في (الشمال، والوسط ، والجنوب) ومدى تاثيرها في التركيب البنائية لتلك الترب لتحديد الطرائق الملائمة في اداراتها ورفع كفاءتها الانتاجية ، اذ تمثلت مواقع ترب الدراسة في شمال العراق من محافظة دهوك بمناطق (بردرش، زاخو) ووسط العراق بمناطق (تكريت، الرمادي) وجنوب العراق من محافظة العمارة بمناطق (الكحلاء، قلعة صالح). استحصلت عينات الترب المدروسة من العمقين (0-30) سم، (30-60) سم، حسب التحاليل المعدنية لجزيئات الرمل بينت نتائج التحليل أن المعادن الخفيفة ذات الوزن النوعي الأقل من 2.89 تشكل الجزء الأكبر من مفصول الرمل، وتسيدت المعادن كالتالي Carbonate Rock Fragments، معدن Quartz، معادن Feldspars، ومجموعة Coated Grains by Clay. كما اظهرت النتائج بالنسبة للمعادن الثقيلة ان مجموعة المعادن المعتمة تحتل المرتبة الأولى من حيث السيادة، إذ تسيدت هذه المعادن في معظم افاق ترب الدراسة. أظهرت النتائج اختلافات واضحة في نسب المعادن الخفيفة والثقيلة وصفاتها الشكلية بين مناطق الدراسة، مما يعكس تباين الخصائص الجيولوجية والبيئية لهذه المناطق. بينت الدراسة ان النسبة المئوية للمعادن الخفيفة في نماذج الرمل المدروسة كان اعلى بكثير من نسب المعادن الثقيلة وفي جميع ترب الدراسة، مما يوضح لنا تأثير العوامل المختلفة كالتجوية والنقل والترسيب، كذلك بينت النتائج عند دراسة مؤشر دليل التجوية Weathering Index للمعادن الخفيفة تباين قليل بين قيمه لجميع المناطق لكن يلاحظ ايضا ارتفاع في مؤشر دليل التجوية في الطبقة السطحية لموقع تكريت ولموقعي قلعة صالح والكحلاء والذي يدل على تعرض هذه الترب وتأثرها بعوامل التجوية.

**الكلمات المفتاحية:** الخصائص المورفولوجية، معادن الرمل الثقيلة، معادن الرمل الخفيفة، تركيب التربة، دليل التجوية

## INTRODUCTION

Soil is a living ecosystem with various biological interactions, which is a complex mixture of organic and inorganic substances. Soil is considered to be one of the most important sources on the planet, it can perform many functions. The soil is also the equivalent of a multifunctional system that supports the essential functions of life on Earth. Sandy soil is a type of soil that is made up of mostly sand particles. Sandy soils are formed through various weathering and erosion processes affecting these rocks and minerals. Across time, the fragmentation of rocks occurs due to several factors such as wind, rain, and temperature, which finally leads to the formation of small-sized particles that were combined to create sandy soils.

Sandy soils are defined as having a coarse texture with a high proportion of sand, typically 85% or more. They are mainly composed of individual sand grains made of quartz and chemically inert feldspar. Their clay content is low (up to 15%) and silt content is minimal (1.5% or less). Sandy soils have a weak structure, lack flexibility, and become loose when dry. They have good aeration and drainage properties. These soils have a low cation exchange capacity (the ability to hold and exchange nutrients) and contain few organic materials, making them less fertile for agriculture. Due to their low fertility, sandy soils are difficult to manage for agricultural purposes. They are prone to continuous erosion by wind and water, depending on their geographical location. One of the main issues with sandy soils is their tendency to be unstable and not remain in one location.

Iraqi soils, especially in the central and southern areas, are predominantly sedimentary. They result from continuous sedimentation processes. Most of these soils are derived from areas that have experienced weathering. Sedimentation occurs through processes involving wind, rivers, and floods, following physical erosion. Sedimentation is described as the last geological process in the formation of these soils. The variability in the intensity of weathering on the parent rocks contributes to the differences in soil characteristics. The differences in weathering intensity are largely attributed to climatic factors over time, which also affect the proportion of heavy minerals compared to lighter ones in the soils. (Al-agidi, 1990), Despite containing the same mineral group, sandy soils exhibit variations in the dominance of heavy versus light minerals. Sand minerals are common in the Earth's crust and result from the weathering of various rock types (igneous, sedimentary, and metamorphic). The composition of sand minerals includes quartz, feldspar, and others, which are significant components of sandy soils. The properties of the soil and the distribution of minerals in the sand are heavily influenced by the type of soil, the primary source of the sand, and the climatic conditions of the area. (Vaezi, 2017, Kahella**,** et al. 2021, AlKhalil, 2020). Light and heavy sand minerals play a crucial role in determining the nature of weathering that soils undergo, including the intensity and source of the weathering. They help identify which factors have significantly influenced the formation of various soils over time. (Al Baghdady and Alabadi, 2021) Sand minerals are widely found in the Earth's crust due to the weathering of rocks. Although heavy sand minerals are present in smaller quantities, they are highly resistant to weathering and erosion, unlike light sand minerals, which lack this durability. **(**Al baghdady and Alabadi,2021)

Sand minerals are categorized into two types: **Primary Minerals**: These are inherited from the parent rock due to physical breakdown and are the most common in the Earth's crust. **Secondary Minerals**: These form from the chemical weathering of primary minerals and are vital for the chemical reactions occurring in sandy soils. Most Iraqi sedimentary soils have formed through continuous sedimentation via river waters, floods, and wind. These soils are transported from areas subjected to weathering. The distribution of sand minerals in these soils varies based on geographical regions and geological conditions. The most common sand minerals found in Iraqi soils include quartz, feldspar, and mica, with their proportions varying according to the nature of the deposits and their sources. (Ismael, 2022). Heavy minerals are crucial for identifying the source of rocks and understanding their transport history. They provide insights into active geological processes and sedimentary environments. These minerals result from the breakdown of primary minerals through weathering and abrasion. Their presence serves as an indicator of the nature of the source rocks in different regions. Al-Ani (2006): In her study of the mineral composition of fine sand from riverbanks in the central alluvial plain, she found that the content of heavy minerals was lower compared to light minerals. This decrease was attributed to effective weathering processes during transport and sedimentation, as well as the mineral composition of the source materials. Al- Shihmani (2020): He emphasized the importance of identifying primary minerals, particularly quartz, which is vital in studying the development and evolution of soils in Iraq. The amount of quartz in fine sand is a key criterion for assessing the homogeneity of soil parent materials. Al-Bayati, et al. (2017): In their study of sand composition in Barbij region of southern Iraq, they noted that light sand minerals dominated over heavy minerals, making up over 93% of the total, indicating a significant prevalence of lighter minerals in that area.

The study emphasizes the significance of analyzing both light and heavy sand minerals to understand the nature of weathering affecting the soil. This includes understanding how heavy minerals contribute to insights about the soil's origin and the processes and environments involved in its sedimentation. The current study aims to investigate the proportions of light and heavy sand minerals present in the soils being examined. It also seeks to assess how the physiographic location (the physical geography of the area) influences the content and distribution of these minerals in the studied soils. The study intends to determine how the presence of these minerals affects the structural composition of the soils. This understanding is crucial for identifying suitable management practices to enhance soil productivity and effectiveness.

## MATERIAL AND METHODS

Twelve soil samples were collected from six representative sites of the study areas the samples were collected from two depths (0-30) cm and (30-60) cm Table (2), Figure (1) air dried, ground using a hand mill, and passed through a sieve with 2 mm diameter holes. Some physical and chemical analyses were conducted on them, Particle size distribution was estimated by pipette method mentioned in (Pansu and Gautheyrou, 2006), and Determine soil reaction pH and the electrical conductivity by soil solution (1:1) Using pH –Meter and EC-Meter (Jones, 2001), organic matter measured by wet oxidation method according to the method (Walkley and Black, 1934), (Table. 3) and mineral analyses included the removal of binding materials to prepare the samples for the separation and fractionation process. Coarse soil particles (>50 µm) were separated by wet sieving using a sieve with a diameter of (50 µm) holes. The sand fraction was taken, air-dried, and weighed to separate heavy metals from light metals in the examined samples. Light minerals were separated from heavy minerals by separating the funnel and using bromoform ($CHBr_3$) liquid with a specific gravity of 2.89. A certain weight of the sample was taken for examination purposes. Light and heavy sand minerals were identified and estimated by polarized optical microscope according to the method of Carver, 1971 and through the special optical properties of each mineral, which are (colour, shape, cleavage, relief, extinction, number of optical axes and angle of opacity for each mineral). The percentage of each mineral was calculated after counting approximately 300-350 grains per slide along straight, parallel lines covering the entire slide. Light and heavy mineral grains in each sample were photographed with a Sony 12.1 m.P camera.

**Table 1. Sampling point with the GPS coordinates**

| Governorate | Samples sites | Depth (cm) | Sand | Silt | Clay | Textural class |
|---|---|---|---|---|---|---|
| | | | $g.kg^{-1}$ Soil | | | |
| Duhok | Bardarash | 0-30 | 293.6 | 398.4 | 308.0 | C.L |
| | | 30-60 | 263.6 | 398.4 | 338.0 | C.L |
| | Zakho | 0-30 | 293.6 | 384.4 | 322.0 | C.L |
| | | 30-60 | 112.0 | 212.0 | 676.0 | C |
| Salah al-Din | Tikrit | 0-30 | 607.0 | 240.0 | 153.0 | S.L |
| | | 30-60 | 635.0 | 235.0 | 130.0 | S.L |
| Al- Anbar | Ramadi | 0-30 | 598.0 | 250.0 | 152.0 | S.L |
| | | 30-60 | 602.0 | 202.0 | 196.0 | S.L |
| Al-Amarah | AL-Kahlaa | 0-30 | 74.0 | 472.0 | 454.0 | Si.C |
| | | 30-60 | 27.2 | 429.2 | 543.6 | Si.C |
| | Qal'at Saleh | 0-30 | 283.6 | 324.4 | 392.0 | C.L |
| | | 30-60 | 200.0 | 396.0 | 404.0 | C |

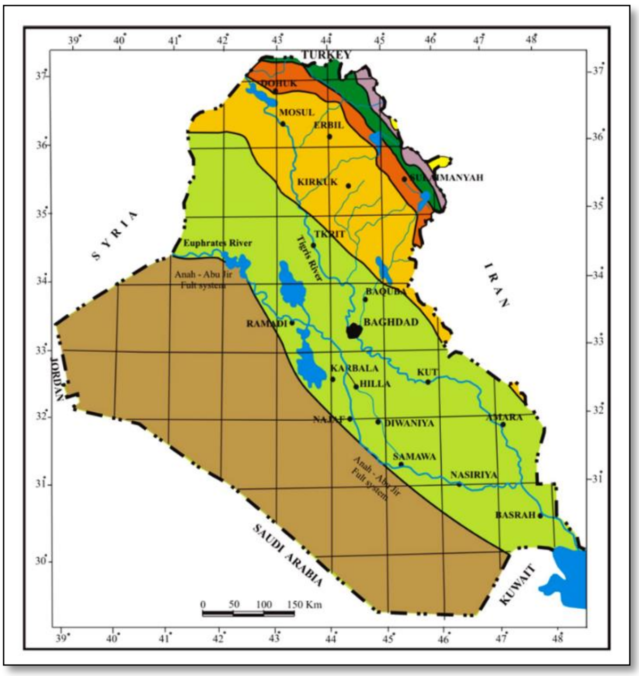


**Figure (1) Locations of the Studied sites in Iraq**

## RESULTS AND DISSCUSION

The results of Table (2) regarding the size distribution of soil fractions for the study soil samples indicated that the clay fraction dominates in the subsurface soil layer of the Zakho site in Dohuk Governorate, as its percentage was 676.0 $g.kg^{-1}$ Soil and also in the subsurface soil layer of the Al-Kahlaa site, as its percentage was 543.6 $g.kg^{-1}$ soil, result of combined effect of morphological factors related to the nature of the sedimentation and the sedimentary environment of each site, as well as site factors and pedogenic processes (Sullivan, 2004; Al-Husayni, 2005). The predominance of sand fraction in the subsurface soil layer of the Tikrit site was 635.0 $g.kg^{-1}$ soil. Through these results, the dominant soil texture in the study soils can be distinguished, ranging from medium to fine.

**Table 2. Soil Particle Size Analysis**

| Governorate | Samples sites | Depth (cm) | pH | Electrical conductivity 1:1 $dS\ m^{-1}$ | O.M $gm\ kg^{-1}$ |
|---|---|---|---|---|---|
| Duhok | Bardarash | 0-30 | 7.9 | 0.68 | 40.0 |
| | | 30-60 | 8.0 | 0.99 | 26.2 |
| | Zakho | 0-30 | 7.5 | 1.12 | 24.5 |
| | | 30-60 | 7.7 | 2.93 | 20.0 |
| Salah al-Din | Tikrit | 0-30 | 7.9 | 3.13 | 1.9 |
| | | 30-60 | 7.6 | 3.12 | 1.7 |
| Al- Anbar | Ramadi | 0-30 | 7.7 | 5.15 | 3.5 |
| | | 30-60 | 7.7 | 4.68 | 1.0 |
| Al-Amarah | AL-Kahlaa | 0-30 | 7.5 | 38.1 | 19.7 |
| | | 30-60 | 7.6 | 27.8 | 13.1 |
| | Qal'at Saleh | 0-30 | 7.3 | 39.8 | 22.3 |
| | | 30-60 | 7.6 | 29.5 | 18.1 |

Table (3) shows some of the chemical properties of the soils under study. The results show that the soils in the study had a reaction ranging from neutral to slightly basic, as the soil reaction values ranged between 7.3 and 8.0, and lower reaction number values characterized the surface soil layer of these soils compared to the deep horizons, which is due to the accumulation of organic matter and decomposition products of plant residues at the soil surface (Haider A. Al-Maamori et al.2024; Hamad et al, 2021). The variation in the values of the degree of soil reaction from one site to another and the variation in values between the surface soil layer and the subsurface soil layer of the same site confirms the influence of some environmental factors represented by rain. The results showed that the degree of soil reaction decreased the surface soil layer in the northern regions. Compared to the subsurface soil layer, this is due to the dominance of continuous salt leaching processes and the dominance of hydrogen ions over the exchange complex as a result of the increased intensity and quantities of precipitation and the decrease in temperatures, which led to the accumulation of organic matter decomposition products and their organic acids in the surface soil layer, which in turn led to a decrease in the degree of soil reaction. Table (3) also shows the electrical conductivity values of the study soils, which is considered a quantitative measure to express the extent of soil salinity for each site. The electrical conductivity values recorded a significant decrease in the sites of northern Iraq, as these values ranged between 0.68 - 2.93 ds.m$^{-1}$ in Dohuk. These results are consistent with most studies of these regions and in this field, which confirmed that the soils of northern Iraq are non-saline soils as a result of the continuous and long-term washing operations to which they are exposed due to the increased amount of precipitation and the density of the vegetation cover due to the prevailing climatic conditions in these regions. Low values in their electrical conductivity were observed in these sites. The electrical conductivity (EC) values for the sites in central Iraq ranged between 3.12 and 5.15 ds.m$^{-1}$ in Tikrit and Ramadi.

**Table 3. Some chemical properties of the study soils**

| Samples sites | | | Weight of Sample (gm) | Weight of Light Minerals (gm) | Percentage of Light Minerals (%) | Weight of Heavy Minerals (gm) | Percentage of Heavy Minerals % |
|---|---|---|---|---|---|---|---|
| Duhok | Bardarash | 0-30 | 5 | 4.78 | 95.6 | 0.22 | 4.4 |
| | | 30-60 | 5 | 4.77 | 95.4 | 0.23 | 4.6 |
| | Zakho | 0-30 | 5 | 4.79 | 95.8 | 0.21 | 4.2 |
| | | 30-60 | 5 | 4.77 | 95.4 | 0.23 | 4.6 |
| Salah al-Din | Tikrit | 0-30 | 5 | 4.79 | 95.8 | 0.21 | 4.2 |
| | | 30-60 | 5 | 4.80 | 96.0 | 0.20 | 4.0 |
| Al- Anbar | Ramadi | 0-30 | 5 | 4.84 | 96.8 | 0.16 | 3.2 |
| | | 30-60 | 5 | 4.80 | 96.0 | 0.20 | 4.0 |
| Al-Amarah | AL-Kahlaa | 0-30 | 5 | 4.81 | 96.2 | 0.19 | 3.8 |
| | | 30-60 | 5 | 4.84 | 96.8 | 0.16 | 3.2 |
| | Qal'at Saleh | 0-30 | 5 | 4.82 | 96.4 | 0.18 | 3.6 |
| | | 30-60 | 5 | 4.83 | 96.6 | 0.17 | 3.4 |

In comparison, the electrical conductivity values for the sites in southern Iraq ranged between 27.8 and 39.8 ds.m$^{-1}$ in Amara. These results are consistent with the conditions of the region, which is characterized by arid and semi-arid climate accompanied by high temperatures, increased evaporation processes at the soil surface, low precipitation, and weak vegetation cover density, which leads to a gradual and aggregate accumulation of salts, especially at the surface soil layer. These results were consistent with what was mentioned in (Makttoof and Nafawa.2024; Rahim and Neima, 2022). The results of Table (3) also showed the amount of organic matter in the study soils, as its values ranged in the regions of northern Iraq between 20.0 - 40.0 g.kg$^{-1}$ in Bardarash and Zakho. From these results, there was an increase in the amount of organic matter in these sites as a result of the availability of a source of organic matter close to the soil surface, such as natural and seasonal vegetation cover that produces organic waste on the surface soil layer, in addition to the availability of suitable environmental conditions such as low temperatures, which contributes to a decrease in the oxidation rates of organic materials. The results also showed that the amount of organic matter in the soils of the central and southern regions of Iraq, represented by Tikrit, Ramadi, Al-Kahlaa and Qal'at Saleh, ranged between 1.0 - 3.5 g.kg$^{-1}$ and 13.1 - 22.3 g.kg$^{-1}$, respectively. In general, most studies have shown that the organic matter content of Iraqi soils begins to decrease as we move from the north to the south as a result of the prevailing arid and semi-arid climatic conditions, including low rainfall, low moisture content, and high annual temperatures, which increase the chances of oxidation and decomposition processes occurring. In addition to the activity of wind erosion processes that increase the erosion and reduce the vegetation cover, this is in line with the opinion of Al Maamouri and Al Shamary**(2024)** .

Separating light and heavy minerals from the sand fraction in the study soil layer showed that light minerals with a specific weight of less than 2.89 constitute the largest part of the sand fraction, as shown in Table (4). These minerals included Carbonate Rock Fragments that fall within Rock Fragments, Quartz, Feldspars, and Coated Grains by Clay. Table (5) shows the percentages of light minerals in the sand fraction, where carbonate rock fragments were dominant in all the study soil layer, and their percentage ranged between (27.9 - 38.6%). The results also showed that the vertical distribution of carbonate minerals within the study soil layer was not homogeneous. The dominance of carbonate minerals in the study soils is due to the influence of the nature of the original soil material, which was originally rich in carbonate minerals. Quartz, a mineral with high weathering resistance, ranked second, with its percentage ranging between 1.4 and 33.8%. It had a heterogeneous vertical distribution in all the study soil layer, and its increased percentage in these soils is attributed to the temporal variation in soil age and the nature of the mineral composition of the parent material. Polycrystalline Quartz was also less abundant than monocrystalline Quartz. As for feldspar minerals, their presence rates in the study soil layer ranged between (2.2 - 5.6%) and were close in most of the study soil layer. They are considered among the minerals that are greatly affected by different weathering processes, and they are also affected by the nature of the soil components, the nature of the parent material, and the weathering intensity. Therefore, it can be noticed that its percentages decrease greatly in some soil layer, and perhaps the reason for this is the ease of its weathering and transformation into muscovite and quartz minerals (AL-jibury,2019; Al-Bayati and Al-Obaydi,2023). To clarify the weathering condition of light minerals, the ratio of quartz/feldspar was adopted as an indicator of the weathering intensity of light minerals in the study soils. Table (5) shows the values of the weathering index of light minerals, as these values ranged between (3.3 and 6.1), as the lowest value appeared in the soils of the subsurface soil layer of the soil samples of the Bardarash and Zakho regions. The highest values appeared within the surface soil layer of the soil samples of the Tikrit, Qal'at Saleh, and Al-Kahlaa regions. The results generally indicate higher weathering index values in the surface soil layer or those following them. This is probably due to higher microbial and biological activity in these soil layer, which are more affected by changes in climatic and environmental conditions such as temperature and rainfall, in addition to the increased decomposition of plant residues, which encouraged increased microbial activity in them, which helped in the weathering of these minerals and their transformation into other minerals. To clarify the weathering condition of light minerals, (the ratio of quartz/the ratio of feldspar minerals) was adopted as an indicator of the weathering intensity of light minerals in the study soils, as the values of the weathering index for light minerals appear in Table (5), as these values ranged between (3.3 - 6.1). Whereas the lowest value appeared in the soils of the subsurface soil layer of the soil samples of the Bardarash and Zakho regions, and the highest values appeared within the surface soil layer of the soil samples of the Tikrit, Qal'at Saleh and Al-Kahlaa regions. The results generally indicate higher weathering index values in the surface soil layer or those following them. This is probably due to higher microbial and biological activity in these soil layer, which are more affected by changes in climatic and environmental conditions such as temperature and rainfall, in addition to the increased decomposition of plant residues, which encouraged increased microbial activity in them, which helped in the weathering of these minerals and their transformation into other minerals.

**Table 4. Percentages of heavy and light sand minerals for soils in study sites**

| **Light Components** | | **Samples sites** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Duhok** | | | | **Salah al-Din** | | **Al- Anbar** | | **Al-Amarah** | | | |
| | | **Bardarash** | | **Zakho** | | **Tikrit** | | **Ramadi** | | **Qal'at Saleh** | | **AL-Kahlaa** | |
| | | **0-30** | **30-60** | **0-30** | **30-60** | **0-30** | **30-60** | **0-30** | **30-60** | **0-30** | **30-60** | **0-30** | **30-60** |
| **Quartz** | Monocrystalline Quartz | 21.5 | 21.8 | 22.1 | 22.2 | 26.3 | 25.7 | 23.3 | 28.2 | 33.8 | 32.9 | 32.3 | 31.5 |
| | Polycrystalline Quartz | 2.1 | 1.7 | 2.3 | 3.5 | 2.6 | 2.3 | 1.4 | 2.6 | 1.5 | 3.1 | 2.8 | 2.4 |
| **Feldspars** | Potash Feldspar Microcline | 3.3 | 2.4 | 3.7 | 3.6 | 2.2 | 3.4 | 3.5 | 4.8 | 2.7 | 2.8 | 2.3 | 3.7 |
| | Potash Feldspar Orthoclase | 3.7 | 4.8 | 3.4 | 4.2 | 3.6 | 4.8 | 3.9 | 2.5 | 3.3 | 4.6 | 3.5 | 4.6 |
| | Plagioclase Feldspar | 4.4 | 5.2 | 4.5 | 5.6 | 4.5 | 3.6 | 4.5 | 4.6 | 3.5 | 3.3 | 4.4 | 3.5 |
| **Rock Fragments** | Carbonate Rock Fragments | 37.1 | 38.6 | 36.3 | 34.4 | 32.9 | 34.2 | 35.3 | 30.1 | 27.9 | 28.4 | 28.8 | 29.2 |
| | Chert Rock Fragments | 7.8 | 5.2 | 8.2 | 6.9 | 7.8 | 5.6 | 7.1 | 6.4 | 5.5 | 4.6 | 5.1 | 5.6 |
| | Mudstone Rock Fragments | 6.3 | 6.8 | 5.1 | 6.2 | 3.6 | 3.3 | 4.4 | 5.7 | 6.6 | 7.2 | 6.6 | 6.7 |
| | Evaporites (Gypsum) | 1.7 | 1.5 | 0.6 | 1.4 | 4.7 | 3.5 | 4.6 | 2.3 | 6.7 | 5.8 | 6.5 | 5.4 |
| | Igneous Rock fragment | 4.5 | 4.4 | 5.7 | 4.2 | 5.5 | 4.4 | 5.7 | 4.2 | 3.3 | 2.9 | 2.6 | 2.1 |
| | Metamorphic Rock Fragments | 5.2 | 5.3 | 4.8 | 5.5 | 4.4 | 5.8 | 4.2 | 5.8 | 2.7 | 2.1 | 3.3 | 3.6 |
| Coated Grains by Clay | | 2.1 | 1.7 | 2.4 | 1.7 | 1.6 | 2.9 | 1.5 | 2.5 | 1.6 | 1.7 | 1.2 | 1.4 |
| Others | | 0.3 | 0.6 | 0.9 | 0.6 | 0.3 | 0.5 | 0.6 | 0.3 | 0.9 | 0.6 | 0.6 | 0.3 |
| Weathering index* | | 3.4 | 3.3 | 3.4 | 3.3 | 5.0 | 3.4 | 3.3 | 4.2 | 5.9 | 4.9 | 6.1 | 4.1 |

**Table 5. Percentages of Light Minerals for soils in Study sites**

| Heavy Minerals | Samples sites | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Duhok | | | | Salah al-Din | | Al- Anbar | | Al-Amarah | | | |
| | Bardarash | | Zakho | | Tikrit | | Ramadi | | AL-Kahlaa | | Qal'at Saleh | |
| | 0-30 | 30-60 | 0-30 | 30-60 | 0-30 | 30-60 | 0-30 | 30-60 | 0-30 | 30-60 | 0-30 | 30-60 |
| **Opaques** | 37.2 | 35.1 | 35.3 | 38.3 | 43.7 | 38.4 | 40.1 | 40.2 | 38.7 | 39.6 | 37.3 | 39.2 |
| **Chlorite** | 8.1 | 9.2 | 10.1 | 9.6 | 7.4 | 8.3 | 7.5 | 7.6 | 7.2 | 9.3 | 8.2 | 7.9 |
| **Pyroxene** | 7.4 | 7.8 | 8.1 | 7.5 | 7.1 | 7.8 | 7.4 | 7.7 | 5.3 | 4.0 | 5.5 | 4.8 |
| **Hornblende** | 7.0 | 6.0 | 7.9 | 6.3 | 5. 8 | 6.8 | 7. 3 | 6.2 | 4.1 | 3.4 | 4.5 | 5.3 |
| **Biotite** | 5.2 | 6.3 | 4.1 | 6.1 | 5.3 | 5.7 | 4.9 | 6.1 | 5.3 | 7.2 | 6.7 | 4.8 |
| **Muscovite** | 6.8 | 8.1 | 7.4 | 5.7 | 4.5 | 5.4 | 7.4 | 5.7 | 4.5 | 5.4 | 6.3 | 4.2 |
| **Epidote** | 6.3 | 6.5 | 7.1 | 6. 5 | 5.5 | 5.9 | 6.5 | 5.5 | 6.2 | 5.5 | 6.4 | 8.6 |
| **Zircon** | 4.8 | 3.1 | 3.2 | 4.5 | 3.9 | 4.4 | 3.4 | 3.7 | 7.9 | 6.4 | 5.9 | 7.2 |
| **Tourmaline** | 2.4 | 3.5 | 2.4 | 2.4 | 3.7 | 4.3 | 4.7 | 5.8 | 6.5 | 6.2 | 5.5 | 5.4 |
| **Rutile** | 3.9 | 4.8 | 3.3 | 3.2 | 3.5 | 3.6 | 2.7 | 2.6 | 5.7 | 4.6 | 4.2 | 3.3 |
| **Garnet** | 5.7 | 4.5 | 5.4 | 5.1 | 5.4 | 3.7 | 4.6 | 5.1 | 5.4 | 4.7 | 4.4 | 4.2 |
| **Kyanite** | 4.7 | 3.6 | 4.5 | 3.9 | 3. 3 | 4.2 | 2.9 | 2.9 | 2.3 | 2.2 | 3.9 | 4.2 |
| **Others** | 0.5 | 1.5 | 1.2 | 0.9 | 0.9 | 1.5 | 0.6 | 0.9 | 0.9 | 1.5 | 1.2 | 0.9 |
| ***Weathering index** | 0.50 | 0.48 | 0.35 | 0.50 | 0.59 | 0.60 | 0.55 | 0.68 | 1.53 | 1.70 | 1.14 | 1.25 |
| *** Index minerals** | 16.80 | 15.90 | 14.30 | 15.20 | 16.50 | 16.00 | 15.40 | 17.20 | 25.50 | 21.90 | 20.00 | 20.10 |

Rock Fragments> Quartz> Feldspars> Coated Grains by Clay

* The ratio of (quartz/feldspar) was adopted as an indicator of the weathering intensity of light minerals in the study

The results shown in Table (6) also showed the values of heavy minerals as a percentage of the sand fraction and their distribution with depth. They included a large number of minerals and were distributed according to the dominant, opaque minerals group, then the minerals chlorite, Pyroxene, epidote, muscovite, hornblende, Zircon, biotite, Tourmaline, rutile, Garnet, and kainite. The results shown in Table (6) show that the group of opaque grains ranked first in terms of dominance, as these minerals dominated most of the study soil layer. Opaque grains ranged between 35.1 and 43.7%, with the lowest value recorded in the subsurface soil layer of the soil model in the Bardarash area and the highest value recorded in the surface soil layer of the soil model in the Tikrit area. The reason for the dominance of the opaque mineral group over the rest of the minerals is due to the role of the parent material rich in oxides. Furthermore, Kerr, **1959** showed that opaque minerals are found in metamorphic and re-deposited sedimentary rocks. Chlorite is the second most prevalent mineral group in soil layer in most studies, with chlorite values exceeding those of other minerals. Chlorite mineral values ranged between (7.2-10.1%), as the vertical distribution of these minerals with depth was heterogeneous. Pyroxene minerals were the dominant minerals in the study soils, as their percentages ranged between (4.0 and 8.1%), with a homogeneous vertical distribution with depth within all study soil layer. The values of these minerals were generally close, and their distribution pattern was not vertically homogeneous. Ali, 2021 showed that these minerals' sources in Iraqi soils are either medium basic and ultrabasic igneous rocks or acidic rocks. Table (6) also shows the presence of epidote in percentages ranging between (5.5 and 8.6%), a mineral resistant to weathering and common in metamorphic rocks. It may be an additional mineral in igneous rocks (Pettijohn,**1975** ). Among the dominant minerals in the study soils are muscovite minerals, whose percentages ranged between (4.2 - 8.1%) and with a vertically inhomogeneous distribution with depth within all the study soil layer. Table (6) shows the hornblende or amphibole minerals, as their percentages ranged between (3.4 - 7.9%) and with a vertically inhomogeneous distribution with depth within all the study soil layer. Zircon ranged in percentage from (3.1 to 7.9%) in all the study soil pedons. This mineral may have originated from igneous and metamorphic rocks. As shown in Table (6), the presence of biotite minerals ranged between (4.1 - 7.2%). The results show that the proportions of muscovite minerals were superior to the proportions of biotite minerals in all the study soils due to their higher resistance to weathering than biotite minerals. Tourmaline minerals were found in low proportions in all the study soils compared to the other heavy minerals. This may be related to the nature of the original material of the study soils. The source of these minerals may be igneous and metamorphic rocks as well as sedimentary rocks. The tourmaline value ranged between (2.4 - 6.5%) in the study soil pedons. Garnet minerals were also observed, ranging in percentage from (3.7 to 5.7%), and their values were low and close to the soil layer of the study soils. Garnet is considered a weathering-resistant mineral (Milner,**1962** ). The low percentages of this mineral may indicate the nature of the parent material, which may have a low content of this mineral. Garnet is a common mineral in metamorphic rocks and may be found in igneous rocks as an additional mineral (Pettijohn,**1975** ). Rutile appeared in percentages ranging between (2.6 and 5.7%), as its percentage was low in all the study soils compared to the rest of the heavy minerals. The decrease in this mineral may be attributed to the nature of the original rocks from which these soils came, which may have a low mineral content. As for the mineral Kyanite, it appeared in proportions ranging between (2.2 - 4.7%). Kyanite is a heavy mineral resistant to weathering (Flok, **1974**). To clarify the weathering condition of heavy metals, the ratio of (Zircon + Tourmaline) minerals / (Amphibole + Pyroxene) minerals was adopted to indicate the weathering intensity of heavy metals in the study soils. The values of the weathering index for heavy metals are shown in Table (6), as these values ranged between (0.35 - and 1.70), with the highest value appearing in the soil of the subsurface soil layer of the Al-Kahlaa site in Al-Amarah Governorate. The results generally indicate high weathering index values in the surface soil layer or those following them in the Al-Amarah Governorate soil samples for the Al-Kahlaa and Qal'at Saleh sites. This is perhaps due to the high pedological and microbial activity in those soil layer, which are more affected by changes in climatic conditions, such as temperature and increased soil moisture, as they are soils with high moisture content. In addition, the increased decomposition of plant waste encouraged increased microbial activity, which helped weather these minerals and transform them into other minerals. The results of the weathering index in Table (6) showed that the amount of variation in the values of the index between the soil layer of the same site was weak. In contrast, the variation in the index values between the soil layer of the study soils differed from one site to another. It can be noticed that the values are close in the northern and central sites due to the similarity of the environmental conditions. The index values differed or were distinguished in the southern location due to the sharp change in the influencing environmental conditions, such as high temperatures and variations in humidity levels during the agricultural seasons. The percentage of the mineral index has also been calculated, which is the sum of the percentages of minerals resistant to weathering (Zircon + Garnet + rutile + tourmaline). These percentages showed more precisely the occurrence of weathering processes in the study soil layer. There was an increase in this percentage in the surface and subsurface soil layer in the soil samples of the southern site (Al-Kahlaa, Qal'at Saleh), noting that these percentages were low in the study soil layer in the northern and central sites. Still, they are also influential percentages and indicate the occurrence of metal weathering, which shows the extent of the effect of plant residue decomposition products on the weathering of sand minerals and their transformation into other minerals.

**Table 6. Percentages of Heavy Minerals for soils in Study sites**

| Light Components | | Samples sites | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Duhok | | | | Salah al-Din | | Al- Anbar | | Al-Amarah | | | |
| | | Bardarash | | Zakho | | Tikrit | | Ramadi | | Qal'at Saleh | | AL-Kahlaa | |
| | | 0-30 | 30-60 | 0-30 | 30-60 | 0-30 | 30-60 | 0-30 | 30-60 | 0-30 | 30-60 | 0-30 | 30-60 |
| Quartz | Monocrystalline Quartz | 21.5 | 21.8 | 22.1 | 22.2 | 26.3 | 25.7 | 23.3 | 28.2 | 33.8 | 32.9 | 32.3 | 31.5 |
| | Polycrystalline Quartz | 2.1 | 1.7 | 2.3 | 3.5 | 2.6 | 2.3 | 1.4 | 2.6 | 1.5 | 3.1 | 2.8 | 2.4 |
| Feldspars | Potash Feldspar Microcline | 3.3 | 2.4 | 3.7 | 3.6 | 2.2 | 3.4 | 3.5 | 4.8 | 2.7 | 2.8 | 2.3 | 3.7 |
| | Potash Feldspar Orthoclase | 3.7 | 4.8 | 3.4 | 4.2 | 3.6 | 4.8 | 3.9 | 2.5 | 3.3 | 4.6 | 3.5 | 4.6 |
| | Plagioclase Feldspar | 4.4 | 5.2 | 4.5 | 5.6 | 4.5 | 3.6 | 4.5 | 4.6 | 3.5 | 3.3 | 4.4 | 3.5 |
| Rock Fragments | Carbonate Rock Fragments | 37.1 | 38.6 | 36.3 | 34.4 | 32.9 | 34.2 | 35.3 | 30.1 | 27.9 | 28.4 | 28.8 | 29.2 |
| | Chert Rock Fragments | 7.8 | 5.2 | 8.2 | 6.9 | 7.8 | 5.6 | 7.1 | 6.4 | 5.5 | 4.6 | 5.1 | 5.6 |
| | Mudstone Rock Fragments | 6.3 | 6.8 | 5.1 | 6.2 | 3.6 | 3.3 | 4.4 | 5.7 | 6.6 | 7.2 | 6.6 | 6.7 |
| | Evaporites (Gypsum) | 1.7 | 1.5 | 0.6 | 1.4 | 4.7 | 3.5 | 4.6 | 2.3 | 6.7 | 5.8 | 6.5 | 5.4 |
| | Igneous Rock fragment | 4.5 | 4.4 | 5.7 | 4.2 | 5.5 | 4.4 | 5.7 | 4.2 | 3.3 | 2.9 | 2.6 | 2.1 |
| | Metamorphic Rock Fragments | 5.2 | 5.3 | 4.8 | 5.5 | 4.4 | 5.8 | 4.2 | 5.8 | 2.7 | 2.1 | 3.3 | 3.6 |
| Coated Grains by Clay | | 2.1 | 1.7 | 2.4 | 1.7 | 1.6 | 2.9 | 1.5 | 2.5 | 1.6 | 1.7 | 1.2 | 1.4 |
| Others | | 0.3 | 0.6 | 0.9 | 0.6 | 0.3 | 0.5 | 0.6 | 0.3 | 0.9 | 0.6 | 0.6 | 0.3 |
| Weathering index* | | 3.4 | 3.3 | 3.4 | 3.3 | 5.0 | 3.4 | 3.3 | 4.2 | 5.9 | 4.9 | 6.1 | 4.1 |

Opaques > Chlorite> Pyroxene> Epidote> Muscovite> Hornblende> Zircon> Biotite> Tourmaline> Garnet> Rutile> Kyanite.
* The ratio of (Zircon + tourmaline) / (amphibole + Pyroxene) was adopted as an index of the weathering intensity.
Index Minerals (Garnet + Rutile + Zircon + Tourmaline).

The morphological properties of sand fraction particles were studied after they were separated into two parts using a bromoform ($CHBr_3$) solution with a specific gravity of less than 2.89. The first part contained light minerals, and the other part contained heavy minerals. The focus was on studying the morphological characteristics adopted in this study, such as the metal surfaces' colour characteristics and morphological appearances. The images of light metals, Figure (2), showed large differences in the size of the metal particles and a large variation in the colour of the metal particles between the study sites. The mineral images also showed the effect of different weathering processes on the outer edges of the mineral particles, which appeared in a pale colour surrounding the mineral particles. Dark spots also appeared. The dark brown colour of the spots on the mineral surfaces may be due to the deposition of the remains of decomposing organic materials. The images (2) also showed that these spots differed in their distribution on the metal surface. Sometimes, they covered the surface almost completely, and others were intermittently distributed. These different patterns of spot distribution on the surfaces could be due to the difference in the amount of organic material decomposition products and the type of plants growing in these soils. Moreover, Certini *et al*, 2003 showed in their study of forest soils that the difference in the distribution of organic matter accumulated on the surface of chlorite in these soils is mainly due to the difference in the nature and quantity of decomposed organic matter depending on the type of forest trees growing in these soils.

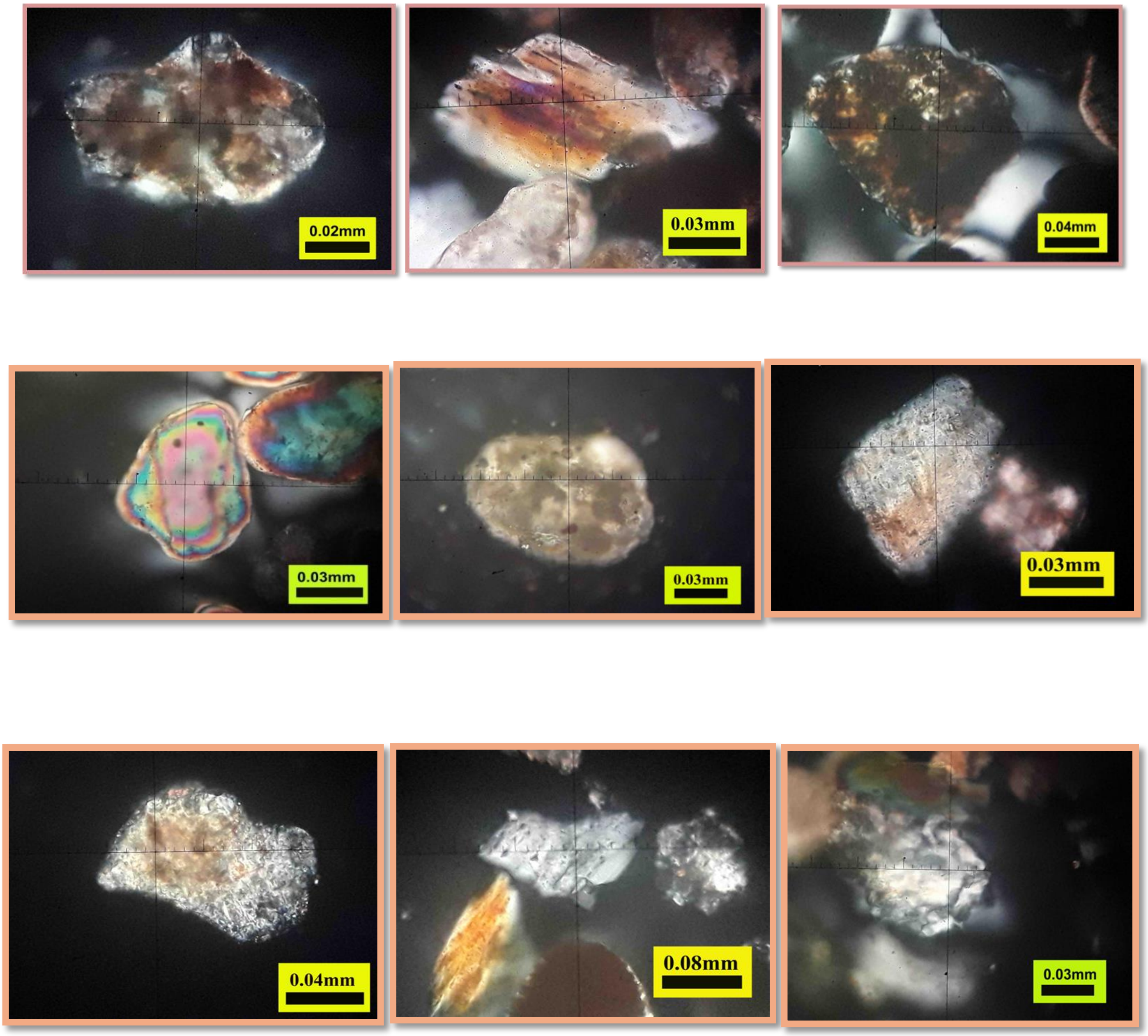


**Figure (2) Images of light mineral particles in the sand fraction in the study soils**

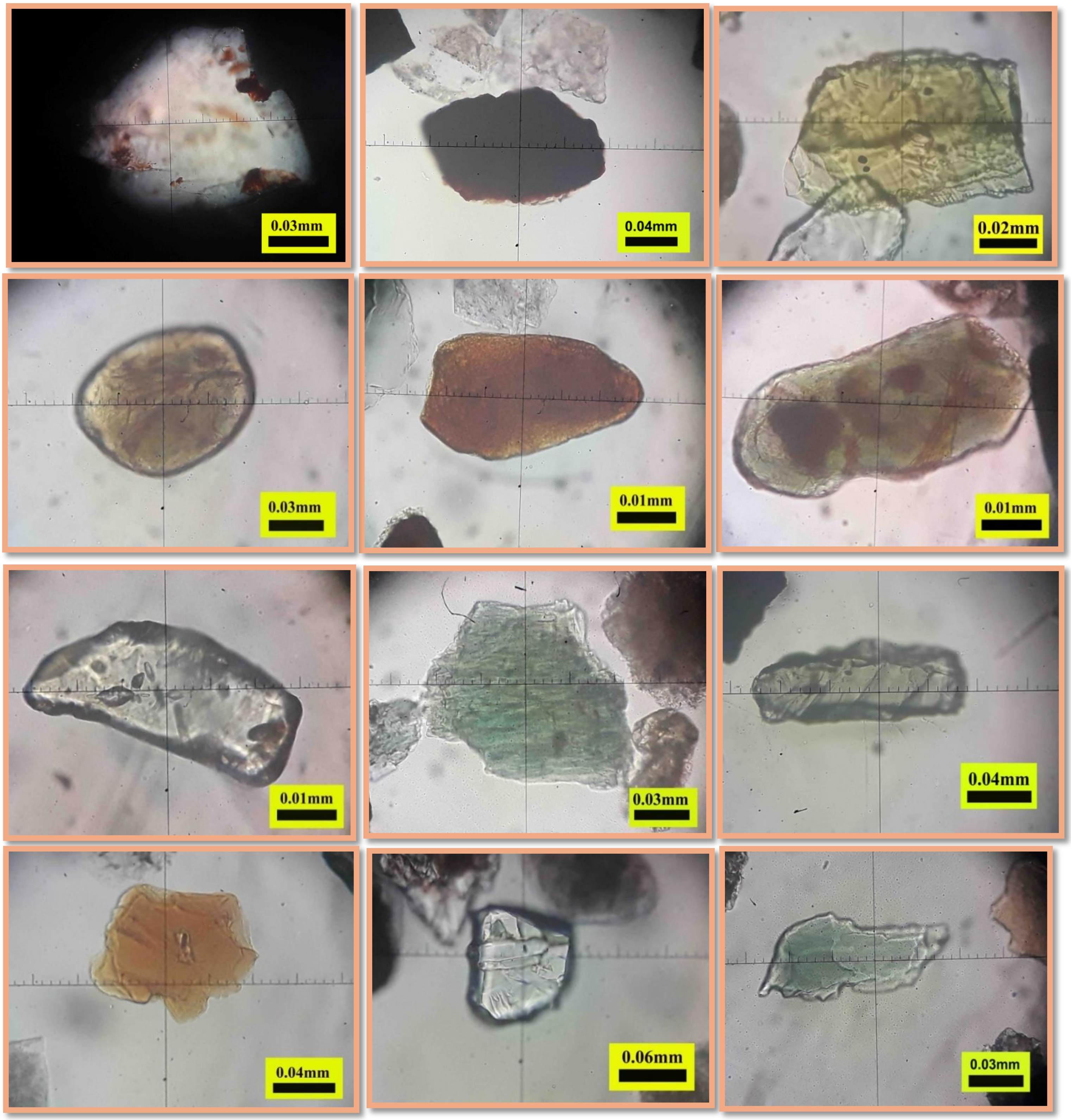


**Figure (3) Images of heavy metal particles in sand fraction in the study soils**

## CONCLUSION

The study documents the heavy and light mineral composition of the sand fraction in some Soils of Iraq and compares their distribution and Affected by climate factors. The variation in the values of the degree of soil reaction from one site to another and the variation in values between the surface soil layer and the subsurface soil layer of the same site confirms the influence of some environmental factors represented by rain. Light minerals with a specific weight of less than 2.89 constitute the largest part of the sand fraction. The dominance of carbonate minerals in the study soils is due to the influence of the nature of the original soil material. The ratio of quartz/feldspar was adopted as an indicator of the weathering intensity of light minerals in the study soils. The results generally indicate higher weathering index values in the surface soil layer or those following them. Results showed that Light Minerals for soils in Study sites took the following order Rock Fragments> Quartz> Feldspars> Coated Grains by Clay. Results showed that heavy Minerals for soils in Study sites took the following order Opaques > Chlorite> Pyroxene> Epidote> Muscovite> Hornblende> Zircon> Biotite> Tourmaline> Garnet> Rutile> Kyanite.

## CONFLICT OF INTEREST

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