Characterization and potential upgrading of El-Zaafarana White Sand by Attrition scrubbing.

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Abstract – *White sand deposits are the most widely used non-metallic minerals in various industrial applications, and this explains the significant increase in demand for them, especially in recent years. Almost all countries of the world produce silica sand deposits, but high purity silica sand deposits are produced from a few sites in the world. This is the main reasons for the continuous research studies of the methods used in the treatment of silica sand deposits to match their chemical and physical specifications with industrial requirements. Egypt has many silica sand localities, among these silica sand localities, and the most important is the El-Zaafarana area. Unfortunately, not many studies have been conducted on this region. In our study, Sibelco Egypt Co. supplied samples from that area. Samples are well prepared in order to obtain fully representative sample. In addition, a complete characterization was performed to show the physical, chemical and mineral characteristics of the silica sand deposits occurring in that area. This characterization included a dry sieving analysis of the samples that were prepared, and then the sample was introduced to a mineralogical study to provide more details about the shape and size of the grains and the nature of associated impurities. An X-ray diffraction analysis was performed on the original sample to find out the predominant mineral phases in it. Moreover, an XRF analysis was conducted to accurately determination of the amount of impurities present in the sample and the silica content.*

A sand sample subjected to Attrition scrubbing process, the best condition of the Attrition scrubbing process was determined based on preliminary experiments in order to determine the optimal conditions for the washing process, which were determined for a time of 30 min., a speed of 3000 rpm, and a solid-to-liquid ratio of 25%. The whole bulb of the attrition product subjected to wet mechanical sieving and separation on a 25 micron sieve. Fraction of + 25 micron of the attrition product characterized by XRF, while the - 25 micron fraction characterized by XRD and mineralogical study by using an optical microscope.

The obtained results of our study indicated that, the physical and chemical specifications of the white sand samples was improved. Silica content increasing from 95.69 % to 97.0518 %, in addition to, decreasing of the main impurities such as, iron content and alumina content from to 0.2379 % and 0.6619 % respectively 0.0455 % and 0.1921 % respectively.

1. Introduction:

Quartz (SiO2) is found in nature in varying purity and is traded in varying quality for modern industrial applications. Industries such as advanced ceramic materials, electronic chips, integrated circuits (ICs), optical fibers, and photovoltaic panels (PV) are based on high-quality quartz. Lower-quality quartz may be used for ordinary applications such as foundry sand for metal castings or as a filler for adhesives and grouts. The advances of quartz-based industries have resulted in a significant increase in demand in recent years [1, 2]. Silica sand represents another important resource of quartz that can be found with huge reserves in some countries. However, silica sand usually contains other impurities that must be removed to meet the requirements of high-tech industries, which makes effective processing methods of high importance.

Impurities of clay minerals and oxide minerals are common in natural silica deposits. Such impurities have a significant impact on the chemical quality of silica raw materials, and hence on their technical qualification [1]. The suitability of quartz sand for different industrial applications is determined by the quality of the sand in terms of: Grain size distribution, Chemical analysis, Color [2].

Iron oxide (Fe_2O_3), aluminum oxide (Al_2O_3) and titanium oxide (TiO_2) impurities are among the most frequent impurities in silica sand, and they inflict the most harm due to their color and qualities [3]. Iron oxides, siderite, pyrite, rutile, tourmaline, and mica are the most common ferruginous minerals found as impurities [1]. These impurities may prevent the use of silica sand in some advanced industrial applications, even if it is present in a small percentage.

To meet the required specifications for a specific product, the sand often has to be subjected to extensive physical and chemical processing or a combination of them. This involves crushing, screening and adjusting the size distribution, together with removing the impurities in the bulk and from the surface of the individual sand grains using attrition scrubbing followed by sizing process to reject fine particles [4].

In Egypt, silica sand is widely distributed in some localities in Sinai, Northern part of Eastern Desert, and in the Western Desert. For the last few decades, the Egyptian glass and crystal factories have been using the white sand for their first-class international products Quartz generally occurs in the Eastern Desert while, quartzite is commonly found in the Western Desert

The high quality and the potential value of the Egyptian white sand attracted the attention of many researchers [5-11]. About 16 localities containing high-grade silica sands have been identified in Egypt. The most important of these are Wadi Qena and Wadi El-Dakhl

(El-Zaafarana) located in the Northern part of the Eastern Desert and El- Maadi located in Cairo suburb, and Gebel El-Gunnah in Sinai. The reserves at the mentioned areas exceed 3 billion of tons of the high quality silica sand, which fulfill the specifications of the glass industry, paints, foundry, chemicals, and ceramics raw materials.

Some research studies were found focusing on the beneficiation potential of the Egyptian white sand and its potential industrial applications. Suzan S. Ibrahim et al conduct gravity separation of silica sands for value addition for samples obtained from Abu Zeneima locality, the results of this study indicated that, the dry screening upgraded the sand sample to give a fourth-quality grade suitable for sheet and plate glass. The application of attrition scrubbing of the classified sand gives a product that matched the chemical specifications of the second-quality glass sand for flint containers and tableware. When the attrition sand product was further subjected to shaking table at the optimum separating conditions a sand product matched the first-quality glass sand grade for optical applications was produced [12].

Mohamed S., et al conduct enhancing the technical qualifications of Egyptian white sand using acid leaching for white sand samples were collected from Zafarana area. The results of this study indicated that, leaching of Egyptian white silica sand by oxalic acid can upgrade its quality and its technical qualifications to match the specifications of some advanced and high technical applications [1].In addition to a lot of other research conducted in order to raise the value of Egyptian silica sand [1, 4, 10, 12-18].

As indicated above, very few beneficiation studies were found on the Egyptian silica sand and probably only one study was found addressing the upgrade potential of the white sand from El-Zaafarana area. This will conceal a lot about the potential uses for the Egyptian sand. The objective of this work is to characterize the silica sand from El-Zaafarana area and their potential upgrade using attrition scrubbing.

In Egypt, surface mining is usually used for mining of silica sands as a result of the presence of little or no overburden, about 115 m, in almost all the white sand deposits. The ore is drilled and blasted using ANFO and gelatin in the ratio of 3:1. The broken rock is transported to a size reduction and screening section, to be prepared for washing and processing [18]. The type of processing or beneficiation of silica sand is directly related to the nature of the sand deposit and the purity of the required product. Regardless of markets, sands are, at a minimum, washed, dried, and screened.

2. Experimental work:

2.1.Materials:

The representative white sand sample subjected to investigation supplied by Sibelco co. from Wadi El-Dakhl (El-Zaafarana area), northern eastern desert, Egypt. Between the latitudes of 28 30' and 28 55' N and the longitudes of 32 20' to 32 50' E, the region covers roughly 2880 km^2. The area has a reserve of nearby 10 million tons of loose or friable materials that are not covered by rock [4] [19]. The sand sample was prepared based on the coning and quartering method to obtain a good representative sample. Figure 1, showing EL-Zaafrana area in Egypt.

Figure 1: Location of EL-Zaafrana area in Egypt

2.2.Characterization:

Characterization of the head sample was carried out by dry sieve analysis using Fritsch shaker and analytical sieves 200 mm diameter, 50 mm height according to the German standards as research papers [20] [21]. The arrangement of the sieve set was as 710, 630, 425, 300, 180, 90 and 25 µm respectively. 200 g of sample was weighed and placed dry in the upper sieve, followed by the installation of the lid on this upper sieve, and the sieves being fastened on the shaker and run for 30 minutes.

A mineralogical study was conducted by using Leica MZ6, stereo-microscope (Leica-Germany) equipped with Leica Application Suite EZ software to provide more information about the mineral composition of the investigated samples and associated impurities.

X-ray diffraction analysis (XRD) using a *PANalytical X'Pert* PRO *X*-ray diffractometer operated at 40 kV and 30 mA with 2θ ranging from 5° to 50° using Cu Kα radiation to determine the major mineral phases exist in the head sample. In addition to a complete chemical analysis using X-ray fluorescence (XRF) using a Rigaku super mini 200 X-ray fluorescence spectrometer.

2.3.Attrition scrubbing and separation:

The head sample of white silica sand was subjected to attrition scrubbing followed by separation process. Attrition was carried out to detach clay minerals and dust coat silica particles that make an improvement in a chemical and physical characteristics of silica samples. The determination of the attrition scrubbing time, speed and solid liquid ratio based on preliminary experiments and analysis of silica content by using atomic absorption as a shown in Figure 2, 3 and 4.

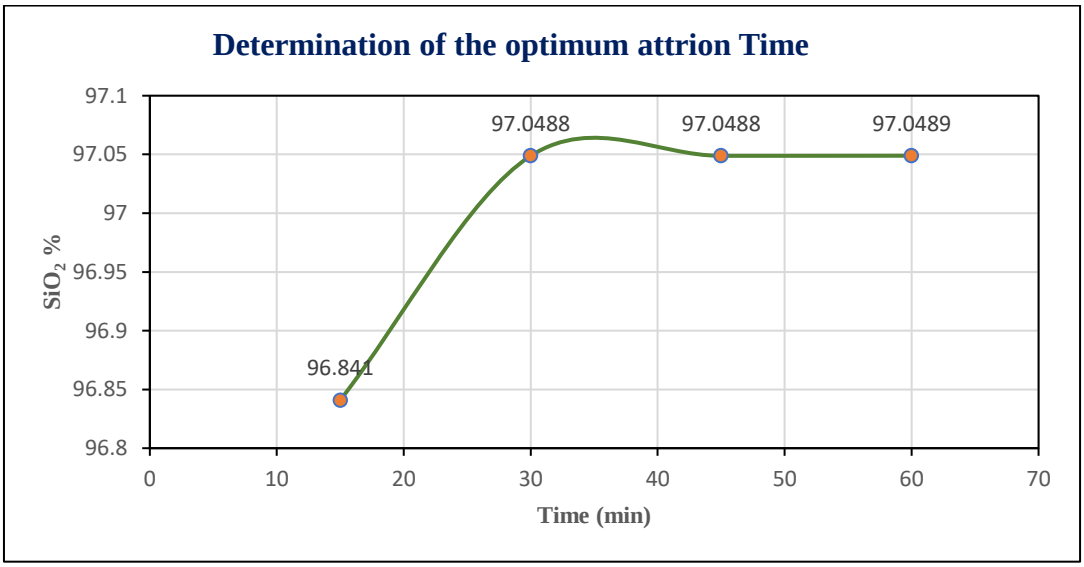


Figure 2: Effect of the attrition time on the silica content of the final silica product.

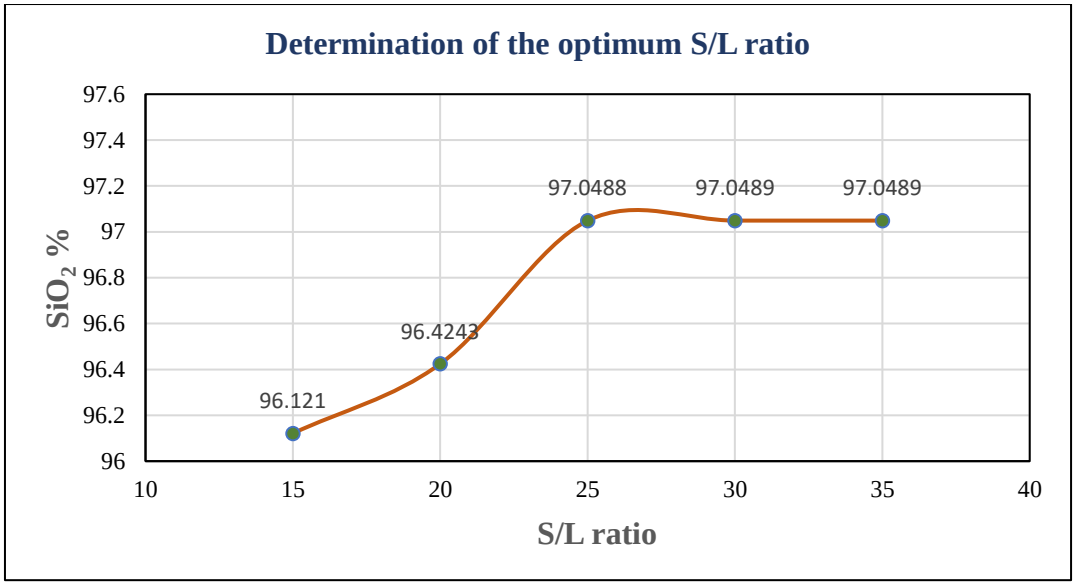


Figure 3: Effect of the solid liquid ratio on the silica content of the final silica product.

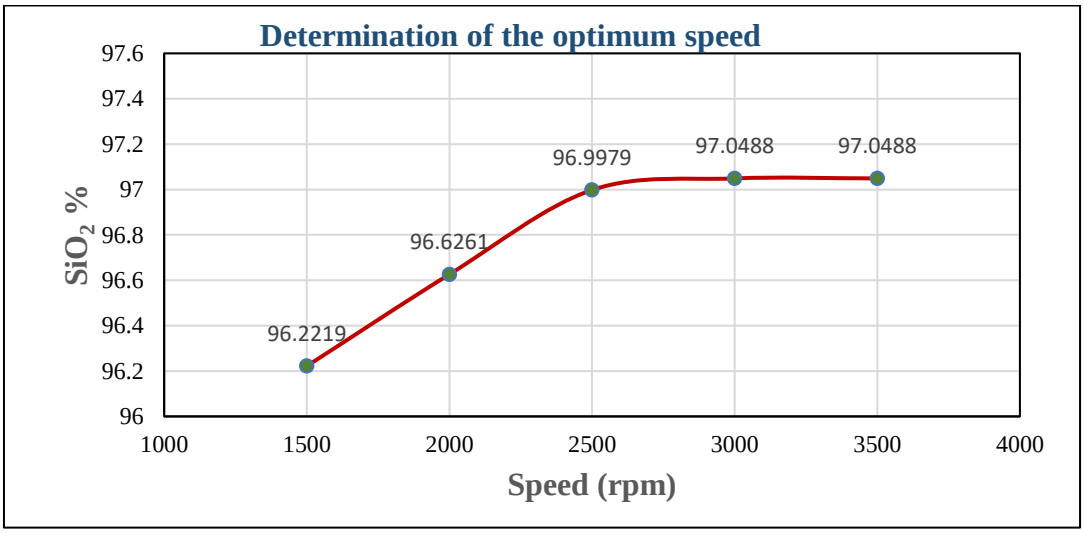


Figure 4: Effect of the mechanical agitation speed on the silica content of the final silica product.

Results of the preliminary experiments indicated that, the best condition for conducting the attrition scrubbing process at a rotation speed of the mechanical stirrer 3000 rpm, solid to liquid ratio of 25 % and attrition time 30 min.

In a 2 L glass beaker, attrition experiments were conducted using a 250 g sand sample and 1000 ml distilled water (25 percent solids). An overhead mechanical stirrer with a 3000-rpm plastic impeller was used to agitate the pulp for 30 minutes. To remove clay minerals and fine-grain contaminants, the entire pulp was wet sieved through a 25-meter sieve.

The silica sand particles (+25 m) were cleaned with distilled water several times before being dried for 24 h. at 105 ^{o}C. While, the -25 m fraction of attrition product was left for one day to settle the sediments and allow decantation to remove the majority of the water. Filtration

is used to collect the -25 m solids, which are subsequently dried at 105 ºC for 24 hours. XRD and XRF were used to characterize the separated fractions as a shown in Figure 5.

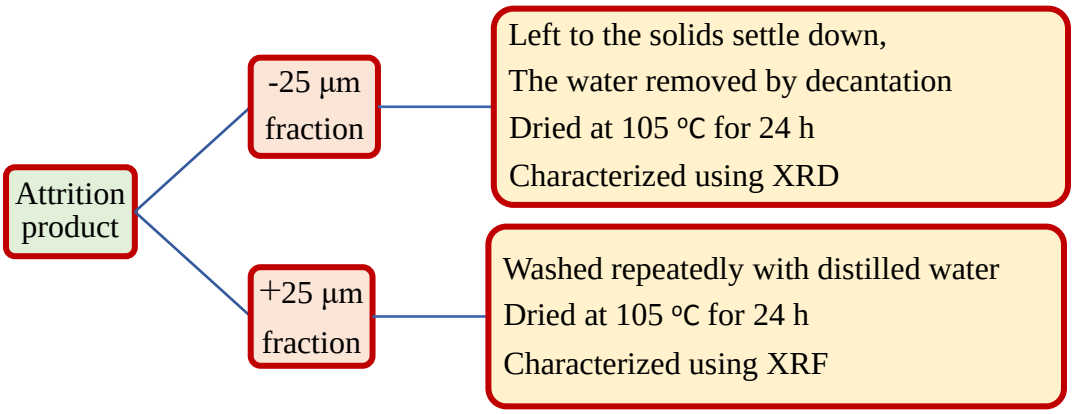


Figure 5: separation of the attrition product and characterization of each separated fraction

3. Results:

3.1.Size distribution of the original sample and attrition product:

The obtained results of dry sieve analysis of the original sample and wet sieve analysis of the attrition product showed in Figure 6 and Figure 7, indicated that, The sample's mode size is represented by the size fraction (-300 +180) µm. The D_{50} is approximately 270 µm, and about 95% of the grains fall between 630 and 90 µm. the removal of the impurities coatings off the surfaces of the silica grains is aided by attrition scrubbing process. During the attrition process, some silica particles may break down into finer particles. For this reason, there is an increase in the weight of the finest sized fractions (-90 +25) and -25 µm.

3.2.Mineralogical study of the original sample and attrition product (- 25 µm):

The mineralogical investigation revealed further information regarding the types of small impurities found in the sand grains. Figure 8 [A-C], shows optical microscope images of the El-Zaafarana white sand sample as supplied. The sample is mostly quartz, with tiny quantities of feldspars and rutile, zircon, heavy silicates, mica, iron oxides, and opaque minerals. Quartz grains range from extremely fine-to-fine grain, rounded to subangular particle shape. The grains are translucent and range in hue from white to light pink. Iron oxides are primarily responsible for the opaque fine to extremely fine brown granules.

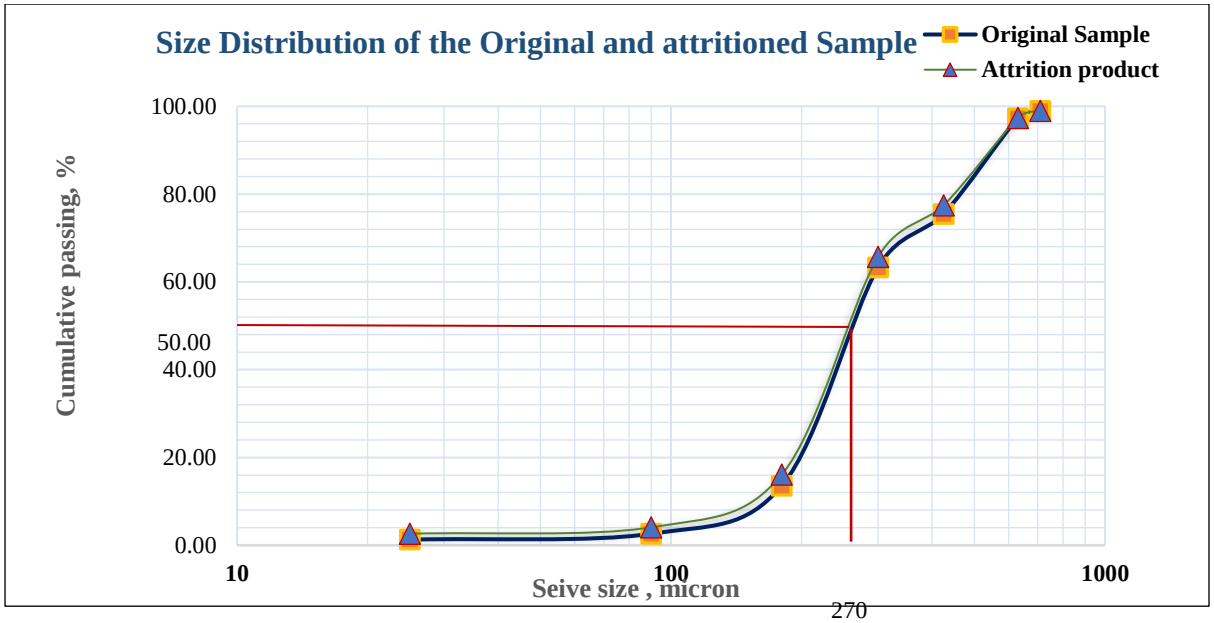


Figure 6: Size distribution curve for the original sample and attrition product

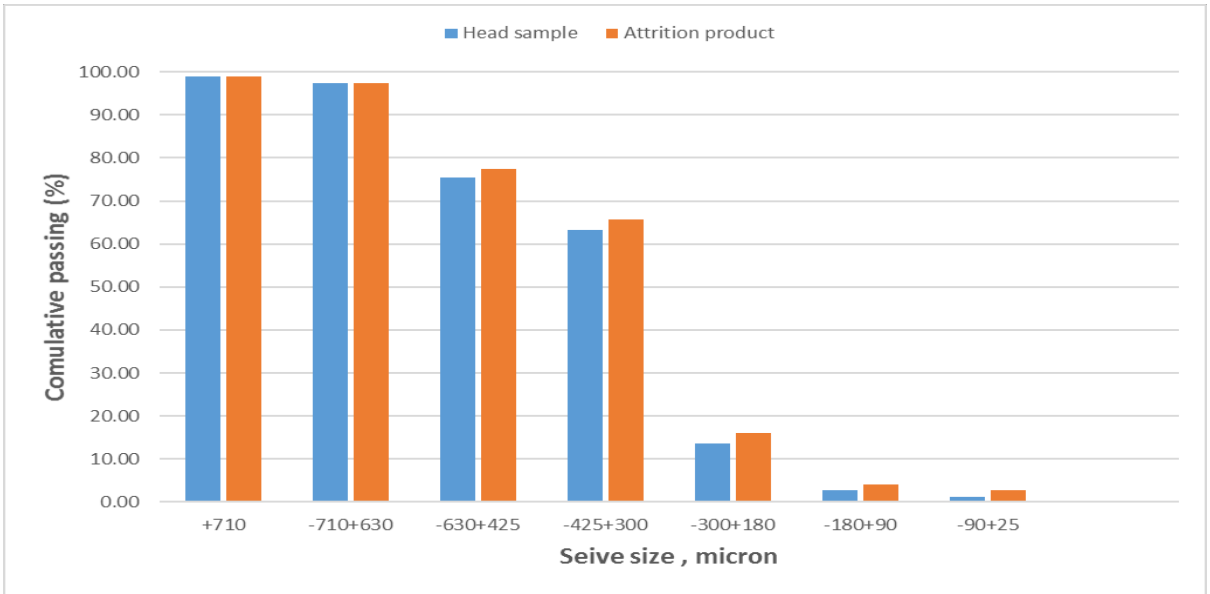
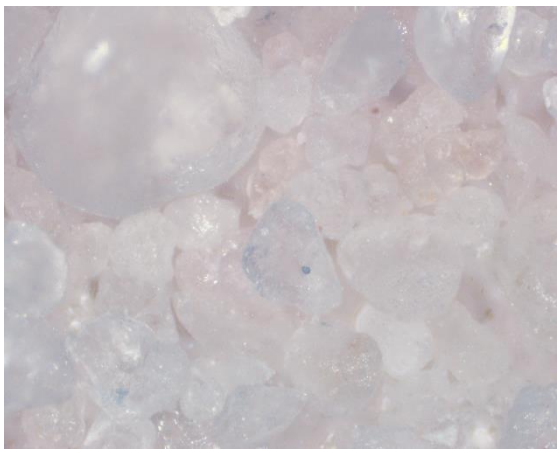
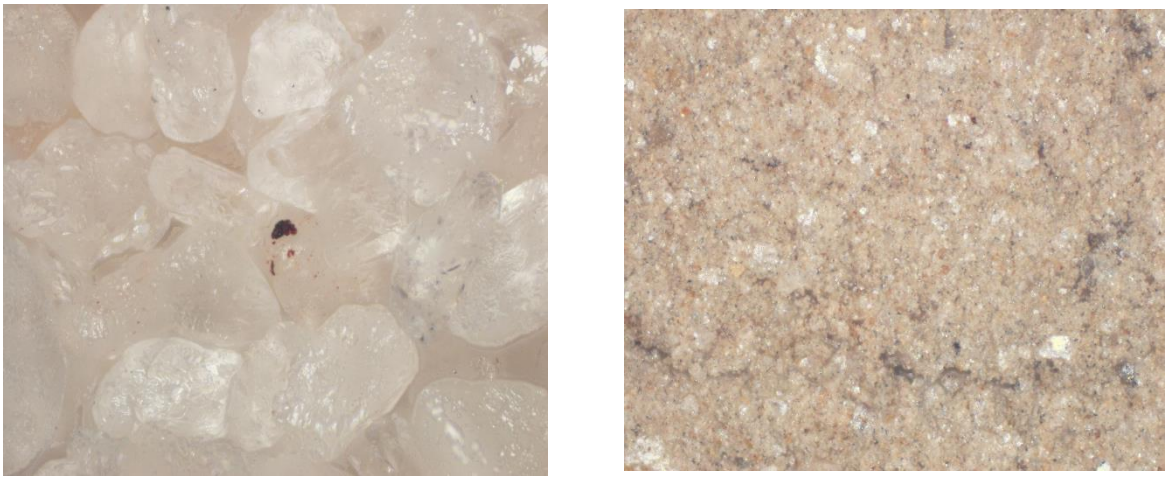


Figure 7: histogram for Size distribution analysis for the original sample and attrition product.



[22]

[B]



[C] [D]

Figure 8: Optical microscope images of the [A-C] El-Zaafarana white sand sample as supplied [D] attrition product separated on a 25-micron sieve

Figure 8 [D], optical microscope images of the attrition product (- 25 µm) show the rejection of fine colored minerals.

3.3.X-ray diffraction of the original sample and attrition product (- 25 µm):

Figure 9, shows the XRD patterns of the El-Zaafarana bulk sand sample and the -25 µm washed sample in Figure 10. When the sample is washed and screened over the 25 m sieve, it only displays diffraction peaks from quartz [1] [23].

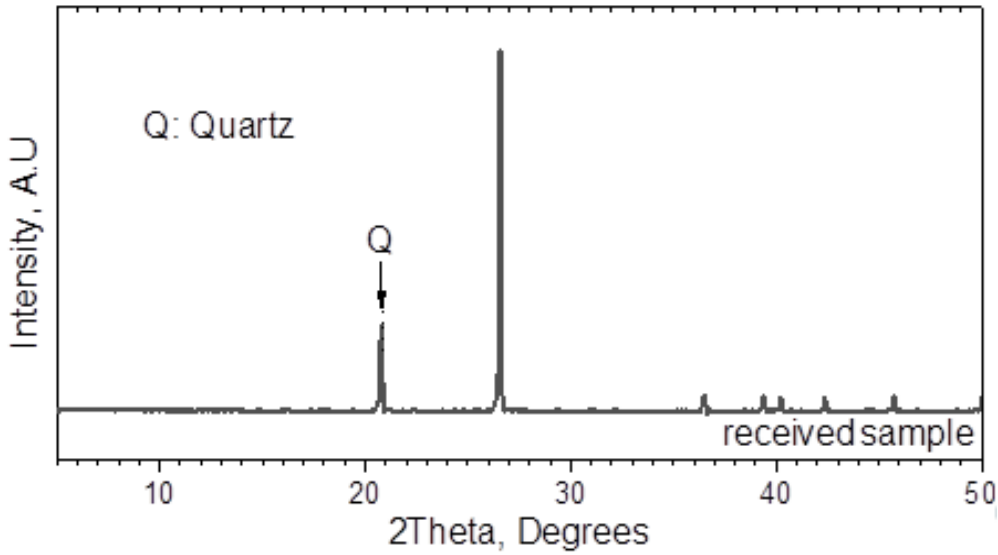


Figure 9: Shows the XRD patterns of the El-Zaafarana bulk sand sample.

When it is washed and screened over the 25 m sieve, it reveals additional peaks. This implies that the sand sample is mostly quartz, with modest amounts of kaolinite, calcite, and perhaps a small fraction of additional minerals that XRD could not identify.

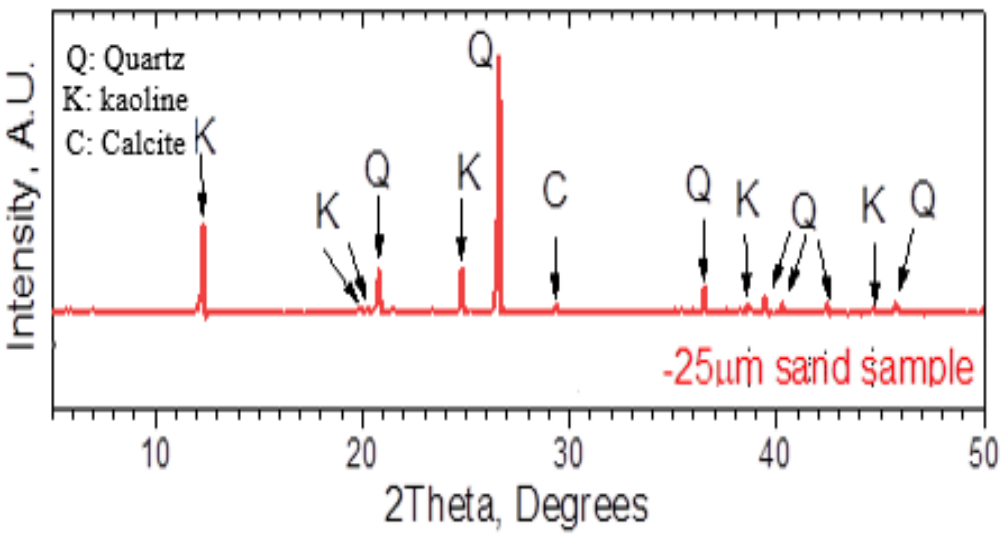


Figure 10: Shows the XRD patterns of the El-Zaafarana attrition product (-25 micron)

3.4.Chemical analysis of the original sample and attrition product (+ 25 µm):

Obtained results of the XRF analysis was conducted for the original sample indicated that, silica is the most abundant component reach 95.69 %, followed by Iron oxide (Fe_2O_3) 0.2379 % aluminum oxide (Al_2O_3) 0.6619 % and calcium oxide, confirming the results obtained by XRD analysis. Orthoclase and plagioclase feldspars can also include aluminum, sodium, potassium, and calcium. Minerals such as hematite, dolomite, rutile, and zircon are confirmed by the presence of iron, magnesium, titanium, and zirconium.

The content of silica in the sample significantly increased by simply washing the sample, which reject the fine particles that mainly cause contamination of the sample, whether these impurities exist as a free particles or cover the surface of quartz particles or as a result of cracking quartz particles during stirring and disintegration and removal of the impurities inside.

The results of XRF analysis was conducted for the attrition product (+ 25 µm) show an improvement in the chemical characteristics, where the silica content increasing to 97.0518 %, moreover, decreasing of the main impurities in the investigated sample such as, iron content and alumina content to 0.0455 % and 0.1921 % respectively.

4. Conclusion:

From the previous characterization results we note that, the dominate constituents of El-Zaafarana White Sand is the quartz and minor quantities of iron oxide (Fe_2O_3) aluminum oxide (Al_2O_3), calcium oxide.

In case of comparison between the physical and chemical specifications and properties of the white sand deposit exist in El-Zaafarana area with the British Standard Specifications for Silica Sand Industrial application without any treatment, we find that it could be used in the

industry of the Insulating fibers, foundry and construction applications. While, according to the American Ceramic Society and National Bureau Standard El-Zaafarana White Sand could be used in the industry of the flint, green, amber and sheet or flat glass.

Just, the application of the attrition scrubbing technique to the investigated sample lead to a significant upgrading in the physical and chemical specifications of the white sand samples. Silica content increasing from 95.69 % to 97.0518 %, in addition to, decreasing of the main impurities such as, iron content and alumina content from to 0.2379 % and 0.6619 % respectively 0.0455 % and 0.1921 % respectively.

The use of the attrition scrubbing technique add value to the El-Zaafarana White Sand and make to suitable for the more industrial application such as; Colored container according to the British Standard Specifications for Silica Sand Industrial application.

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