Chemical and Mineralogical Nature of The Sediments of Sawa Lake in Muthanna Governorate, Southwestern Iraq

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Abstract

The sediments of the Sawa lake surrounded area, southern Iraq, have unique proprieties that are interesting to researchers. Four sites located at varying distances from the lake were selected to study some of the properties of the lake sediment. The results indicate that the study soil is saline soils because of the values of the three salinity criteria (EC, TDS, and NaCl). The values of electrical conductivity ranged between (100.11 and 74.78) ds.m$^{-1}$ for surface depths, whereas for subsurface depths ranged between (14.66 and 38.55) ds.m$^{-1}$. The values of the total soluble salts ranged from (7.4 and 85.67) g/L. The percentage of sodium chloride ranged between (3.1 and 8.5)%.

The dominance of the intermediate soil texture (loam) category for most depths of the study soil (S.C.L, S.L, and S.W) was more than clay and loam proportions, which ranged between (420 and 780) g.kg$^{-1}$. The sand proportion in the second ranged between (5 and 5.5) m, while it rises above the level of the surrounding land about (2 to 5) meter.

Therefore, this study aimed to identify the chemical and mineralogical properties of the sediments that formed the soil of the lakesite and its relationship to the lake water and the original material for the soil of the region in general.
The stratigraphic sequence of Sawah Lake region consists of the oldest to the most recent of the following configurations:

- Composition of stacking: its rocks consist of anhydrite that interferes with marl, shale, and limestone. Its thickness in the region ranges between (20 and 50) m [4].
- Damam formation: This formation consists of white limestone to yellowing and chalky sometimes the thickness of the formation in the region ranges between (30 and 40) m [2]. The lake is also surrounded by sulfur deposits, which are among the oldest modern deposits to form the lake shelf [5].

Regarding the hydrogeological situation, the area that includes the Sawa Lake contains three underground water reservoirs, which are the pile formation reservoir, the Damam formation tank, and the Euphrates formation tank. Damam Reservoir is the most important as it is the main feeding source for the lake [6], [7]. showed that Sawa lake has a distinct chloride-sodium water quality of mixed origin between Damam and Al-Ras meteoric water reservoirs and the Euphrates reservoir of Marin water. Figure 1 presents the class sequence and geology of the study area.

![Figure 1. Geology of the study area.](image)

2. Soils of the studied area

The soil represents the crumbling upper part of the earth's crust, which results from the different weathering processes of rocks, or in other words, it represents the reaction states of climate elements, the organism, and the vegetation with the rock material. The result of weathering is different minerals that mix together in different proportions, forming the soil material. Studies indicated that the soils scattered in the study area and according to the geological division are as shown in Figure 2. Of the pedological aspect, the study of [3], indicated that the results of chemical and physical analyses and morphological characterization present that the soil of the region belongs to the rank of Aridisols according to the modern quantitative system [8].

This soil is characterized by moisture stress for more than 90 days, in addition to the accumulation of weathering and salt collections. It also has weak evolutionary characteristics. Salt, limestone and gypsum horizons were also observed in these soils, so they were ranked below the Salids in the taxonomic system. The largest group of these soils is Haplosalids and under the Great Gypsic Haplosalids group.
3. Methods and Materials

3.1. Lake location

The lake is astronomically located at (31.91) degrees north latitude and (45) degrees east longitude within what is known as the Samawa Desert, which is affiliated with Al Muthanna Governorate. The Southern Badia constitutes the largest part of its area, as its area is (47,000) km², equivalent to (90.84)% of the governorate’s area. The lake is 18 m above the sea level and the climate of the study area is dry to semi-dry. As the annual rainfall amounting to the region reaches (100) mm and the annual amount of evaporation is around (3400) mm. The topography of the area is approximately flat and the depth of the groundwater (1) m. The original material is a calcareous material in addition to some gypsum deposits, while the vegetation was diverse. Four locations were chosen at varying distances from the lake.

They were represented by the sites; the first was (451) meters away in the southeastern part of the lake, the second site, which was the closest site to the lake, is only (12) meters away from the lake and is located to the northeast of the lake, and the third site is located to the southwest of the lake and about (155) m away from the lake, while the fourth site is located in the southern part of the lake, (147) meters from the lake, respectively.

3.2 Laboratory procedures

The soil samples were dried aerially, and manually mashed and by a wooden hammer, in order to preserve the morphology of the minerals there, and was passed through a sieve with a diameter of (2) mm and kept in plastic boxes.

Physical estimates: The volumetric distribution of the soil separators by the Hydrometer method mentioned in, [9] .

Chemical estimates: Chemical properties were estimated after saturated pulp extract was obtained for dried and ground soil models that were passed through a sieve with a diameter of (2) mm. The degree of interaction (pH) and electrical conductivity was estimated according to the methods suggested by the American Salinity Laboratory described by [9] .

Mineral estimates: (1) g of the sandy portion is taken after the sand part is isolated by sieving with (63) micron sieve. The heavy metals then separate from the light by the heavy liquid bromoform of specific gravity (2.89) g/cm³ according to the [10] . After separation, the heavy and light metals fraction is weighed and the percentage is recorded for each fraction. After isolating a portion of light metals from heavy metals, the metals are isolated by acetone for the purpose of cleaning and purification in order to be easily diagnosed with a polarized microscope.

After washing, the minerals are scattered on glass slides after air drying and affixed to the types of adhesives conditioner, according to [11] . After the slides were dried, the minerals are examined and diagnosed under the polarized optical microscope, the percentages for each metal are determined, as well as the imaging of the minerals by a digital camera, the scale of the drawing for each image is calculated by the force of magnification and the use of a microscope ruler [12] .
4. Results and discussion

4.1. Physical properties

4.1.1. Volumetric distribution of soil separators

Table 1 presents the results of the volumetric distribution of the soil separations, which indicates the dominance of the sand separation over the rest of the crops, which ranged between (420 and 780) g.Kg\(^{-1}\) for all depths. The supremacy of the sand separation in the soil of the study may be due mainly to the nature of the calcareous material, whose sizes are close to the sizes of sand particles [13].

Especially if we know that these sediments are due to the lake close to the sedimentation site, and therefore the rough parts increase relatively to the soft part. As for the values of clay and silt, they were close to most of the depths of the study soils. The results also showed the dominance of the medium texture class (loam) for most of the study depths (S.C.L and S.L). This systematic distribution of the different soil crops may be attributed to the influence of the locational factors of the study area, especially the sedimentation processes of the lake during periods of flooding, or that the lake previously covered the study areas and later receded, leaving their sediments in these areas, which was reflected in the affinity of the soil texture in the depths of the study soils.
### Table 1. Some chemical and physical properties of the studied depth of the soils.

| Site | Depth cm | pH   | EC ds.m⁻¹ | TDS gm.L⁻¹ | NaCl (%) | Sand g.kg⁻¹ | Silt g.kg⁻¹ | Clay g.kg⁻¹ | Soil Texture |
|------|----------|------|-----------|------------|----------|-------------|-------------|-------------|--------------|
| 1    | 0-25     | 7.55 | 99.60     | 60.4       | 8.50     | 445         | 300         | 255         | S.C.L        |
|      | 25-50    | 7.00 | 22.20     | 10.90      | 4.5      | 560         | 220         | 220         | S.C.L        |
| 2    | 0-25     | 7.4  | 75.60     | 75.60      | 3.5      | 600         | 140         | 260         | S.L          |
|      | 25-50    | 7.00 | 14.66     | 7.40       | 3.1      | 680         | 120         | 200         | S.L          |
| 3    | 0-25     | 7.00 | 74.78     | 21.60      | 6.8      | 620         | 240         | 180         | S.L          |
|      | 25-50    | 7.00 | 38.55     | 50.00      | 7.00     | 740         | 140         | 120         | S.L          |
| 4    | 0-25     | 7.5  | 100.11    | 85.67      | 6.5      | 520         | 240         | 120         | S.C.L        |
|      | 25-50    | 7.10 | 30.56     | 16.50      | 5.55     | 620         | 140         | 240         | S.C.L        |

It is noted from the results that the closer the site to the lake, the greater the values of the roughness, and vice versa. This is logical because coarse parts are usually deposited near the sedimentation source due to their heavy weight, while the soft parts can carry a further distance and precipitate when the current speed slows down.

### Table 2. Parts of sand and total sand (g Kg⁻¹).

| Site | Depth cm | Very soft sand | Soft sand | Intermediate size sand | Rough sand | Very rough sand | Total sand |
|------|----------|----------------|-----------|------------------------|------------|-----------------|-----------|
| 1    | 25-0     | 68.42          | 172.56    | 118.02                 | 59.50      | 26.50           | 445       |
|      | 50-25    | 55.70          | 197.05    | 140.75                 | 111.40     | 55.10           | 560       |
| 2    | 25-0     | 37.35          | 117.54    | 144.45                 | 142.88     | 157.78          | 600       |
|      | 50-25    | 47.12          | 103.66    | 118.19                 | 177.01     | 234.02          | 680       |
| 3    | 25-0     | 120.27         | 235.06    | 104.57                 | 103.59     | 56.51           | 620       |
|      | 50-25    | 210.18         | 108.47    | 121.58                 | 219.21     | 80.56           | 740       |
| 4    | 25-0     | 73.11          | 186.5     | 136.45                 | 85.23      | 38.71           | 520       |
|      | 50-25    | 46.48          | 200.78    | 290.94                 | 63.67      | 18.13           | 620       |

### 4.2. Chemical properties

#### 4.2.1. Soil salinity

This trait was studied using three important criteria: electrical conductivity of soil (EC), total salinity (TDS) and (NaCl) sodium chloride. The results indicated in Table 1, present the values of electrical conductivity ranged between (74.78 and 100.11) decimeters.m⁻¹ for surface depths.

The lowest value appeared on the third site, while the highest value appeared on the fourth site. It is noted from the results that the conductivity values were increasing in the surface depths compared to the subsurface depths, whose values were generally decreasing with the depth in most of the study soils, ranging from (14.66 and 38.55) decimeters.m⁻¹. The soil of Sawa Lake is highly saline soils especially in the surface layer, which indicates that the recent sediments of the site are saline compared to the old sediments represented by subsurface depths that were less salty. In other words, lake water and its sediments were previously less salty than the present time.

These results apply with the total dissolved salts properties, which ranged between (7.4 and 85.67) g per liter, while a decrease in sodium chloride values was observed, which ranged between (3.1 and 8.5)%. These results are consistent with many studies, which indicated the high salinity content in the soils of the Sawa Lake region, [2,3,14,15]. The high salinity in the soils of the Sawa Lake region may be due to the following reasons:
1. The study area is part of the southern desert, so it is affected by the dry desert climate, where the general rise in temperatures reflects the high rates of evaporation values that cause an increase in the concentration of salts.

2. The salinity of the water sources feeding the Lake of Sawa, which is believed to be reflected in its sediments in the nearer regions, whether they are geological formations or water reservoirs and bear the many minerals and ions that increase the concentrations of salts, [4,6] and this is what we covered in the introduction.

3. The topographical position of the study area represented by the slight slope of the layers from the desert side (feeding areas) towards the Euphrates River and the sedimentary plain (drainage areas), because the water moves with the tendency of these layers from the feeding areas in the west and south to the drainage areas in the east and northeast. Thus, this lake is part of the drainage area of this water, as it was estimated that the productivity of El-Ayoun feeding Sawa Lake is about (37.5) million m³, which is equivalent to (1190) liters per second [16].

The results of the chemical analysis presented that the value of the degree of soil interaction in the study area ranged between (7.0 and 7.55) and thus the soils are neutral soil to low alkaline soil based on [17]. The reason for the low pH of the soil, despite the fact that the calcium soils are due to the high levels of salinity and the prevalence of sulfur-bearing minerals and hexagonal oxides, and this is what he pointed out by [18] when studying this soil, which works to reduce the values of pH.

4.2.2 Mineral composition

The metallic analysis of the second depth of the studied samples was conducted to identify the nature of the light and heavy minerals of the sediments of Sawa Lake and their sedimentary nature. Table 3 shows the percentages of light and heavy metals, the percentages of light metals ranged between (90 and 93)%. The highest percentage at the site (4) and the lowest percentage at the site (3), while the proportions of heavy metals ranged between (7 and 10)% and the highest percentage at the site (3), while the lowest percentage at the site (4) was in soil under consideration.

It is noted from the results that the percentages of light and heavy metals within the sand separation in all soils of the study were close at all sites studied. This clearly indicates the homogeneity of the original materials of the study soil, and that the sediments come from one source, which is the lake, as the distribution of these proportions was one in all locations, and that its distribution depends on the origin [19] the matter material and the degree of its development.

The results in Table 4 and Plate 1 and 2 showed the relative distribution of the group of light and heavy metals of the sand separation in soils under study by polarized optical microscopy. The results indicated the prevalence of monocristalline quartz mineral within the light minerals of the sand separation, over the rest of the light minerals that make up the study soils. Its percentage ranged between (31.3 and 32.5)%, as the highest value appeared at the site (3), while the lowest value appeared at the site (2).

The carbonic rock pieces in terms of sovereignty, with the percentage ranging between (29.7 - 32.3)%; the highest percentage was at the site (3), while the lowest percentage appeared at the site (4). Sawan stone was present at a rate ranging between (12.3 - 17.7)% and the highest percentage was at the site (1) and the lowest value at the site (4). Vaporizers, which mostly include gypsum and anhydrite, and their percentages ranged between (4.1 - 4.9)% and the highest value appeared at the site (4), while the lowest value appeared at the site (1).

Clay rocks ranged between (4.0 - 4.6)% and the highest value was at the site (3), while the lowest value appeared at the site (4). The values of polycristalline quartz minerals, orthoclase, microcline, fiery, metamorphic and other minerals in terms of dominance were converged. Their values ranged between (1.0 - 2.5)% and the highest value for other minerals were at the site (3), while the lowest value for other minerals appeared at the site (1). There was a dominance of the dark minerals represented by Mkenite iron oxides, as well as hematite and chromite, as their rates ranged between (36.4-40.4)% and the highest value was at the site (3) while the lowest value was at the site (1).

It was followed by sovereignty of zircon, tourmaline, muscovite, amphibole, pyroxene, epidote, carnit, rutile and other minerals in proportions ranging from (8.2 - 8.9), (8.0 - 8.9), (7.5 - 7.9), (4.4 - 7.9), (4.5 - 7.5), (5.7 - 6.8), (3.7 - 4.7), (3.5 - 5.7), (1.0 - 2.1), respectively. Through the results of Table (4), it was found that the percentages of light and heavy metals group within the sand separation were found in all soils of study, and this indicates that the sediment source is the same.

This was confirmed by [20] through their studies of mineral composition within the sand separation of soil south of the Nile River in Egypt, as we indicated that the differences in the percentages of these minerals within the sand separation in all soils of the study indicate multiple precipitation systems in the region.
The microscopic analyses of the sand separation confirmed the dominance of quartz in all study samples within light metals. This is natural because most of the desert soils within the study area are sand originating material containing mainly quartz mineral in addition to the resistance of this mineral to weathering because its chemical bonds are strong in addition to its hardness and not to contain cracks.

This is consistent with what [21,22], in which quartz is formed as a result of physical weathering factors without any change in its chemical composition. It is made up of a tetradaedra, which is connected to each other by the corners, forming a three-dimensional structure, very solid and weatherproof. The results also showed the high levels of carbonate rock pieces that represent the origin material for the study area and indicated by the geological formations of the study area, which was reflected in the high content of calcium carbonate in the soil of the study [18] indicated. This is further evidence that most of Sawa Lake deposits are calcareous deposits rather than gypsum deposits.

Table 3. Percentage of light-heavy metals of the studied samples.

| Sample | Light Minerals | Heavy Minerals |
|--------|----------------|----------------|
|        | (gm)           | (%)            |
| 1      | 0.92           | 92             |
| 2      | 0.91           | 91             |
| 3      | 0.90           | 90             |
| 4      | 0.93           | 93             |

Table 4. Types of mineral composition and percentages of studied samples.

| Light Minerals and Components | 1  | 2  | 3  | 4  |
|------------------------------|----|----|----|----|
| Monocrystalline Quartz       | 31.5| 31.3| 32.5| 31.5|
| Polycrystalline Quartz       | 2.1| 1.4| 1.2| 1.7|
| Alkali Feldspars (Orthoclase)| 1.2| 1.5| 1.3| 1.5|
| Alkali Feldspars (Microcline)| 1.1| 1.3| 1.4| 1.1|
| Plagioclase Feldspar         | 1.4| 1.3| 1.5| 1.9|
| Carbonate Rock Fragments     | 30.4| 30.4| 32.3| 29.7|
| Chert Rock Fragments         | 17.7| 16.1| 15.9| 12.3|
| Igneous Rock Fragments       | 1.2| 1.5| 1.6| 1.2|
| Metamorphic Rock Fragments   | 1.2| 1.2| 1.8| 1.6|
| Mudstone Rock Fragments      | 4.2| 4.3| 4.6| 4.0|
| Evaporates                   | 4.1| 4.7| 4.7| 4.9|
| Others                       | 1.0| 1.7| 2.5| 1.5|
| Heavy Minerals               | 36.4| 38.0| 40.4| 37.1|
| Opaques (Iron Oxides)        | 4.2| 5.8| 4.6| 5.8|
| Chlorite                     | 3.8| 5.7| 4.0| 5.0|
| Rutile                       | 8.2| 8.9| 9.9| 8.7|
| Pyroxene                     | 7.5| 6.2| 5.3| 4.5|
| Amphibole                    | 7.5| 7.9| 4.8| 4.4|
| Biotite                      | 4.4| 4.4| 3.5| 3.6|
| Muscovite                    | 7.5| 7.8| 8.7| 7.9|
| Tourmaline                   | 8.0| 8.9| 8.2| 8.2|
| Epidote                      | 5.9| 5.7| 5.8| 6.8|
| Garnet                       | 4.4| 4.7| 4.7| 3.7|
| Kyanite                      | 1.1| 1.1| 1.7| 2.1|
| Others                       | 1.0| 2.1| 1.1| 1.3|
Figure 4. Images of the light minerals in the studied samples.
Figure 5. Images of the light minerals in studied samples.
Figure 6. Images of the light minerals in studied samples.
Conclusions

1- Sawa lake has a clear effect on soil formation in the studied area.
2- The studied soil was characterized by high salinity levels because of the high level of the groundwater.
3- The lake water and its sediments were less salty in previous periods compared to recent periods since there is high salinity in the surface layers and their decrease in subsurface depths.
4- The lake sediments were of rough separators due to the increase in sand values compared to silt and clay, and the increase in very rough sand type was as being closer to the lake.
5- The results indicated the convergence of the sediment content of light and heavy metals in all locations and the homogeneity of the distribution of minerals in all locations.

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