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ORIGINAL RESEARCH ARTICLE

Weathering indices and mineralogical composition of the sand fraction in soils from the western desert of holy Karbala governorate, Iraq

Shireen Mudhafar Ali Alkhalil

Department of Desertification Combat, College of Agricultural Engineering Sciences, University of Baghdad, Baghdad, 10071,Iraq

***Corresponding author:** Shireen Mudhafar Ali Alkhalil; shiren.modhufer@coagri.uobaghdad.edu.iq

ABSTRACT

This study focuses on analyzing the mineral composition of sand fraction was separated from clay and silt in selected soils of the Western Desert in Karbala Governorate, Iraq, and assessing the intensity of Mineral Weathering Index MWI and ZTR indicators. Sixteen samples were collected from depths of 0–30 cm, sand was separated from clay and silt, then light and heavy minerals were identified with polarized light microscope. The results showed that monocrystalline quartz dominated by 21.1-26.9%, while polycrystalline quartz ranged between 2.7–4.6%. Feldspar content ranged 2-3.9%, and carbonate rock fragments accounted for 28.2–40.2%. Heavy minerals were the most abundant which resented by iron oxides at 39.5-47.7%. Chlorite is present with 7.8-10.1%, biotite mica 4.4-6.5%, and muscovite 4.9–6.9%. Unstable minerals such as pyroxene and amphiboles ranged from 3.4–6.8%. MWI values ranged from 0.33-0.44, and ZTR values between 21.1-26.9, moderate to low weathering and low to moderate mineral maturity. These results reflect the nature of sedimentary deposits and the impact of a dry desert environment on limited chemical weathering.

Keywords: Light and heavy minerals; Mineral weathering Index MWI; ZTR indicators

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1. Introduction

Desertification poses an environmental challenge that threatens the ecosystems of dry and semi-arid regions around the world. Mainly in desert environments characterized by scarcity of vegetation cover, low intensity of weathering processes. The severity of depending on several factors, including the parent material, climatic conditions, erosion factors and the sedimentation environment. Studying the mineral composition of the sand fraction in the soil essential for understanding geological and geochemical processes and thus affects the development of the soil, as sand minerals, especially heavy sand minerals, retain their mineral footprint over time [1]. These studies provide an indication of the intensity of weathering processes and thus help to classify the soil and understand its development and the dynamics of the ancient environment.

Desert soils in the western regions of Iraq are an important geomorphological study model because of their dry climate. Weathering processes are limited due to high temperature, low of rainfall and limited vegetation cover. Therefor chemical weathering processes are less active or almost non-existent and physical weathering processes are the most influential and therefore depends on understanding and studying the type of geological formation, which includes calcareous and stratified formations. Most of these deposits consist of young sediments [2,3].

Recent studies [4-6] have confirmed that the mineralogical analysis of the components of the sand fraction of light minerals such as quartz, feldspar and rock fragments, and heavy minerals such as opaque minerals, stable and semi-stable minerals and others are relied upon to track the precipitation chest and sedimentation conditions, as well as to study them. This study provides a natural record that helps in understanding the history of the soil and its development and linking it to the geological source. Therefore, this study aims at evaluating the mineralogical composition of the sand separator in selected soils of the Western Desert in Karbala Governorate, as well as assessing the degree of weathering of these soils.

2. Materials and methods

The soil sampling site was selected in the Ain al-Tamr district, located about 85 Km west of the city of Karbala, which is an extension within the western desert in Iraq that extends between latitudes 32° 34' 0" N and longitudes 43° 29' 17" E. It is bordered to the north by Lake Razara, to the south by the governorate of Najaf Ashraf and to the west by the governorate of Anbar (Figure 1).

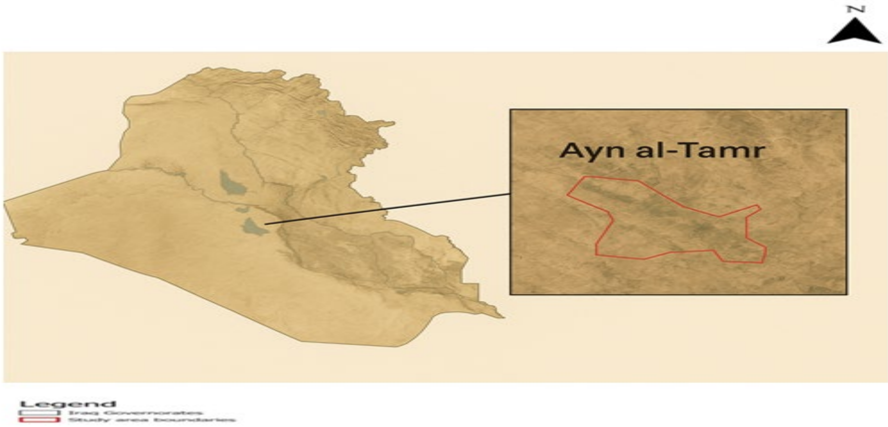

Figure 1. The study area

This area is characterized by natural sand structures as well as the presence of various geological formations. Sixteen soil samples were collected at a depth of 0-30 cm. The locations of the samples were determined using GPS. The samples were air dried and then grinded. The sand was separated from clay and silt using the method of wet sieving with a sieve of 50 microns. Using $CHBr_3$ with a specific weight of 2.89, the sand components were separated into heavy and light minerals [7]. The percentage of sand minerals was calculated using a point counter device, counting 250-300 sand grains per slide using the polarized light microscope according to the [8] in the laboratories of the Department of Earth Sciences College of Sciences University of Baghdad.

3. Results and discussion

3.1. Light sand minerals

The results of Table 1 show the mineral composition of the sand fraction revealing clear difference in the proportions of light minerals. Quartz is predominant mineral in all studied soils samples, especially monocrystalline quartz, which extinction in both straight and undulose extinction, indicating contribution from igneous and metamorphic rocks, The monocrystalline quartz are coarse to smooth single crystals (Figure 2a) ranging from 21.1-26.1%. In contrast polycrystalline quartz ranged between 2.7-4.6%, its grains appeared as composted quartz, of two or more crystalline units with different optical orientations, the grain exhibited angular to semi-circular shapes (Figure 2b), and its grains are characterized as medium-sized undulating. This reflects a high degree of mineral maturity, as its high percentage is due to the influence of the parent materials it is the main component of the sand separator as well as its high resistance to chemical and physical weathering due to the nature of its chemical bonds, especially in desert environments with limited water activity [9,10].

The results showed that the proportions of feldspar minerals ranged between 2.3-3.9% for potash feldspar, which is characterized by its fuzzy shape, corroded edges, minus faces, with a simple twinning (Figure 2c), and its colors ranged between pink, white, red, or colorless glass shimmer, with black spots on the surface, and this is due to the state of transformation that occurs in the mineral towards other minerals [11]

Table 1. Light Minerals (%) in Sand Fraction of the Studied Soils

Light Components	**Sample Numbers**															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Monocrystalline Quartz	21.4	23.4	21.1	25.8	24.8	25.7	24.2	23.1	24.7	26.9	22.1	23.2	25.5	21.7	25.2	26.2
Polycrystalline Quartz	3.2	2.7	4.0	3.5	2.7	3.6	3.9	4.6	3.7	3.8	4.1	3.6	4.2	3.5	4.6	3.3
Alkali Feldspar	2.3	2.4	2.7	2.4	3.0	2.9	2.6	3.1	2.8	2.3	2.8	3.2	2.4	3.1	3.4	3.9
Plagioclase Feldspar	2.1	2.8	2.2	2.7	2.5	2.7	2.3	2.2	2.5	2.4	2.1	2.6	2.1	2.3	2.4	2
Carbonate Rock Fragments	33.7	33.4	34.7	39.7	32.0	34.8	35.9	32.3	29.3	31.3	40.2	31.8	28.2	36.3	31.6	30.1
Chert Rock Fragments	9.4	9.6	7.5	10.9	8.1	7.9	8.5	9.4	7.7	8.8	6.8	9.5	9.3	10.2	7.4	8.1
Igneous Rock Fragments	2.8	2.1	2.5	2.6	2.8	1.9	2	2.2	2.6	1.7	1.5	2.3	1.8	1.9	2.4	1.4
Metamorphic Rock Fragment	2.0	2.9	2.1	2.6	2.4	2.5	1.9	1.2	1.8	2.2	1.6	2.7	2.2	2.5	1.4	1.6
Mudstone Rock Fragments	4.6	3.9	3.6	2.8	4.5	3.7	3.5	4.0	3.8	3.3	4.3	3.5	3.8	4.1	4.2	3.4
Evaporates	7.7	6.8	7.5	7.9	4.4	6.3	7.4	8.6	6.4	9.7	5.6	7.2	11.6	6.7	7.8	6.1
Coated Clay	1.8	1.2	2.4	1.7	2.9	3.2	2.8	3.3	2.9	3.1	2.6	2.4	2.8	2.6	2.4	2.2
Others	2.5	1.3	2.5	2.3	1.7	1.8	2.4	1.9	1.8	1.6	2.3	2.0	2.1	0.9	2.3	1.7

The plagioclase feldspar minerals ranged from 2 to 2.8%. The dominant mineral is the Albite that appeared angularly to semi-angular (Figure 2d), which is characterized by multiple twinning and clear cracking in two directions, one complete and the other less clear. Reference [12] stated that since feldspar minerals are less resistant to weathering, their presence is affected by the nature of the components of the soil and the substance of origin. As most of them are of fiery origin in garnet rocks and its transformation from gneiss rocks, as well as the intensity of weathering processes and drought conditions and its transmission through dry environment systems [13]. As for the carbonaceous rock fragments, they formed high proportions (28.2-40.2%). This reflects the prevalence of calcareous sedimentary rocks, which is one of the main sources of the original material, as they are characterized by a wide spread such as the opening, Rumaila, and the western and southern region of Iraq, which contain limestone and dolomite rocks [14].

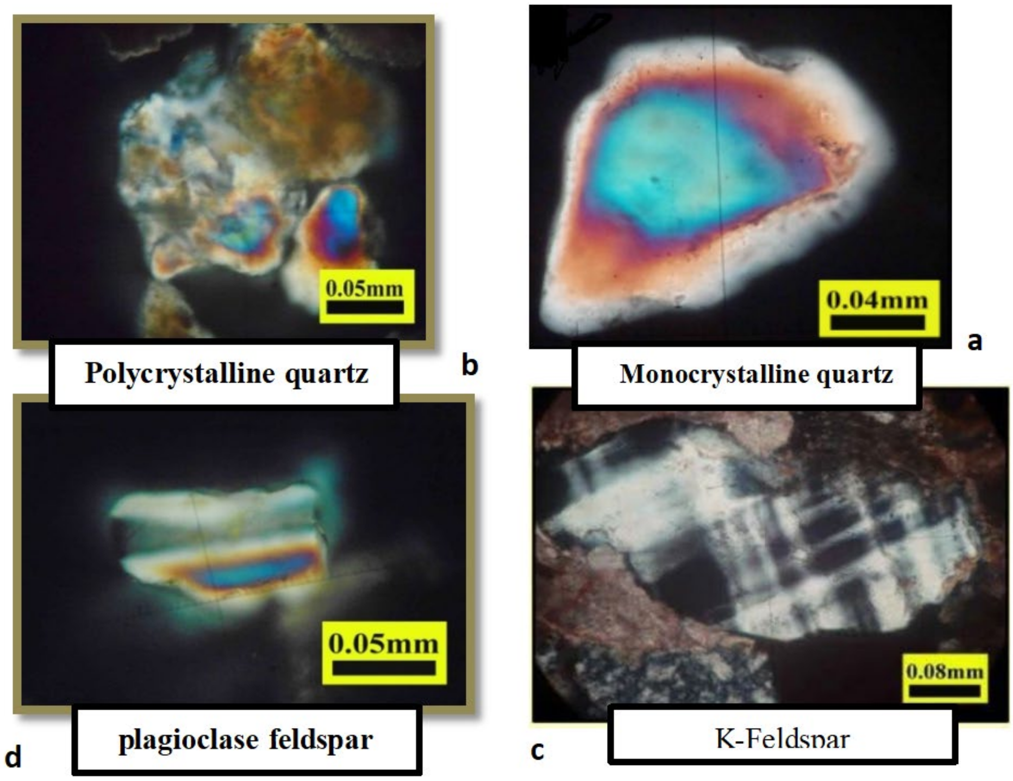

Figure 2. Photo micrographs shoeing some light minerals in the studied soils (40x magnification).

While the presence of other rock fragments (Chert,Igneous, Metamorphic, Mudstone) is low and its contribution is limited and it is from pyrotechnic or metamorphic sources and may be the result of deposits that have been transported over long distances or materials that have disintegrated and decomposed and descended from old solid blocks from distant areas [15]. The evaporators with remarkable proportions ranged between 4.4-11.6%, which indicates very dry climatic conditions that led to the deposition of gypsum and halite within desert environments, and this is reinforced by the presence of sabkha and gypsum deposits in low surfaces in the study area [16]

The Feldspar + Rock Fragments /Quartz ratio was used as an indicator to calculate the MWI for light minerals in all studied soils (Table 2). Most of the studied soils fell within the range of 0.27 - 0.32 (Figure 3). It indicates that the soils are exposed to low to moderate weathering with relative stability of quartz mineral and varying contributions of less resistant minerals such as feldspar and rock fragments. The level of this weathering is attributed to the desert environment, which is characterized by poor water activity, with the continued impact of physical factors such as erosion and wind transport, which is consistent with the geological and ecological structure of the study area.

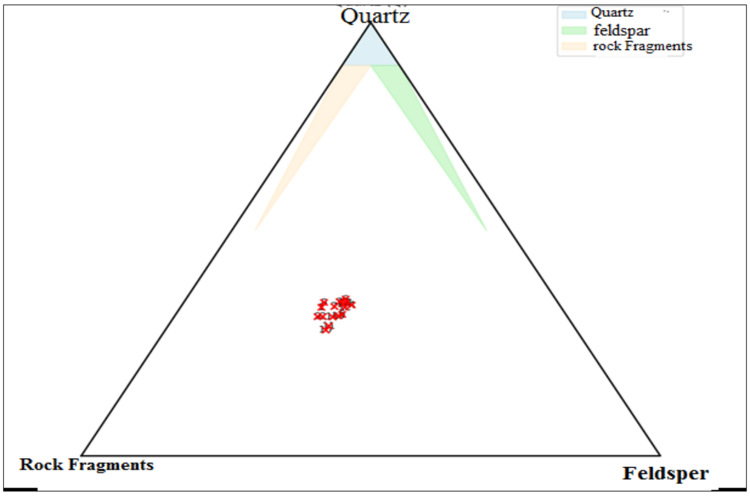

Figure 3. Classification of the studied soils according to the weathering coefficient of light minerals

Table 2 . Weathering index and mineral maturity index of light minerals in the study soils

Sample	Weathering index (relative)	Interpretation
1	0.33	Low Medium
2	0.35	Medium Weathering
3	0.34	Medium Weathering
4	0.41	Good temperate weathering
5	0.38	Moderate Weathering
6	0.41	Good temperate weathering
7	0.39	Moderate Weathering
8	0.38	Moderate Weathering
9	0.40	Good temperate weathering
10	0.44	Relatively high weathering
11	0.36	Medium Weathering
12	0.37	Moderate Weathering
13	0.42	Good temperate weathering
14	0.34	Low Medium
15	0.42	Good temperate weathering
16	0.42	Good temperate weathering

3.2. Heavy sand minerals

The results in Table 3 indicate that the opaque minerals represented mainly by iron oxides are predominant in all the soils of the study, as their proportions ranged between 39.5-47.7%. This is due to the fact that these minerals are more stable and resistant to weathering, so their source is due to the accumulation of deposits rich in iron oxides as a result of the presence of geomorphological or climatic activities. Magnetite oxide and black chromite of opaque color have diagnosed the mineral sparkle (Figure 4a) as well as hematite oxide of red-brown color with irregular shape (Figure 4b).[17]

In the current study, the average quantitative values of chlorite mineral ranged from 7.8-10.1 of the total components of heavy minerals.

Table 3. Heavy Minerals (%) in Sand Fraction of the Studied Soils

Heavy Components	Sample Numbers															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
(Opaques) Iron Oxides	42.9	39.5	46.9	44.3	45.7	43.3	45.3	47.7	45.7	43.2	45.1	44.5	46.3	46.1	45.8	42.4
Chlorite Group	8.5	10.1	8.6	9.7	9.9	9.1	8.7	8.9	8.8	8.4	8.1	8.0	7.8	8.4	9.2	9.0
Garnet Group	6.1	5.0	3.8	4.2	4.6	5.7	3.8	4.2	4.7	5.3	4.2	6.2	5.9	4.4	5.0	5.2
Zircon	6.3	6.4	5.3	5.5	5.5	4.2	4.6	3.9	4.3	4.4	5.6	4.3	4.5	3.2	5.2	5.0
Pyroxene	6.8	6.2	5.8	6.7	6.2	5.7	6.2	5.3	4.6	6.2	5.9	4.6	6.1	5.4	4.9	4.6
Amphibole	5.1	5.6	3.7	6.1	5.7	5.3	4.9	3.4	4.4	5.9	4.7	5.8	4.6	5.2	4.2	6.1
Epidote	4.1	6.5	5.6	4.2	6.3	4.8	5.6	6.2	6.0	6.8	5.8	4.2	6.1	5.7	5.1	5.5
Biotite	6.2	5.9	5.4	4.4	6.5	5.3	6.2	5.8	5.3	4.5	5.2	5.1	4.7	5.4	5.7	4.9
Muscovite	6.5	6.1	6.4	5.1	6.0	4.9	4.9	6.0	6.3	5.7	6.9	5.5	5.2	5.6	6.4	5.8
Tourmaline	1.2	-	1.8	1.6	0.6	-	2.3	2.2	2.8	1.4	0.8	1.3	2.0	1.7	2.2	1.5
Staurolite	1.7	1.2	-	1.3	1.1	0.9	-	1.4	-	1.6	1.3	1.5	0.8	2.0	1.9	1.8
Kyanite	2.4	1.8	2.6	2.6	1.5	-	1.9	1.7	2.0	1.1	2.4	2.1	2.2	1.9	2.0	2.3
Rutile	0.9	1.1	-	1.3	1.0	1.2	-	-	1.0	1.2	0.9	1.3	0.8	1.1	-	0.7
Celestite	0.5	1.4	1.2	1.3	0.9	1.1	0.8	0.6	-	1.0	-	0.7	0.2	-	0.4	0.6
Others	1.4	2.0	2.6	0.9	2.3	2.8	2.5	2.9	2.7	1.6	1.4	1.9	2.1	1.4	2.7	1.8

The color of the Chlorite phylosllicet mineral is mostly green to pale green with a round shape (Figure 4c) and is often derived from the transformation of biotite minerals, amphiboles, paroxene, or derived from metamorphic rocks [18]. One of the good indicators of the stability of the original minerals is the emergence of the minerals of garnet, zircon, tourmaline and rutile, despite their medium to low ratios. These minerals are considered weathering-resistant minerals and are attributed to the type and nature of the original rocks, as most of the rocks from which these minerals are derived are basic igneous rocks and metamorphic rocks [19]. The Biotite and Muscovite Mica minerals appeared in varying proportions (4.4-6.5%) and(4.9-6.9%) respectively. Their presence indicates a medium transport distance, as biotite is less resistant to weathering than muscovite, indicating a transformed volcanic source or resulting from rapid decomposition in the sedimentary environment [20].

It is noted from Table 3 that there is a group of unstable minerals represented by pyroxene and amphibole, as the proportions of pyroxene ranged from (4.6-6.8). Pyroxene is found in igneous rocks (basal and supra-basal), which are characterized by being colorless or pale yellowish green (Figure 4d).As for the Amphiboles, whose proportions ranged between (3.4 - 6.1%), their presence indicates an undeveloped source of igneous rocks, which are distinguished by the pale brownish green color [21]. The presence of these unstable minerals in the studied soils indicates the multiplicity of sources, the difference in transport distances and the speed of sedimentation, and that chemical weathering was not severe.

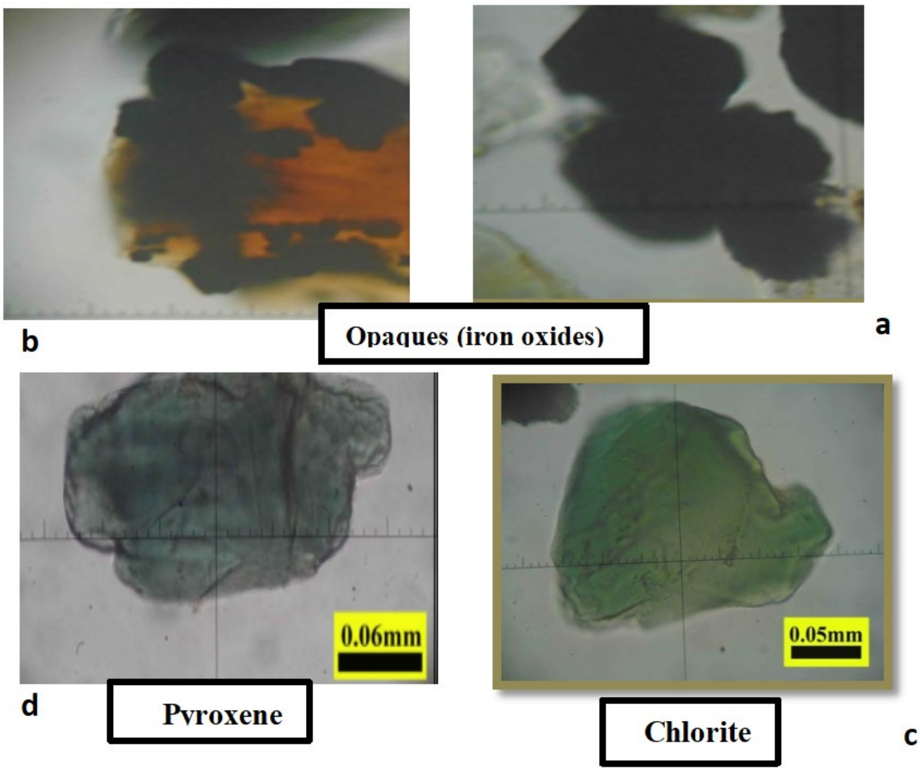

Figure 4. Photo micrographs shoeing some Heavy minerals in the studied soils(40x magnification)

As for the minerals of rutile, staurolite, kyanite, celestite, and others, their presence is limited or not available in a number of samples, and this indicates a disparity in the conditions of formation, transport, sedimentation, and the selectivity of sedimentation or weathering processes.

3.3. Calculation of weathering index ZTR index

An indicator was calculated as follows

ZTR Index= Zircon +Tourmaline +Rutile

Its value ranged between 21.1-26.9 (Figure 9). These values are considered low to medium according to the classification of mineral pumping [22], as the sand separation is considered mineral mature if the ZTR value is 25-30, which indicates the exposure of sediments for long periods of weathering and erosion processes.

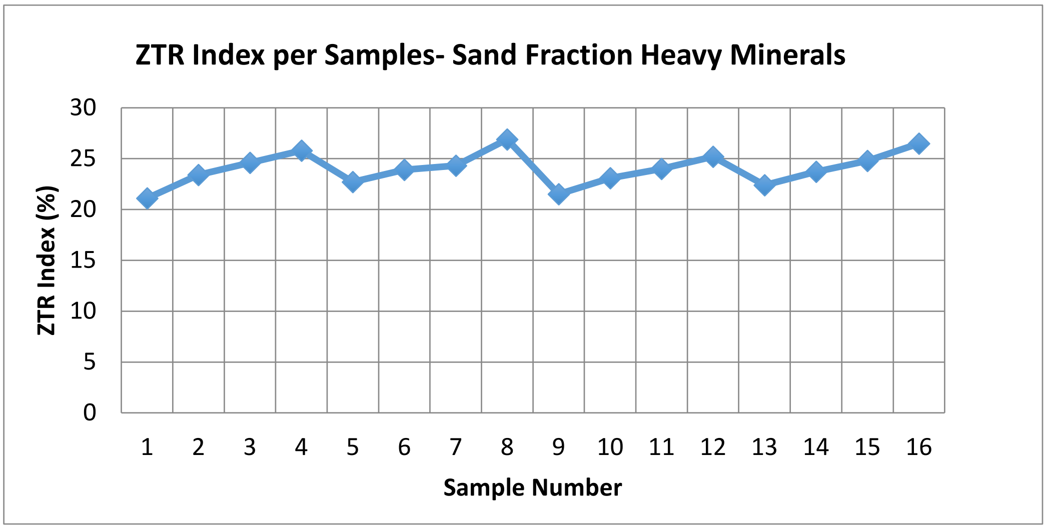

Figure 5. ZTR Index per Samples

These low values indicate that the transport distance is short from its original source or has been rapidly deposited without sufficient exposure to chemical weathering processes, as well as from newly formed metamorphic or igneous rocks. These results are consistent with the geological nature of the study area, as it is a transitional sedimentary area affected by sediments carried from neighboring highlands such as the western plateau or sedimentary rocks, as these deposits are not exposed to long and frequent weathering cycles.

4. Conclusion

The results of the study showed that the sand fraction in the western desert soils of Karbala Governorate has a varied mineral composition that reflects the nature of the parent material and the prevailing climatic conditions. Monoclinic quartz appeared as the main component of light minerals, along with varying proportions of polycrystalline quartz, feldspars, and carbonaceous rock fragments, indicating the predominance of calcareous sedimentary rocks as the main source. In contrast,(Opaques) iron oxides were found to represent the largest proportion of heavy metals, while unstable metals such as amphibole and pyroxene were present in limited proportions, reflecting the multiple sources of deposition and short transport distance This is what the weathering indices results showed, as the MWI showed weak to moderate weathering, while the ZTR showed low mineral maturity. It represents a transitional sedimentary environment that is predominantly A characteristic consistent with the dry desert environment that limits the effectiveness of chemical weathering and increases the role of mechanical processes, As well as low mineral maturity, suggesting that the sediments had not undergone long cycles of resedimentation or extended weathering

Conflict of interest

The authors declare no conflict of interest

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