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Assessing Parent-Material Homogeneity of Soil Pedons Around Mosul Dam Lake Using Sand-Size Distribution and Chemical Weathering Indices

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ABSTRACT

Four soil pedons (P1, P2, P3, and P4) were selected around Mosul Dam Lake in semi-arid sedimentary soils. The study aimed to asses soil homogeneity using sand particle-size distribution and some chemical weathering indices. Morphological descriptions and laboratory analyses were conducted for all pedons. Element chemical oxides within very fine sand particles (0.05 mm) were analyzed by X-ray Fluorescence (XRF) technique to calculate weathering indices and homogeneity curves. The results showed variability among pedons. Pedon P1 was homogeneous with its parent material because no clear intersections occurred among horizon curves. In P2, A and B horizons intersected with C2 within fine sand particles (0.125 mm). In P3, intersections occurred within coarse sand particles (1.18 mm), whereas in P4, the B horizon intersected with A and C horizons within medium sand particles (0.5 mm). These variations were attributed to pedogenic processes including additions, losses, translocation, and transformation. The values of Chemical Index of Weathering (CIW) index ranged between 12.59 and 16.22 in horizon A of P4 and horizon B of P1 respectively, while the values of Chemical Index of Alteration (CIA) were 12.12-15.83 in horizon A of P4 and horizon C2 of P2 respectively. CIW was more accurate to description the chemical weathering processes for all studied sites. The findings provide important information for understanding soil characteristics and supporting sustainable agricultural land management in the study area.

1. INTRODUCTION

Soil is one of the most important basic elements in the ecosystem because it effective role in increasing agricultural production and improving the economic situation of countries [1, 2]. Soil is a dynamic natural body in constant change under the influence of many important factors and processes [3-5]. Several main factors and processes work to bring about changes in soil development state and determine its morphological, physical, chemical, biological, and mineral properties. [6, 7]. The process of soil development is very difficult and requires a long period of hundreds or thousands of years and perhaps more [8], during which the soil undergoes multiple changes and transformations for its original components and materials to form diagnostic horizons [9]. The processes of soil development begin with the transfer and movement of different soil elements vertically and horizontally [10]. After that, soil diagnostic horizons are formed that differ from each other in morphological, chemical, physical, and mineral properties, with the presence of the genetic factor for these horizons [11]. The development of the soil profile is the result of the influence of five main factors: climate, organisms, topography, parent material, and time [12]. Climate controls the rate of weathering through annual precipitation, temperatures, and winds, while organisms contribute to enriching the surface horizons with organic matter, in addition to the significant influence of the soil's parent material, topography, and slope in this process [13]. Parent material plays a very important role in determining some of the morphological, physical, chemical, and mineral properties of the soil [14]. Soil parent material determines the extent of the development of that soil, because the changes that take place in the parent material of the soil are a quantitative scale of the degree of development of the soil pedon and the amount of weathering of the original mineral [15]. Most differences in the homogeneity degree for soil pedon horizons and the particle size distribution of soil particles result from differences in the nature of the parent material of those soils, and the parent material of soils is a measure and basis for the homogeneity degree between soil pedon horizons [16]. Assessing the homogeneity degree of soil profile horizons with the parent material is essential and important for understanding the pedogenic processes and lithological interruptions that occurred in the soil earlier [17]. Weathering processes contribute to changes in the original soil material properties, which lead to changes in the nature of the distribution of soil components and their various properties. This is done by calculating the Uniformity Value [18]. The study of soil development and soil homogeneity or uniformity depends on many indicators related to soil mineral weathering processes that called weathering indices [19]. Numerous chemical weathering indices are employed to quantify the extent and intensity of pedogenic processes within soil profiles, such as Chemical Index of Alteration (CIA), Plagioclase Index of Alteration (PIA), Base/R_2O_3 Ratio, Weathering Index (WI), Chemical Index of Weathering (CIW), and other indices [20-22]. Chemical weathering indices such as CIA, CIW, Base/R_2O_3, WIP, and PIA have proven the accuracy of the results related to the study of soil development and homogeneity determination of soil pedons, and CIA and CIW serve as good metrics for assessing the intensity of chemical weathering in sediments, effectively reflecting how feldspar is transformed into clay minerals in soils [23, 24]. The chemical weathering indices CIA and CIW are measures of assessing weathering degree in sedimentary soils and minerals such as feldspars (especially plagioclase) and their transformation into clay minerals by determining the ratio of Al_2O_3 to CaO, Na_2O, and K_2O [25, 26]. Furthermore, to calculate the percentages of sand separations from fine to coarse sand, by knowing the percentages of chemical element oxides in sand particles were analyzed using XRF technology and some other indices [27]. Many previous studies have confirmed the application of a method of calculating the percentages of sand particles to determine the homogeneity or heterogeneity degree of soil horizons with parent materials [28]. The aims of this research were: (1) to study the morphological, physical, and chemical characteristics of the soil horizons surrounding the Mosul Dam lake, (2) to determine the development degree of these soils by studying chemical weathering indices and oxide elements in soil, and (3) to assess the homogeneity of soil pedon horizons with different parent materials of soils surrounding the lake.

2. MATERIALS AND METHODS

2.1 Location of study

Four sites were selected for soil pedons with different types of parent material, representing the eastern and western sides of Mosul Dam Lake, in the northwest of Nineveh Province, Iraq (Figure 1). These sites are located within a semi-arid zone and climate like the Mediterranean [29]. Table 1 shows the average temperatures and rainfall depths for the study sites. first site in eastern direction of the lake (P1) represents the pedon near of the lake in Namrek area, has coordinates (36.7261° N, 42.8746° E), it has an elevation (332 m), the land has moderate drainage, is gently sloping to level, parent material of the site is gypsum and limestone, and it's uncultivated, the vegetation cover consists of herbals and seasonal grass. Second site (P2) represents the pedon far from the lake (150 m from P1) in the Namrek area, which has coordinates (36.7275° N, 42.8749° E), representing a gently sloping land planted with wheat. The third site in the western direction of the lake (P3) represents the pedon near the lake in Tayibat AL-Riyah area, has coordinates (36.7186° N, 42.7362° E), it has an elevation (328 m), the land is moderately to well-drained, moderately sloping, parent material of the site is limestone, and it's uncultivated.

Fourth location (P4) represents the pedon further from the lake (150 m from P3) in the Tayibat AL-Riyah area, has coordinates (36.7172° N, 42.7341° E). This area has moderately sloping land and is cultivated with vegetables.

2.2 Field work

Four soil pedons (P1, P2, P3, and P4) were dug depending on field information obtained at the study sites, and the soil profiles exposed to direct sunlight were described morphologically according to the method mentioned in USDA [30]. Soil samples were taken from each horizon, totaling 14 soil samples, put into Polythene bags with numbering, then the samples were transported to the laboratory for required analyses.

2.3 Laboratory work

After preparing the disturbed and undisturbed soil samples for laboratory analyses, the following physical measurements and chemical analyses were performed (size distribution of soil particles, bulk density, porosity, pH, EC, Organic Matter (O.M.), CEC, $CaCO_3$, $CaSO_4$) that depended on methods [31].

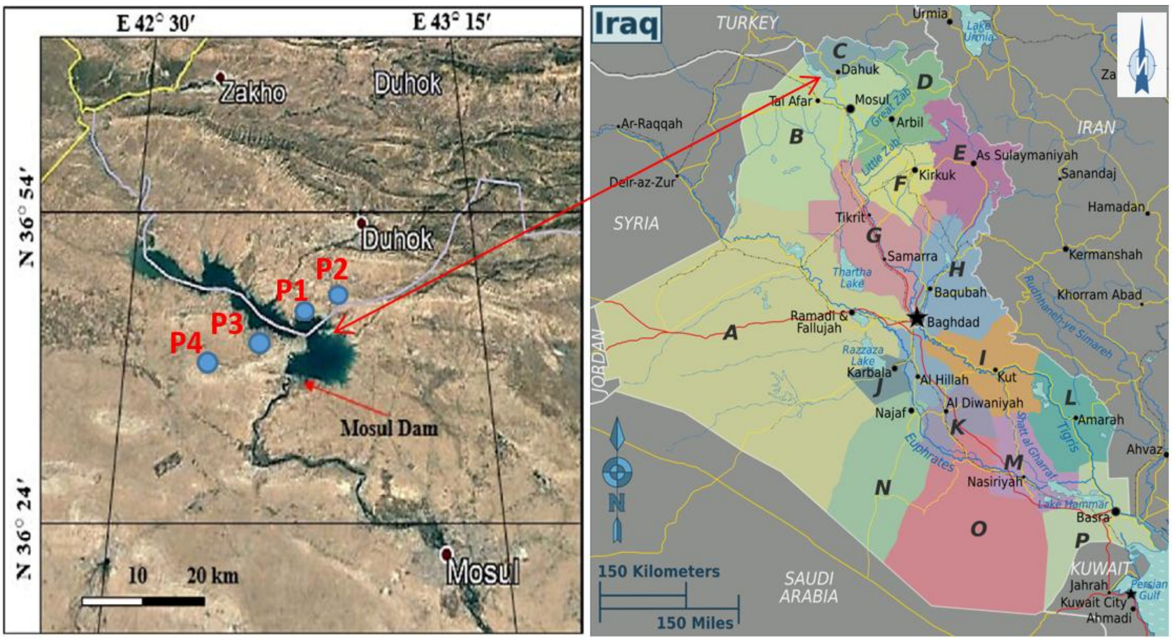

Figure 1. The map of study sites

2.4 Separating sand particles and XRF analysis

The process of separating sand from soil particles (silt and clay) was carried out according to the method mentioned [32] by using (500 g) of soil samples put into plastic containers, adding a certain volume of dilute HCl (10%) to remove $CaCO_3$ and O.M., and added a certain quantity from Calgon $(NaPO_3)_6$ to separate the soil particles [33], then hot water was added to soil samples with repeated shaking, and they were left to stand for 40 seconds to allow the sand particles settle according to Stokes' law, after obtaining pure sand particles, they were passed through a series of sieves varying by diameters (2, 1.18, 0.5, 0.125, and 0.05 mm) to obtain sand particles ranging from very coarse sand (2 mm) to very fine sand (0.05 mm). Very fine sand samples (0.05 mm) were analyzed using the XRF method with a Spectro XLAB 2000 spectrometer. The analytical procedure involved grinding the samples to a particle size of 0.05 mm; 3 g of the sample were mixed with wax and then pressed at 20 bars to prepare pressed pellets. The XRF spectrometer was using certified reference materials (CRMs). This analysis was conducted to determine the presence of chemical oxides such as Fe_2O_3, SiO_2, Na_2O, K_2O, CaO, MgO, MnO, ZrO_2, Al_2O_3, TiO_2, Cr_2O_3, and ZnO, in order to calculate the weathering indices presented in Table 2 and to determine the homogeneity of soil horizons with their parent materials at the study sites.

Table 1. Average of temperatures and rainfall for study sites

Year		Month											
		Jan.	Feb.	Mar	Apr.	May	Jun.	Jul.	Aug	Sep.	Oct.	Nov	Dec.
2020	T.	9.1	14.5	22.1	28.2	33.3	41.6	45.7	45.1	36.4	23.5	18.2	12.9
	R.	42.4	28.2	24.1	15.3	7.5	0.8	0	0	0	0.2	11.7	34.9
2021	T.	10.3	17.2	23.0	29.5	33.3	39.4	46.2	45.2	35.0	26.8	18.3	13.1
	R.	37.5	28.3	17.1	14.2	4.6	2.8	0	0	0	0.5	19.3	30.4
2022	T.	10.0	15.6	23.1	27.1	35.2	39.0	45.5	44.8	36.3	25.1	18.3	15.0
	R.	32.4	26.1	25.4	16.6	7.5	1.1	0	0	0	0.4	15.8	29.1
2023	T.	8.0	13.6	21.7	27.5	35.2	37.8	46.3	46.0	35.2	25.3	16.6	12.9
	R.	38.4	24.5	20.3	14.8	5.7	3.5	0	0	0	1.4	8.8	28.3
2024	T.	7.3	13.6	20.3	25.6	34.2	37.4	45.8	45.5	36.2	24.3	17.8	14.1
	R.	35.4	29.6	25.7	18.1	17.0	6.3	0	0	0	0	7.5	23.1
2025	T.	9.4	15.5	22.0	27.8	35.2	39.1	46.5	45.7	37.0	25.1	16.8	13.6
	R.	29.3	20.1	11.6	8.0	4.8	1.4	0	0	0	0.6	35.5	36.7

Note: T. = Temperature average (°C), R. = rainfall (mm), the source of climate data is: Agromet.gov.iq.

Table 2. Some weathering indices used in the study

No.	Weathering Index	Definition	Equation	Source
1	WI	Weathering Index	$(SiO_2+CaO) / (Al_2O_3+Fe_2O_3+TiO_2)$	[34]
2	CIA	Chemical Index of Alteration	$Al_2O_3 / (Al_2O_3+CaO+Na_2O+ K_2O)*100$	[35]
3	Si/Ses	Silica / Sesquioxides	$SiO_2 / (Al_2O_3+Fe_2O_3)$	[36]
4	CIW	Chemical Index of Weathering	$Al_2O_3 / (Al_2O_3+CaO+Na_2O)*100$	[37]
5	WR	Weathering Ratio	$(CaO+MgO+Na_2O) / TiO_2$	[38]

2.5 Homogeneity calculations of soil horizons

Homogeneity of soil pedon horizons were determined using the ratio of very fine sand particles (0.05 mm) / total sand particles (2-0.05 mm) depend on research [39], because sand particles mainly contain primary minerals resistant to geochemical weathering, and it's influenced by soil formation variables and processes especially soils that developed from sediment materials, the ratio of very fine sand to total sand, and fine sand to coarse sand were calculated to study uniformity of parent material. Cumulative curves of sand particles were designed using the Excel program.

3. RESULTS AND DISCUSSION

3.1 Morphological properties of the study soil pedons

Table 3 shows the results of morphological properties for the studied soil pedons based on information from the American Soil Survey staff [40]. The results show some differences between soil pedons of the studied sites, and between soil horizons of a single pedon, because the variations in soil nature, parent material, and pedogenic processes affecting soil formation and development, soil color is one of the most important properties and easily observable morphological characteristics. The (Hue) values for all studied soil horizons were in page (10YR) of the Munsell Soil Color chart. These Hue values represent most soils in arid and semi-arid areas, as noted in research [41]. For the surface and subsurface soil horizons, the color intensity (Value) and color purity (Chroma) values were 7/4–5/3 in the dry state and 4/6–3/3 in the moist state. These values are related to soil moisture content, as well as mineral and organic components, as confirmed by research [42]. The type of soil structure was fine to moderate granular and semi-angular in the surface horizon of P1, and moderate to coarse angular blocky in the subsurface horizons, while in P2, P3, and P4, it was moderate angular and semi-angular blocky for surface horizons, and it was moderate to coarse angular prismatic in the surface horizon of P2.

This variation of soil structure between horizons of studied soil pedons is a result of the clay loamy and silty clay soil texture of surface horizons because the organic matter on the soil surface, as well as human activities (plowing and sheep grazing), while the clay texture of subsurface horizons of studied soil pedons is a result to pedogenic sediments processes and the nature of cementing materials such as lime. The soil Consistency ranged from slightly hard to friable in surface horizons of all the studied sites' pedons, and plasticity to sticky in most of the subsurface horizons of the pedons. This difference may be due to the nature of the parent material for soils, as well as the fine texture of the soil and the size of particles for the studied soils.

Table 3. Some morphological characteristics of the studied soils

Pedon	Horizon	Depth (cm)	Soil Color				Structure	Consistency	Boundary
			Dry		Wet				
P1	A	0-20	10YR 5/3	B	10YR 4/3	B	gfm	Shpl	c
	B	20-38	10YR 5/4	yB	10YR 3/3	dB	bma	SFpl	c-w
	C1	38-70	10YR 5/6	yB	10YR 4/6	dyB	bma	SFpl	w
	C2	70-95	10YR 5/4	yB	10YR 4/6	dyB	bma	SFpl	w
P2	A	0-8	10YR 5/3	B	10YR 3/3	dB	bfm	FSpl	c-w
	B	8-30	10YR 5/4	yB	10YR 4/4	dyB	prma	Shpl	w
	C1	30-57	10YR 7/4	ypaB	10YR 4/4	dyB	bma	SFpl	w
	C2	57-100	10YR 6/3	paB	10YR 3/3	dB	bma	SFPl	w
P3	A	0-12	10YR 6/4	LyB	10YR 4/4	dyB	bfsa	SFpl	w
	B	12-57	10YR 5/3	B	10YR 3/3	dB	bmsa	SFpl	w
	C	57-100	10YR 5/3	B	10YR 3/3	dB	bma	SFspl	w
P4	A	0-15	10YR 6/4	LyB	10YR 4/4	dyB	bfsa	SFpl	w
	B	15-48	10YR 5/4	yB	10YR 3/3	dB	bma	SFpl	w
	C	48-95	10YR 5/3	B	10YR 3/3	dB	bma	Shp	w

Notes: Color: L = light, y = yellowish, B = brown, d = dark, v = very, pa = pale.
Structure: b = blocky, f = fine, sa = subangular, m = moderate, a = angular, pr = prismatic, g = granular.
Consistency: S = slightly, h = hard, F = friable, pl = plasticity, s = sticky.
Boundary: c = clear, w = wavy.

Table 4. Some physical and chemical properties of soils

Pedon	Horizon	Depth (cm)	Soil Particles g·kg^{-1}			Texture	Bulk Density Mg·m^{-3}	pH	EC ds·m^{-1}	O.M.	$CaCO_3$	$CaSO_4$	CEC cmol·kg^{-1} soil
			Sand	Silt	Clay						g·kg^{-1}		
P1	A	0-20	173	406	421	SC	1.41	7.50	1.46	18.60	176	12.70	28.00
	B	20-38	193	366	441	C	1.50	7.60	0.55	12.10	200	13.10	25.60
	C1	38-70	298	312	390	CL	1.43	7.80	0.33	9.30	190	15.80	19.40
	C2	70-95	278	292	430	C	1.49	7.80	0.42	7.00	207	17.70	19.00
P2	A	0-8	230	372	398	CL	1.40	7.30	0.60	17.30	200	11.80	26.10
	B	8-30	164	369	467	C	1.52	7.60	0.51	11.40	220	10.50	26.40
	C1	30-57	296	272	432	C	1.51	7.80	0.32	8.60	231	13.40	20.70
	C2	57-100	175	414	411	SC	1.48	7.70	1.70	6.60	223	15.80	20.00
P3	A	0-12	212	395	393	CL	1.46	7.40	1.16	14.00	189	10.70	22.30
	B	12-57	198	412	390	SCL	1.41	7.60	0.51	9.60	230	10.40	19.80
	C	57-100	158	372	470	C	1.54	7.50	0.58	7.00	228	13.50	20.20
P4	A	0-15	258	312	430	C	1.45	7.50	1.22	14.50	185	8.30	25.60
	B	15-48	172	332	496	C	1.55	7.50	0.54	10.10	215	10.10	23.00
	C	48-95	252	332	416	C	1.50	7.90	0.83	6.50	243	12.80	20.40

Notes: SC= Silty Clay, C= Clay, CL= Clay Loam, SCL= Silty Clay Loam.

3.2 Some physical and chemical properties of the study soil pedons

Table 4 shows some of the physical and chemical properties of soil particles of the studied sites. The soil particle size distribution was varied between samples for the same pedon and different sites. The soil texture of all studied soils was loamy clay and silty clay; moreover, clay was predominant in most sites. The lowest sand content (158 g/kg) was in horizon C in soil pedon P3, and the highest was 298 g/kg in horizon C1 in pedon P1. The lowest silt content (272 g/kg) was in horizon C1 in soil pedon P2, and the highest was (414 g/kg) in horizon C2 in pedon P2. The lowest clay content (390 g/kg) was equally found in horizon C1 in pedon P1 and horizon B in pedon P3, while the highest clay content (496 g/kg) was in horizon B in pedon P4. The reason for these differences relates to the nature of the soil parent material in the studied sites [43]. Bulk density values of the studied sites were varied between the horizons of the same pedon and between different sites. The lowest bulk density value was (1.4 Mg·m^{-3}) in surface horizon A of soil pedon P2, and the highest value was (1.55 Mg·m^{-3}) in subsurface horizon B of pedon P4. Bulk density values are affected by soil texture, soil organic matter content, and other soil components. Low bulk density values have an impact on soil water retention and porosity, which fosters chemical weathering. Generally, bulk density is a useful measure of soil growth and degree of weathering, especially in arid and semi-arid regions [44]. Soil pH values were neutral and slightly alkaline in all soil pedon horizons, with the lowest value (7.3) in surface horizon A of pedon P2 and the highest value (7.9) in horizon C for soil pedon P4. The reason for the variation between these values is that surface horizons contain soil organic materials, which leads to a reduction in soil pH values, while subsurface horizons are affected by the parent material of soil, which is $CaCO_3$ and basic elements present in the composition of primary and secondary soil minerals [45]. Soil EC values were noticeably low in most of the soil pedons' horizons, ranging between 0.32 and 1.70 ds·m^{-1}. This indicates that the soils in the study area are not affected by salts, and they are based on rain during the rainy seasons in the study area. The content of soil organic matter exhibited significant variability across the studied sites in relation to different soil horizons, it ranging between (18.6 g/kg) in surface horizon A of pedon P1, and (6.5 g/kg) in horizon C for soil pedon P4, this variability can be ascribed to the relative disparities in the characteristics of the vegetative cover present in the study area, in conjunction with the biological activities of soil microorganisms, alongside the concomitant variation in organic matter quantities. The surface horizons of the soil demonstrated an elevation in organic matter values, whereas a decline in these values was observed with increasing depth, thereby illustrating the inherent distribution patterns of organic matter within the soil body. $CaCO_3$ content showed a decrease in the surface horizons and began to increase with depth for all pedons of the studied soils. Values of $CaCO_3$ were between 176 and 243 g/kg for all studied soils. Similarly, the soil $CaSO_4$ content followed the same pattern as the soil $CaCO_3$ content; the values of $CaSO_4$ were between 8.30 and 17.7 g/kg for all soil pedons. This difference in soil $CaCO_3$ and $CaSO_4$ content between surface and subsurface horizons is perhaps the reason for the continuous leaching of calcium carbonate and gypsum from soil surface horizons, which then accumulates in subsurface horizons, as well as in the parent material of these soils in the studied sites [46]. While the soil cation exchange capacity CEC, values ranged between (19-28 $cmol \cdot kg^{-1}$ soil) for all soil pedons, this results may be because the organic matter and clay texture of soil has a clear effects on increasing soil CEC, since organic colloids carry a negative charge on their surfaces due to the presence of carboxyl, phenol, hydroxyl, and carbonyl groups, as well as humus. Therefore, these colloids have the ability to adsorb cations.

3.3 Chemical elements oxides for the studied soil pedons

Results of Table 5 showed differences in percentages of chemical elements oxides that were analyzed using an XRF device in very fine sand particles (0.05 mm) for soil pedons. The percentage of CaO was the highest percentage for all soil studied sites, ranging between (33.88-37.44%) in the C2 horizon of P1 and the B horizon of P3 respectively. While the percentage of TiO_2 was the lowest compared to other elements' oxides, it ranged between (0.65-0.84%) in the C2 horizon of P1 and the C1 horizon of P2, respectively. Other element oxides showed variation in all soil pedons. Fe_2O_3 ranged between (4.01-6.64) in B horizon of P2 and A horizon of P1 respectively, K_2O value was between (1.11-1.77) in C2 horizon of P2 and A horizon of P3, while percentage of SiO_2 ranged between 19.13 and 23.26 in C2 horizon of P2 and C1 horizon of P2 respectively, Al_2O_3 value ranged between 6.11 and 7.63 in B horizon of P3 and B horizon of P1. This difference in oxide values may be due to the difference in parent material and minerals present in the soil in the study area. Additionally, the environmental conditions surrounding the study area control the intensity of weathering processes to which these minerals were exposed during different time periods.

3.4 Weathering indices for the studied soil pedons

The results of Table 6 showed clear differences between chemical weathering indices that depended on this study. The WI showed some variations between soil horizons and pedons; its value was 3.94 in the surface horizon A of P1, and it was 5.16 in the subsurface horizon B of P2. The differences between WI values indicate weak to moderate weathering in some soil pedons, represented by the surface and subsurface horizons of the P1, since the lower value indicates more weathering has occurred due to the loss of mobile CaO from surface soil horizons, while an increase of concentration of relatively immobile oxides such as Al_2O_3, Fe_2O_3, and TiO_2. On the other hand, a high value of WI indicate very weak weathering, as the case in horizon B of the P2, which attributed to continuous loss of CaO from horizon A and its accumulation in horizon B of P2. The CIA values indicate a very low intensity of chemical weathering that happened within soil horizons of P1, P2, P3, and P4, ranging between 15.87 and 12.12, because the lower value of CIA indicates a very weak weathering in the sites, so these results were consistent with the study [47]. Values of the WI (Si/Ses) were almost close for all soil pedons horizons, this may be due to the relatively similar percentages of the weathering-resistant oxides, that is, Fe_2O_3, Al_2O_3, and SiO_2, and values of this index ranged between (1.85-1.46). CIW values showed slight variation among the studied soil pedons' horizons. This result may be attributed to the factors that effect on studied soils, which have undergone weak weathering, and are attributed to the climate and natural factors surrounding the soil pedons, such as rainfall and temperature variations between seasons, as well as anthropogenic activities, erosion, and precipitation. It is observed from these results that the values were slightly high in soil pedons P1, P2, and P3, ranging between 13.95 and 16.22. These values then decreased in soil pedon P4, reaching 12.59 in the surface horizon A of P4. High CIW values indicate different degrees of weathering, meaning that the mobile oxides, such as CaO, were lost through leaching within the soil pedon horizons, compared to relatively weathering-resistant and immobile oxides such as Fe_2O_3, Al_2O_3, and SiO_2. Conversely, low values indicate weak weathering as a result of increased concentration of CaO and Na_2O. The weathering ratio (WR) values showed slight variation between soil horizons in different locations. A significant increase in WR values was observed in horizon C2 of P1, compared to horizon C of P3. These differences are attributed to the lower (TiO_2) content in some locations. The highest WR value (69.63) was recorded in P1C2, while the lowest value (51.91) was recorded in horizon C of P3.

3.5 Homogeneity curves for sand particle accumulations

Figures 2-5 show the relationship between sand particle sizes and cumulative percentage of sand particle diameters for each horizon of the studied soil pedons, which were calculated in very fine sand particles (0.05 mm) for soil pedons, to determine homogeneity or heterogeneity of parent material for each soil pedon. The results showed there was homogeneity of soil pedon P1 with its parent material (Figure 2), which is evident from the parallel curves for all horizons. There is a clear convergence in the cumulative values of sand particle diameters in four horizons in very coarse to coarse sand particles, and a slight variation is observed in fine to very fine sand particles between the horizons. The homogeneity of parent material for this pedon may be because it’s near the lake, which allowed for weathering and soil-forming processes that affected the size similarity of non-clay soil particles of this pedon horizons [48], or because it’s uncultivated land, so there isn’t effected for plowing and irrigation. Figure 3 showed heterogeneity of horizons with parent material in soil pedon P2, through curves intersection of surface (0-8 cm) and subsurface horizon (8-30 cm) with the deeper soil horizons (30-57 cm) and (57-100 cm), and the curves intersection was in the medium and fine sand particles (0.5-0.125 mm). The reason may be attributed to the transfer and deposition of fine sand particles due to plowing, machine movement, and grazing. These major additives continuously affect the mixing of soil components. Figure 4 shows that the surface horizon curve A of soil pedon P3 with a depth of (0-12 cm) intersected with horizons B and C in very coarse sand particles (2 mm) as well as coarse sand particles (1.18 mm). This may be attributed to the exposure of surface soils to erosion and sedimentation processes; furthermore, the influence of parent material and geological factors that would redistribute the soil components. While, the soil pedon P4 in Figure 5, its noted that the curve of subsurface horizon B with a depth of 15-48 cm has intersected with the horizons A and C in medium sand particles (0.5 mm), whereas the results for the remaining parts were similar, this may be attributed to different weathering processes as well as rainwater, which washed away the surface and subsurface horizon components, and the cost of the calcareous, gypsum, and pedogenic processes.

Table 5. Percentage of some element oxides in soil study sites

Pedon	Horizon	Depth (cm)	Fe_2O_3	TiO_2	CaO	K_2O	SiO_2	Al_2O_3	MgO	Na_2O
						%				
P1	A	0-20	6.64	0.74	34.85	1.57	21.13	6.85	4.82	4.01
	B	20-38	5.62	0.70	36.33	1.42	19.31	7.63	4.47	3.07
	C1	38-70	4.99	0.72	36.41	1.19	22.05	7.47	3.74	3.02
	C2	70-95	5.84	0.65	37.44	1.22	21.89	6.56	4.80	3.02
P2	A	0-8	4.05	0.78	37.40	1.16	20.30	7.44	3.50	4.31
	B	8-30	4.01	0.80	35.95	1.32	19.48	6.72	4.83	2.87
	C1	30-57	5.69	0.84	36.54	1.32	23.26	7.51	4.97	3.92
	C2	57-100	4.61	0.72	35.35	1.11	19.13	7.43	3.90	3.06
P3	A	0-12	5.77	0.80	37.34	1.77	20.58	7.60	4.98	3.41
	B	12-57	5.81	0.77	33.88	1.73	21.63	6.11	5.86	3.45
	C	57-100	6.03	0.83	35.87	1.76	22.35	6.60	3.97	3.41
P4	A	0-15	5.96	0.82	34.95	1.71	21.28	5.53	4.86	3.43
	B	15-48	5.37	0.71	34.48	1.50	21.29	6.47	4.49	3.93
	C	48-95	5.96	0.79	36.25	1.60	19.29	6.15	4.71	2.48

Table 6. Weathering indices values of soil study sites

Pedon	Horizon	Depth (cm)	WI	CIA	Si/Ses	CIW	WR
P1	A	0-20	3.94	14.49	1.57	14.99	59.37
	B	20-38	3.99	15.75	1.46	16.22	62.70
	C1	38-70	4.23	15.27	1.77	15.93	59.96
	C2	70-95	4.54	13.60	1.77	13.95	69.63
P2	A	0-8	4.71	14.78	1.77	15.13	58.11
	B	8-30	5.16	14.35	1.82	14.76	54.56
	C1	30-57	4.26	15.24	1.76	15.66	54.10
	C2	57-100	4.27	15.83	1.59	16.21	59.10
P3	A	0-12	4.10	15.16	1.54	15.72	57.12
	B	12-57	4.37	13.52	1.81	14.06	55.88
	C	57-100	4.32	13.85	1.77	14.39	51.91
P4	A	0-15	4.57	12.12	1.85	12.59	52.54
	B	15-48	4.44	13.95	1.80	14.41	60.42
	C	48-95	4.31	13.23	1.59	13.70	54.84

WI: Weathering Index, CIA: Chemical Index of Alteration, CIW: Chemical Index of Weathering, WR: Weathering ratio.

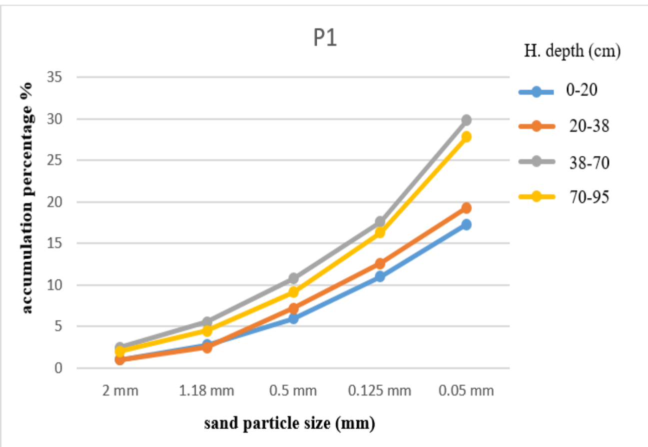

Figure 2. The cumulative percentage curves of sand particle diameters in pedon P1

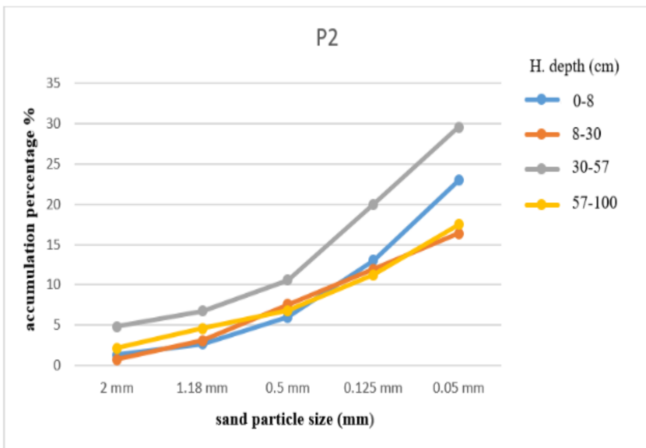

Figure 3. The cumulative percentage curves of sand particle diameters in pedon P2

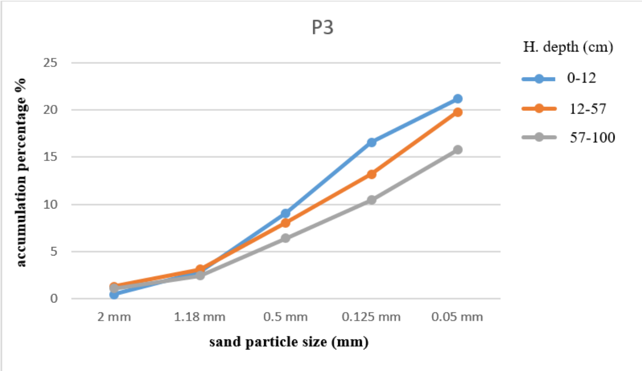

Figure 4. The cumulative percentage curves of sand particle diameters in pedon P3

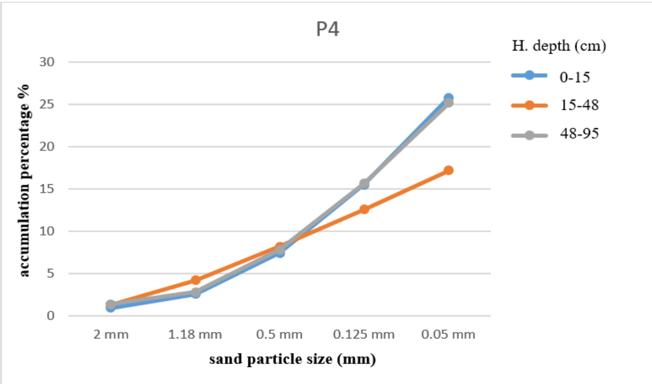

Figure 5. The cumulative percentage curves of sand particle diameters in pedon P4

4. CONCLUSIONS

This study determined the homogeneity of soil parent material surrounding Mosul Dam lake, by depending on some chemical properties. This was achieved by selecting four different soil pedons from chosen locations, all of which have sedimentary parent material. The degree of soil weathering was calculated using various weathering indices, and chemical analyses were performed to determine the concentrations of elements resistant and non-resistant to chemical weathering. Soil homogeneity was also assessed by analyzing the varying diameters and sizes of very fine sand particles, and homogeneity curves were designed for this purpose. The results showed that the soils of selected pedons may differ in their morphological, chemical, and physical characteristics, due to the different conditions surrounding each pedon, and the difference was also clear between the horizons of each pedon. Clear differences were found among the selected weathering indices in the study; these indices were: WI, CIA, Silica/Sesquioxides, CIW, and WR. Each of these chemical indices showed different weathering results, depending on the variation in soil characteristics of each study site. Study results noted that the CIW is the most reliable in describing the weathering process occurring in soil pedons. The results also indicated homogeneity between soil P1 horizons, as evidenced by the parallelism and non-intersection of curves, suggesting that the horizon components were formed from the same parent material. In contrast, other pedons of the studied sites, P2, P3, and P4 was heterogeneity in some soil horizons with their parent material observed by the intersection of the curves. This may be attributed to many factors, including pedogenic and geochemical processes, variations in the nature of the land surface, erosion, sedimentation, and other processes. Therefore, this study indicates the necessity of conducting thorough and numerous studies on these soils, which helps manage the soil properly and preserve soil and its properties sustainably.

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