

## CHEMICAL AND MINERALOGICAL CHARACTERISTICS OF SOME SHALE DEPOSITS IN EGYPT

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Representative samples were collected from some important shale deposits at twelve locations in Egypt. Granulometric analysis and some chemical characteristics were determined. X-ray diffractograms of the separated clay fraction and quantitative estimation of the clay minerals were carried out. Results show that the shale deposits at Kom Oshim and Gabal Hamza contain the highest percentages of clay (88 and 75 %, respectively), while the lowest content of the clay fraction (23 %) was recorded in the shale deposits of Um Qamar and Wadi Kharruba. Data also reveal that the highest value of  $EC_e$  was found in the shale deposits of El-Khatatba, while the lowest value was observed in the shale of El-Belida. Total and DTPA-extractable contents of trace elements and heavy metals in the studied shale deposits were under the permissible limits of toxicity. Mineralogical analysis reveals that the studied shale deposits consist of two assemblages. The 1<sup>st</sup> assemblage is characteristic for the shale deposits of El-Khaboba, El-Tih, Abu El-Rish South, El-Belida and El-Gedida which consist of kaolinite as the main constituent. The 2<sup>nd</sup> assemblage is distinguished in the shale deposits of Qusr El-Sagha, Kom Oshim, El-Qattamia, El-Khatatba, Gabal Hamza, Um Qamar and Wadi Kharruba where montmorillonite is the major clay mineral. Based on the current study, the montmorillonitic shales of Qusr El-Sagha, Kom Oshim, El-Qattamia, El-Khatatba, Gabal Hamza, Um Qamar and Wadi Kharruba are recommended as amendments for coarse-textured soils. Among which Qusr El-Sagha is the best source of amendments. On the other hand, the kaolinitic shales of El-Khaboba, El-Tih, Abu El-Rish South, El-Belida and El-Gedida can be used for industrial purposes. In all cases, economical aspects should be considered.

**Keywords:** shale deposits, X-ray diffraction, clay minerals, trace elements, heavy metals.

The agricultural development of sandy soils which are the most common in desert regions became an unavoidable necessity to increase agricultural production and national income.

Amelioration of sandy soils potentialities is usually practiced by application of amendments, organic manures and fertilizers to improve their physical, chemical, biological and nutritional properties. In this respect, bentonite and shales, which are wide-spreaded natural deposits, should be tried, particularly after the construction of the high dam where the suspended matter in the Nile water has been trapped.

Therefore, the objective of this study is to evaluate some chemical and mineralogical characteristics of some shale deposits, which are among the proper amendments for application in sandy soils reclamation.

## MATERIALS AND METHODS

The studied shale samples were collected from twelve locations as shown in Fig (1). Granulometric analysis of the collected samples, after crushing, grinding and sieving was carried according to Black *et al.* (1965). The total surface area was determined by orthophenanthroline adsorption method described by Lawrie (1961). Amorphous silica and alumina contents were determined as outlined by Hashimoto and Jackson (1960).

The shale deposits were also analyzed for their total contents of Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd in the filtered extracts obtained from samples digested by Conc.  $\text{HNO}_3$  + Conc.  $\text{H}_2\text{SO}_4$  + 60 %  $\text{HClO}_4$  as outlined by Hesse (1972), while the chemically – extractable contents of these elements were extracted using  $5 \times 10^{-3}$  M DTPA in  $10^{-2}$  M  $\text{CaCl}_2$  and  $10^{-1}$   $\mu$  triethanolamine (TEA) at pH 7.3 according to Lindsay and Norvell (1978) and modified by Norvell (1984). In all cases, the elements were determined by graphite furnace atomic absorption (Unicam 929).

The  $< 2 \mu$  clay fraction was separated from the studied samples after the destruction of organic matter, dissolution of calcium carbonate and extraction of amorphous inorganic materials (Jackson, 1969).

For X-ray diffraction (XRD) analysis, oriented preparations were prepared by depositing a clay suspension onto a glass slide (Srodon *et al.*, 1986; Cuadros and Linares, 1995), after Mg-saturation, glycerol solvation and K-saturation of air dried and heated clay subsamples to  $550^\circ\text{C}$  for 2 hrs. All XRD patterns were obtained by a Philips PW 3710 using Ni-filtered Cu radiation (40 kV operating voltage and a current of 35 mA). Calculation of the relative amounts of clay minerals in each of the studied samples was carried out using the method adapted by Brooks and Ferrel (1970).

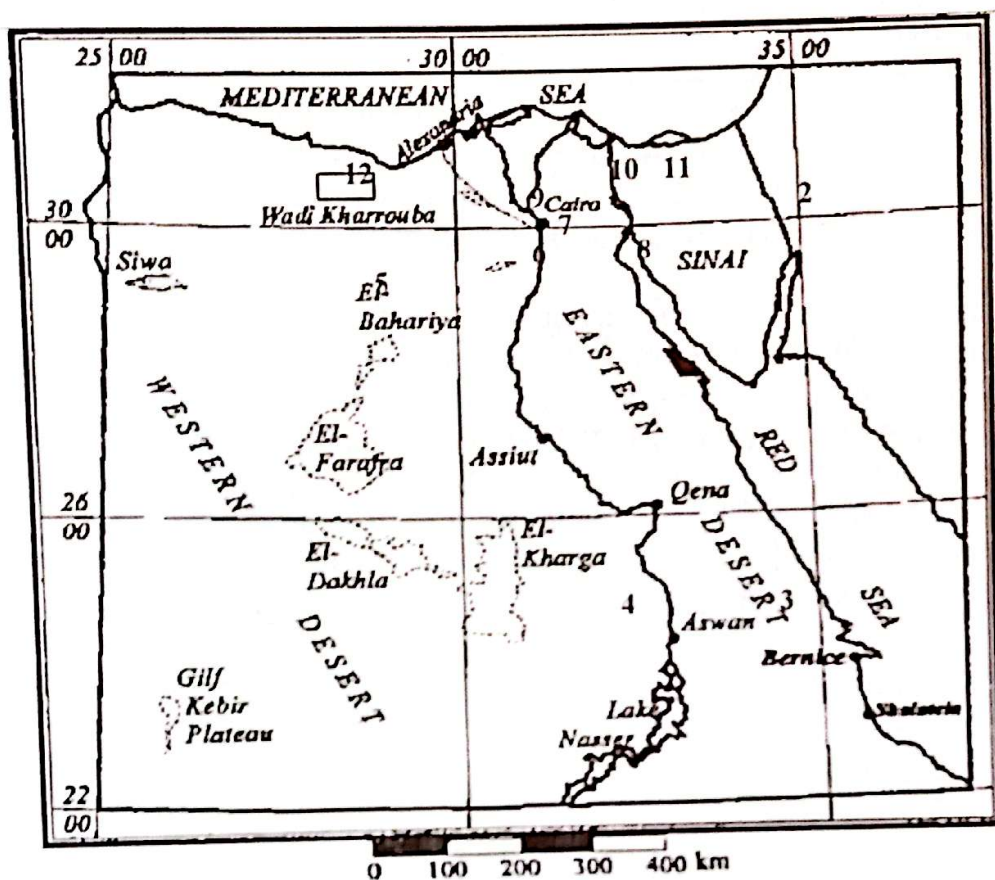


Fig. (1). Location map of the studied shale deposits.

## RESULTS AND DISCUSSION

Data tabulated in table (1) indicate that most of the studied shale deposits contain a considerable amount of clay fraction that ranged between 23.63 and 88.25 %. The lowest content was found in the shale deposits of Wadi Kharruba, while the highest content was recorded in the shale deposits of Kom Oshim. The geological formation of Qusr El-Sagha and Kom Oshim has been reported by Beadnell (1905). The lithology of this formation consists of shales and limestones mixed with sand and sandstone in the upper part, 180 m thickness, which belong to the Upper Eocene. The limit of these sediments in El-Fayoum overlies Birket Qarun formation and underlies the Qatrani formation. Data in table (1) also show that the salinity of the studied shale deposits ranged between slightly saline and extremely saline where the  $EC_e$  values ranged between 1.92 and 47.10  $dSm^{-1}$ . The lowest salinity level was observed in the shale deposits of El-Belida, while the highest level was recorded in the shale deposits of El-Khatatba.

TABLE (1). Average importance values (IV) (out of 300) of the perennial species in the five vegetational groups

| sample No. | location          | shale separates % |           |       |       |  | textural class | S.A. m <sup>2</sup> /g * | C.E.C. me/100g clay | pH (paste) | ECe dS/m | O.M. % | CaCO <sub>3</sub> % | ESP *** | amorphous inorganic materials % |                                |                                | total |
|------------|-------------------|-------------------|-----------|-------|-------|--|----------------|--------------------------|---------------------|------------|----------|--------|---------------------|---------|---------------------------------|--------------------------------|--------------------------------|-------|
|            |                   | coarse sand       | fine sand | silt  | clay  |  |                |                          |                     |            |          |        |                     |         | SiO <sub>2</sub>                | Al <sub>2</sub> O <sub>3</sub> | Fe <sub>2</sub> O <sub>3</sub> |       |
| 1          | El-Khaboba        | 0.15              | 0.75      | 43.70 | 55.40 |  | C              | 56.00                    | 19.29               | 6.48       | 8.53     | 0.16   | 0.42                | 60.00   | 1.75                            | 5.88                           | 0.13                           | 7.76  |
| 2          | El-Tih            | 22.86             | 10.11     | 14.53 | 52.50 |  | C              | 93.00                    | 18.04               | 7.55       | 3.65     | 0.03   | 0.18                | 45.58   | 0.66                            | 3.90                           | 0.25                           | 4.81  |
| 3          | Abu El-Rish South | 9.00              | 1.17      | 60.50 | 29.33 |  | SiC            | 334.00                   | 59.86               | 7.65       | 17.01    | 0.18   | 0.22                | 49.04   | 0.91                            | 1.53                           | 3.10                           | 5.54  |
| 4          | El-Belida         | 44.01             | 10.15     | 6.95  | 38.89 |  | C              | 370.00                   | 14.36               | 8.40       | 1.92     | 0.04   | 0.63                | 47.11   | 0.47                            | 2.31                           | 0.11                           | 2.89  |
| 5          | El-Gedida         | 16.25             | 21.67     | 7.00  | 55.08 |  | C              | 141.00                   | 49.59               | 8.10       | 7.92     | 0.18   | 9.85                | 35.58   | 0.98                            | 6.05                           | 4.25                           | 11.28 |
| 6          | Qusr El-Sagha     | 0.43              | 11.80     | 21.02 | 66.75 |  | C              | 459.00                   | 70.64               | 8.89       | 2.90     | 0.14   | 2.69                | 61.42   | 0.70                            | 0.61                           | 1.27                           | 2.58  |
| 7          | Kom Oshim         | 0.45              | 1.30      | 10.00 | 88.25 |  | C              | 397.00                   | 33.49               | 8.09       | 16.01    | 0.31   | 15.13               | 43.25   | 1.01                            | 0.98                           | 2.51                           | 4.50  |
| 8          | El-Qattamia       | 0.31              | 18.02     | 14.95 | 66.72 |  | C              | 196.00                   | 70.45               | 8.10       | 9.73     | 0.16   | 0.23                | 31.21   | 0.93                            | 0.78                           | 1.10                           | 2.81  |
| 9          | El-Khatatba       | 10.30             | 5.25      | 25.00 | 59.45 |  | C              | 224.00                   | 64.52               | 7.92       | 47.10    | 0.19   | 12.44               | 51.57   | 0.60                            | 1.55                           | 1.45                           | 3.60  |
| 10         | Gabal Hamza       | 0.75              | 9.45      | 14.55 | 75.25 |  | C              | 223.00                   | 45.33               | 7.41       | 19.03    | 0.10   | 0.18                | 56.38   | 0.59                            | 1.98                           | 3.05                           | 5.62  |
| 11         | Um Qamar          | 55.00             | 18.00     | 3.23  | 23.77 |  | SCL            | 111.00                   | 60.54               | 8.35       | 16.11    | 0.05   | 0.28                | 52.21   | 1.38                            | 2.29                           | 0.49                           | 4.16  |
| 12         | Wadi Kharuba      | 1.42              | 46.06     | 28.89 | 23.63 |  | L              | 281.00                   | 121.67              | 10.32      | 11.26    | 0.09   | 2.06                | 43.63   | 0.88                            | 0.76                           | 1.21                           | 2.85  |

\* S.A. = surface area \*\* C.E.C. = Cation exchange capacity \*\*\* E.S.P. = exchangeable sodium percent

With respect to the total content of trace elements and heavy metals in the studied shale deposits, data tabulated in table (2) reveal that the lowest contents of Fe, Mn, Zn, Cu and Ni were recorded in the shale of El-Khaboba, while the lowest contents of Pb, Co and Cd were found in the shales of El-Qattamia, El-Belida and El-Tih. On the other hand, data in table (2) show that the highest total contents of Fe, Cu and Ni were observed in the shale of Um Qamar, while the highest contents of Mn, Zn, Pb, Co and Cd were found in the shales of El-Khatatba, Wadi Kharruba, El-Belida, El-Gedida and Kom Oshim.

With regard to DTPA-extractable contents of the previous elements in the studied shale deposits, data in table (2) show that the lowest contents of Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd were recorded in the shales of Wadi Kharruba, El-Tih, Gabal Hamza, El-Gedida, El-Belida, Qusr El-Sagha and Kom Oshim. The highest contents of DTPA-extractable Fe and Mn was found in the shale of El-Gedida, while the highest contents of Zn, Ni and Cd were observed in the shale of El-Tih whereas the highest contents of Cu, Pb and Co were related to the shale of El-Belida, Gabal Hamza and El-Khaboba.

The data dictate that though the shales content of chemically-extractable elements of the different shale deposits varies widely, yet their addition to soils under reclamation may contribute efficiently to the nutritional supply of some essential micronutrients as well as some polluting elements such as Pb and Cd that are hazardous to the environment.

X-ray diffractograms of the separated clay from the selected samples after the different treatments (Figs. 2-9) reveal that two clay minerals assemblages are identified in these deposits. The 1<sup>st</sup> is characteristic to the shale deposits of El-Khaboba, El-Tih, Abu El-Rish South, El-Belida and El-Gedida, which consist of kandite (kaolinite) as the main constituent with lesser amounts of quartz, minor amounts of illite and traces of feldspars (Figs. 2-6). These findings are in harmony with those of El-Askary (1972) who mentioned that kaolinite is the main clay mineral constituent in Abu El-Rish at Aswan area and Azzam (1996) who found that kaolinite is the dominant clay mineral in some shale deposits of El-Khaboba, El-Gedida and Qusr El-Basel. The latter author further showed that the shape of the 7.10° A peak indicates that kaolinite is generally moderate to well crystalline, he also mentioned that illite is a minor clay mineral in El-Gedida.

The 2<sup>nd</sup> assemblage is distinguished in the shale deposits of Qusr El-Sagha, Kom Oshim, El-Qattamia, El-Khatatba, Gabal Hamza, Um Qamar and Wadi Kharruba where the clay fraction consists mainly of smectite (montmorillonite) with lesser amounts of kaolinite and illite (Figs. 7-9). These results are in agreement with that of El-Hady and El-Sherif (1988) who found that montmorillonite content in Qusr El-Sagha deposits ranged between 57 % and 67 %, while kaolinite didn't exceed 38 %.

TABLE (2). Total and DTPA-extractable contents of Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd in the studied shale deposits.

| sample No. | location          | elements (mg/l) |             |        |             |        |             |       |             |       |             |       |             |       |             |       |             |
|------------|-------------------|-----------------|-------------|--------|-------------|--------|-------------|-------|-------------|-------|-------------|-------|-------------|-------|-------------|-------|-------------|
|            |                   | Fe              |             | Mn     |             | Zn     |             | Cu    |             | Pb    |             | Ni    |             | Co    |             | Cd    |             |
|            |                   | total           | extractable | total  | extractable | total  | extractable | total | extractable | total | extractable | total | extractable | total | extractable | total | extractable |
| 1          | El-Khaboba        | 844.00          | 13.32       | 5.60   | 0.95        | 6.35   | 3.23        | 11.20 | 7.70        | 8.85  | 3.18        | 4.80  | 0.31        | 2.05  | 0.85        | 0.40  | 0.020       |
| 2          | El-Tih            | 982.00          | 3.81        | 12.75  | 0.28        | 27.55  | 6.43        | 12.05 | 5.85        | 15.05 | 2.98        | 37.70 | 0.77        | 3.75  | 0.80        | 0.10  | 0.056       |
| 3          | Abu El-Rish South | 1152.50         | 10.93       | 379.05 | 3.63        | 10.00  | 1.02        | 16.60 | 5.09        | 4.75  | 1.18        | 19.15 | 0.17        | 8.35  | 0.08        | 0.15  | 0.008       |
| 4          | El-Belida         | 983.00          | 3.00        | 6.30   | 0.84        | 28.80  | 5.46        | 42.15 | 28.96       | 15.70 | 2.70        | 6.70  | 0.05        | 1.50  | 0.03        | n.d.  | 0.008       |
| 5          | El-Gedida         | 1172.00         | 45.04       | 718.00 | 25.04       | 15.65  | 0.88        | 16.50 | 1.78        | 3.25  | 0.65        | 31.50 | 0.49        | 24.30 | 0.10        | 0.20  | 0.006       |
| 6          | Qusr El-Sagha     | 1152.50         | 29.30       | 40.75  | 1.50        | 37.15  | 2.89        | 17.15 | 9.43        | 6.10  | 1.33        | 14.10 | 0.35        | 6.55  | 0.02        | n.d.  | 0.004       |
| 7          | Kom Oshim         | 1159.50         | 33.62       | 200.00 | 3.03        | 50.20  | 1.19        | 18.00 | 3.51        | 3.95  | 1.22        | 12.15 | 0.11        | 12.60 | 0.06        | 2.30  | 0.002       |
| 8          | El-Qattamia       | 1155.50         | 11.65       | 36.30  | 1.03        | 47.90  | 1.56        | 17.10 | 5.15        | 2.00  | 1.54        | 12.40 | 0.04        | 5.55  | 0.02        | 0.25  | 0.024       |
| 9          | El-Khatalba       | 1157.50         | 24.62       | 535.50 | 5.49        | 30.60  | 1.53        | 32.55 | 4.08        | n.d.  | 1.29        | 43.35 | 0.36        | 16.50 | 0.17        | 0.75  | 0.004       |
| 10         | Gabal Hamza       | 1139.00         | 23.96       | 29.60  | 2.40        | 21.60  | 0.61        | 16.00 | 2.01        | 3.45  | 5.03        | 12.70 | 0.22        | 4.95  | 0.03        | n.d.  | 0.012       |
| 11         | Um Qamar          | 1302.50         | 6.75        | 340.25 | 0.96        | 133.70 | 0.88        | 42.85 | 1.89        | 2.55  | 1.08        | 57.55 | 0.07        | 16.40 | 0.08        | n.d.  | 0.008       |
| 12         | Wadi Kharruba     | 1104.50         | 30.11       | 163.35 | 1.52        | 146.40 | 1.654       | 22.60 | 6.021       | 4.60  | 0.658       | 16.40 | 0.092       | 6.15  | 0.067       | n.d.  | 0.005       |

n.d. = not detected

The high percentage of smectite (montmorillonite) and, in turn, the high surface area of such clay mineral revealed the possibility of using these shales for improving hydro-physical, chemical and biological properties of sandy soils as well as ameliorating the soil media for plant growth.

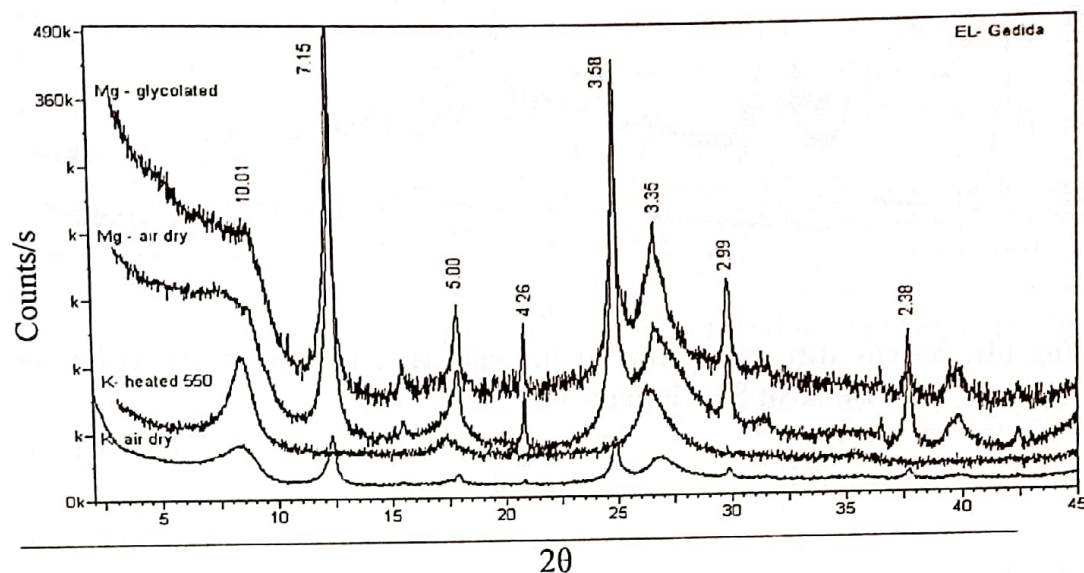


Fig. (2). X- ray diffractograms of the clay fraction separated from the shale deposits of EL-Gedida

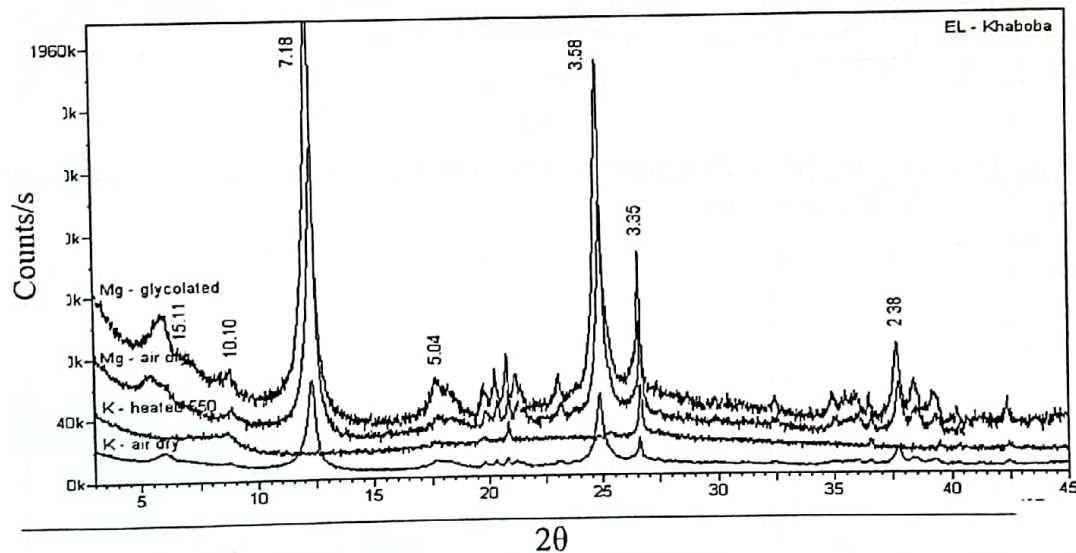


Fig. (3). X- ray diffractograms of the clay fraction separated from the EL-Khaboba deposits

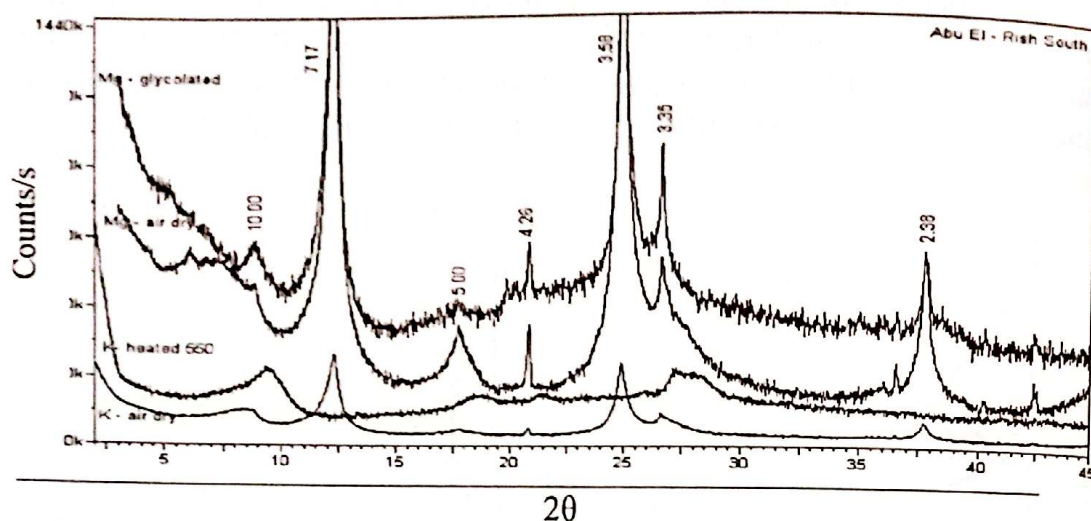


Fig. (4). X- ray diffractograms of the clay fraction separated from the Abu El-Rish South deposits

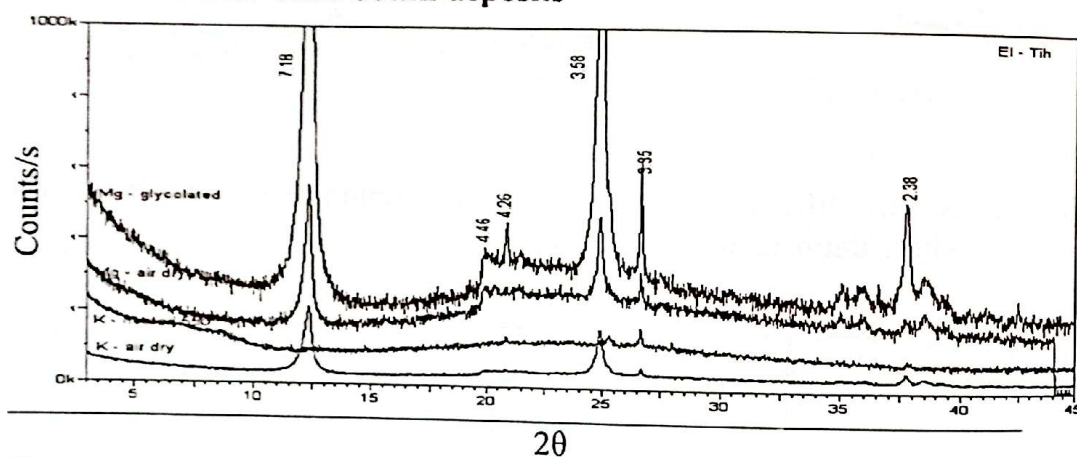


Fig. (5). X- ray diffractograms of the clay fraction separated from the El-Tih deposits

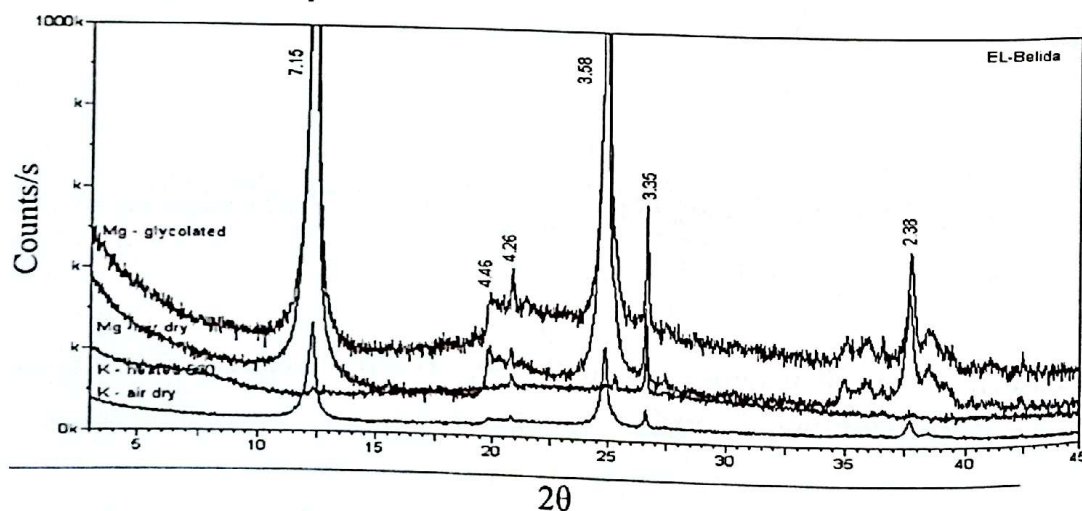


Fig. (6). X- ray diffractograms of the clay fraction separated from the El- Belida deposits

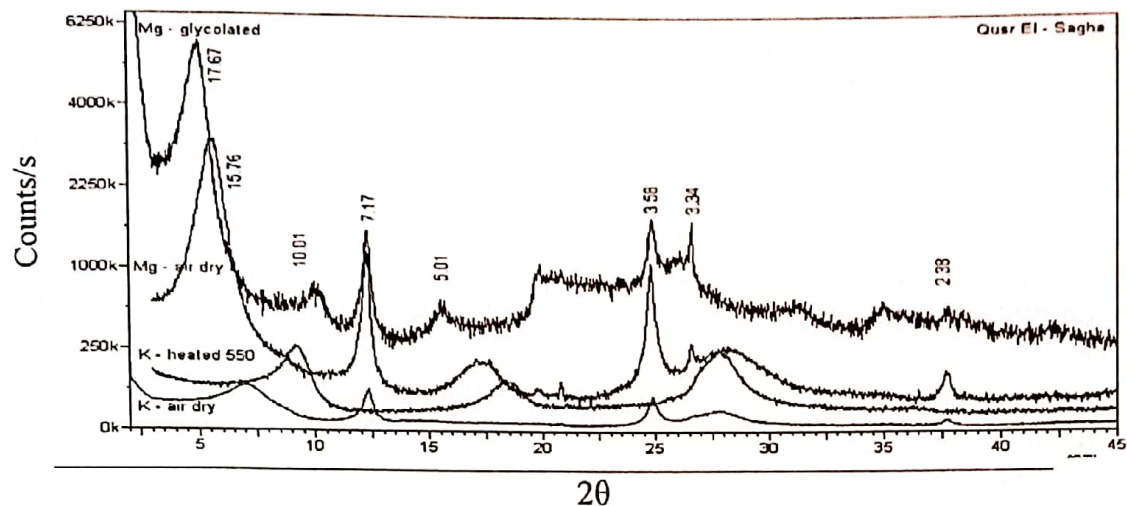


Fig. (7). X- ray diffractograms of the clay fraction separated from the Qasr El- Sagha deposits

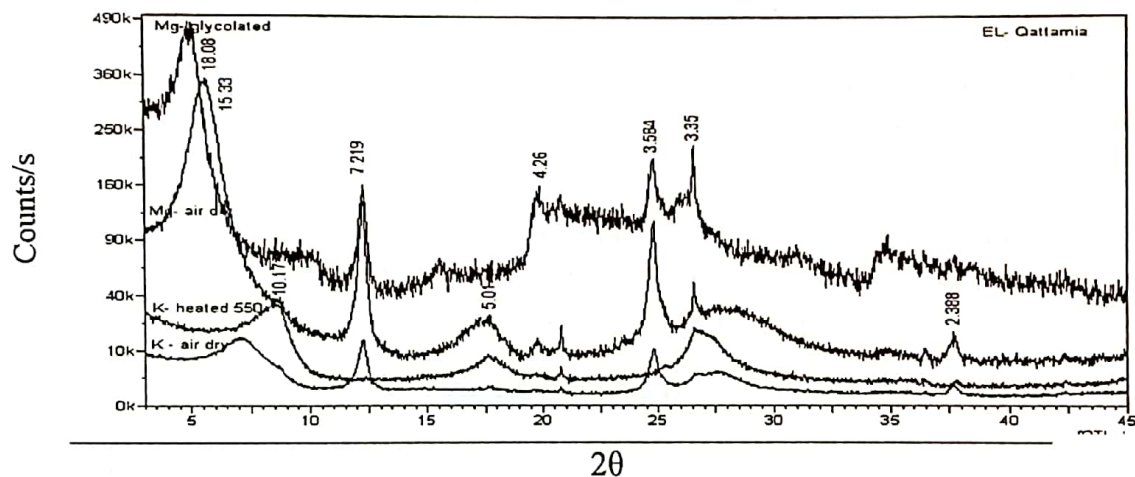


Fig. (8). X- ray diffractograms of the clay fraction separated from the EL- Qattamia deposits.

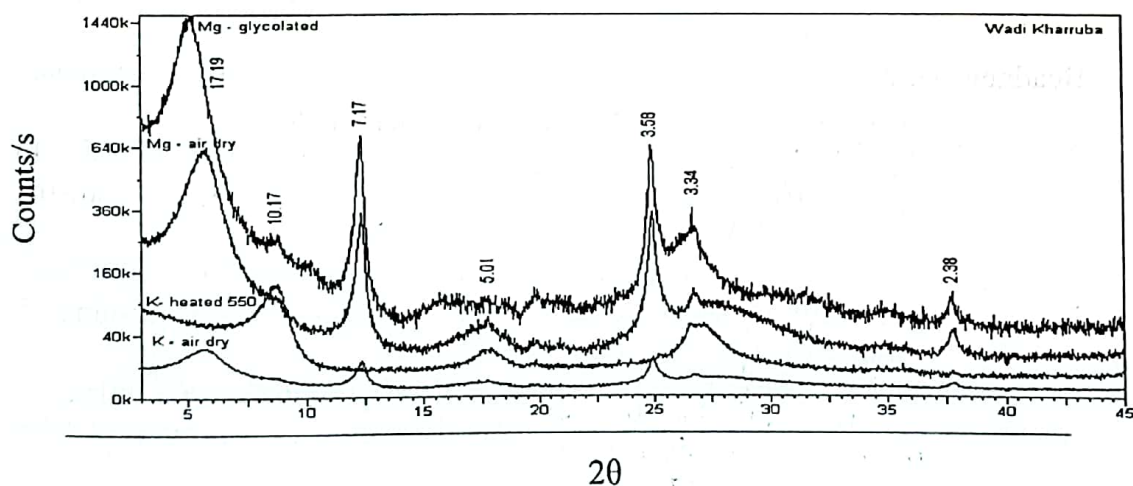


Fig. (9). X- ray diffractograms of the clay fraction separated from the Wadi Kharruba deposits

The aforementioned discussion leads to the conclusion that the percentage of smectite in the clay fraction of the shale deposits is regarded as the limiting factor for using any type of shale in ameliorating sandy soils.

Based on the current study, it could be concluded that the shales of El-Qattamia, Wadi Kharruba, Kom Oshim, Um Qamar and Gabal Hamza can be recommended for soil amelioration and improvement purpose with proper leaching to decrease the salinity impaired by the shale deposits addition. Fortunately, the rapid permeability and deep water percolation and infiltration in sandy soils will greatly help in removal of salinity out of the root zone. In this regard, Qusr El-Sagha sediments, with its high percentage of clay and the highest amount of montmorillonitic clay mineral is considered the best source of clay amendment for sandy soils to improve their physical, chemical and hydrological characteristics. Other factors should be considered, such as the expedient technique applied either in grinding of shales or in the way and rate of addition to the soil. Also, the economical aspect concerning the distance of transport, expenditure, labor and priority of the use of these shales and their exploitation are of a paramount importance.

On the other hand, the kaolinitic shale deposits containing the highest amount of kaolinitic clay minerals represented by the shales of El-Khaboba, El-Tih, Abu El-Rish South, El-Belida and El-Gedida can be used for industrial purposes such as construction, ceramics and pipes, filling material in painting, soap and paper industries.

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## الخصائص الكيميائية والمنرالوجية لبعض رواسب الطفلة في مصر

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أختير لهذه الدراسة إثنتا عشرة عينة تمثل بعض رواسب الطفلة في مصر، حيث أجريت عليها التحاليل الكيميائية والمنرالوجية.

أوضحت النتائج أن رواسب الطفلة في كل من كوم أوшим و جبل حمزة تحتوي علي أعلى نسبة من مكون الطين (٧٥,٨٨%) لكلا الموقعين علي التوالي ، بينما أقل نسبة (٢٣%) فقد وجدت في رواسب الطفلة الموجودة في كل من أم قمر ووادي خروبة.

كما أوضحت النتائج أن أعلى قيمة لدرجة التوصيل الكهربائي كانت برواسب الطفلة الموجودة بالخطاطبة، بينما أقل قيمة كانت بالطفلة المأخوذة من البليدة ، كذلك بينت النتائج أن محتوى هذه الرواسب من العناصر الصغرى والعناصر الثقيلة كان دون مستوى حدود السمية المسموح بها.

أوضح التحليل المنرالوجي أن هذه الرواسب تتكون من مجموعتين:-

المجموعة الأولى والممثلة برواسب الطفلة الموجودة في كل من الخبوبة ، التيه ، أبو الريش القبلي ، البليدة ، الجديدة فتتكون أساسا من معدن الكاولينيت ، بينما المجموعة الثانية والممثلة برواسب الطفلة في كل من قصر الصاغة ، كوم أوшим ، القطامية ، الخطاطبة ، جبل حمزة ، أم قمر ، وادي خروبة فيسود بها معدن المونتموريللونيت.

وبناء علي ما سبق ، فإنه ينصح باستخدام رواسب الطفلة في كل من قصر الصاغة ، كوم أوшим ، القطامية ، الخطاطبة ، جبل حمزة ، أم قمر ، وادي خروبة والتي يسود بها معدن المونتموريللونيت في إصلاح الأراضي خشنة القوام ، وتعتبر طفلة قصر الصاغة أفضل هذه الأنواع. من ناحية أخرى ، فإن رواسب الطفلة الموجودة في كل من الخبوبة ، التيه ، أبو الريش القبلي ، البليدة ، الجديدة والتي تتكون أساسا من معدن الكاولينيت فيمكن استخدامها في الأغراض الصناعية. وبوجه عام ، فإنه في جميع الحالات يجب أن يؤخذ الجانب الاقتصادي في الاعتبار.