Use of Samalayuca Dune Sand on Glass and Ceramics Processes

The Samalayuca sand dunes contain several million tons of feldspatic sand that can be used as raw materials in the glass and ceramics industries.

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The Samalayuca sand dunes are a 2000 km^2 desert located in the state of Chihuahua, Mexico. It is located 50 km south of Ciudad Juarez, which is on the border of El Paso, Texas. The sand has the following characteristics: it contains 90–95% SiO_2 and 5–10% mixed rock grains, and the particle shapes are nodular and spheroid. The several million tons of sand in the Samalayuca dunes can be considered as an enormous potential of silica sand.[1,2]

This eolithic sand was formed by airflow erosion of rocks that created small fragments that were deposited in natural land depressions. Another factor that had a great influence in the formation of these dunes was the abrupt changes of temperature that exist in the desert, which also contributed to breaking up of the rock.[3,4]

Silica sand is widely used in the transformation industry. For instance, it is used in the making of glass, silicates, paints, glass-ceramics and ceramics. Traditionally, glass and ceramic materials have been manufactured using high-purity silica and minerals taken from ore on the surface of the earth. However, during recent decades, the manufacture of household and industrial products has increased, which has depleted the ore supply. The search continues for new deposits to maintain industrial production that needs a great amount of raw materials, such as pure silica. However, many ore deposits contain impurities, and new processes to remove them are needed.

Research has been conducted of the Samalayuca sand dunes to learn its mineralogical and chemical composition and mineral impurity contents. Integral technical planning in related industrial processes is being accomplished gradually. When the sand is within an industrial specification range, it is possible to industrialize silica sands of this magnitude. This can represent an ambitious plan toward challenges of application of larger ore deposits.[5–12]

This desert sand contains impurities that affect tile body color, roofing ceramics enamel and flat-glass color. Moreover, difficult to dissolve titanium oxide can cause flaws in the glass. This sand has a silica composition less than that required for specific industrial processes. A treatment to increase purity to >97.5% SiO_2 is necessary. Attention then can be given the processes of comminution (particle-size reduction), flotation, magnetic separation, acid washing or leaching, alkaline fusion and separation by ion-exchange resins. After one of these processes has been accomplished, the raw materials are ready to be used in the glass industry.[13–16]

An investigation about industrial use of Samalayuca desert sand dunes as raw materials, either in ceramic or glass processes, has been initiated. The first stage of this research is to obtain a chemical–mineralogical composition and to identify the main impurities that need to be removed. The second stage is to purify the sand using magnetic separation and leaching processes to improve the amounts of SiO_2 and Al_2O_3 and to collect impurities, such as TiO_2, Fe_2O_3 and FeO, as subproducts.

Sand Sample

The sand sample used in this experiment is from Samalayuca sand dunes, as supplied by Dune Project Management of Nafta Center S.A. de C.V. Mineralogical observation of this sand using optical microscope analysis shows that it contains mixed-color particles that vary from clear-colorless to dark-brown, blue and red. Its particle shape is subangular, nodular and spheroid. The sand is composed mainly of SiO_2 (quartz) with small amounts of Al_2O_3, Fe_2O_3 and TiO_2 as well as traces of bismuth (Table 1). The sample in this research is called "sand."

During the first stage of processing, the dune sand sample was dried in an oven at 398 K for 24 h. It then was ground to particles <200 mesh (74 µm). During the second stage, the sand was analyzed using spectrophotometry and an inductively coupled plasma (ICP) technique to determine SiO_2, Al_2O_3, Fe_2O_3, TiO_2 and bismuth contents.

Property Characterization

During iron analysis, an agate bowl mill was used to avoid iron contamination from equipment. Stainless-steel bowls were used for SiO_2 and Al_2O_3 analyses. During sieve analysis, 60, 100, 120 and 140 mesh screens were used to obtain particle-size distribution.

Table 1 Chemical Composition of the Sand

Component	Composition
Sand components	
SiO_2	93.20 wt%
Al_2O_3	2.44 wt%
Fe_2O_3	0.31 wt%
MgO	0.06 wt%
MnO	0.02 wt%
TiO_2	0.31 wt%
Element traces	
Bismuth	427.6 ppm
Arsenic	201.4 ppm
Antimony	149.2 ppm

A detailed study of the morphology of the original sand, nonmagnetic and magnetic fractions, and leaching residue was conducted using various techniques. Particle color and morphology were observed using optical microscopy (Model SZ2H10, Olympus). Scanning electron microscopy (SEM; Model JSM 5800LV, JEOL, Tokyo) and energy-dispersive spectrometry (EDAX; Model DX, Prime) were used for quantitative chemical element analysis of particles.

A mapping technique also was conducted. A petrography technique was applied to identify the components of each grain. Briquette preparation was accomplished using resin-cemented sand. The briquettes were cut and placed on microscope slides, polished and covered with cover glass. Once the thin foil was finished, the sand briquettes were analyzed using petrography/microscopy techniques (Model AX70, Olympus).

The Samalayuca sand was refined and purified. The particles that contained iron were removed from the sand using a magnetic drum separator (Model HSD) under dry atmospheric conditions and an inductive magnetic field of 0.3 and 0.1 T. The leaching test was accomplished using a nonmagnetic fraction in a 10 wt% H_2SO_4 acidic environment at a temperature of 363 K and 10 min agitation.

Chemical analysis showed that the sand contained 93.2% silica (SiO_2) and impurities that included iron oxide, titanium oxide and traces of bismuth (Table 1) impurities.

Crystallographic, Sieve and Morphology Analyses

An X-ray diffractometry (XRD) pattern of the sand shows that the highest and primary peak corresponds to quartz mineral **(Fig. 1)**. This indicates that this silica sand contains a high fraction of quartz mineral. Moreover, the feldspar mineral anorthoclase occurs in small amounts as its intensity peak shows. When the XRD patterns of the nonmagnetic, magnetic and residue products are compared, they appear to have the same peak intensity. This occurs because other minerals exist in smaller amounts and <1% of mineral contents are impossible to identify because of equipment limitations. The ICP technique is used to measure the amount of these and other minerals in the sand.

Particle-size distribution of the sand has a significant effect on use specifications. 98.62% of the particles are between –100 and +140 mesh (Table 2). One possible way to supply sand as a raw material is by specifying particles for the glass-smelting process. However, silica sands from the Chihuahua desert cannot be used in operations such as sand blasting because of their small size and spheroid shape.

Microscopic analysis is a primary characterization tool for sand particles to learn their shape and color (Fig. 2). Analysis shows that the original sand particles have irregular, nodular and spheroid shapes. This information can be obtained from megascopic analysis using a stereoscopic microscope. 55% of colorless SiO_2 particles, a small amount of Al_2O_3 and the other particles provide color because of metallic oxide content in the sand particles. Such colors can be dark-green, orange and light-yellow. This assumes that dune sand is composed of crystalline particles of quartz, feldspar, microcline, etc.

When a magnetic separation process is applied to the original sand, two products can be obtained: a dark magnetic product caused by a high amount of iron and titanium and another caused by a nonmagnetic product lighter than the original.

If acidic leaching is used, the residues can be used as raw materials in industrial processes. About 80% of these particles are colorless.

Petrographic Study

Some mineral components are not identifiable using XRD techniques. Hence, a petrographic technique has been conducted. A photomicrograph of particles indicates that various minerals are contained in the sample (Fig. 3). The original sample contains 58% colorless quartz as its main component. Other minerals in lower amounts are 13% alkaline anorthoclase, sanidine feldspars and microcline; 2% oligoclase; and 27% mainly quartzite, rhyolite, granite and epidote fragments. Consequently, the application of the petrographic technique makes it possible to identify more mineral contents in this sand, which better defines its use.

SEM Analysis

The results of morphology identification and the analysis of main elements were obtained using SEM. Photomicrographs of various particles show that they are irregularly shaped (Fig. 4).

The elemental analysis and mapping technique of residues indicates that the main elements are silicon and oxygen. Therefore, the residues are colorless, crystalline and have a high silica content. Small amounts of iron, titanium, aluminum and magnesium are observed. However, they are in such small amounts that they do not affect sand marketing among glass-manufacturing companies.

Table 2 Particle-Size Distribution of the Sand

Mesh No.	Size (mm)	Portion over size (%)
+60	250	0.31
–60 + 100	149	0.28
–100 + 120	125	66.95
–120 + 140	105	31.67
–140	<105	0.76

X-ray mapping of a magnetic product composition was conducted for the original sand sample, aluminum, oxygen, titanium, silica and iron (Fig. 5). The original sand contains metallic oxide, which gives color to the particles. Therefore, it was previously classified using a magnetic separator. Hence, dark particles were selected, because they contained a greater amount of iron, aluminum, manganese and titanium. Thus, the SEM techniques applied to some dark particles indicate that they contain 1–12% iron and 0.5–5% titanium.

A 1 μm crack appears on the particle surface in which an acid solution can dissolve a major amount of iron (Fig. 6).

Magnetic Separation and Leaching Processes

The glass process specifications indicate that sand containing high amounts of iron and titanium particles cannot be used as raw material. Nevertheless, with the purpose of making the procedure less expensive, a dry magnetic separation process is recommended with an inductive magnetic field of 0.1–0.3 T. These operation parameters are satisfactory to remove impurities. Hence, the remaining amount of iron and titanium in the nonmagnetic product can be applied in glass-ceramics processes. Magnetic equipment and the use of a rare-earth magnet help to remove large amounts of impurities that the traditional magnetic drum separator misses. This is possible because the magnet reaches an inductive magnetic field of up to 50 T, and impurities are removed without using the leaching process.

When the refining of nonmagnetic fraction continues with the leaching process, the obtained results indicate that it contains 0.06% iron, which is lower than the required amount in glass-smelting and ceramic-tile industry specifications. When the magnetic separation and leaching processes are combined, it is possible to remove ~90% iron.

The sand from Samalayuca dunes is a possible perspective for the development of an extensive exploitation project. Because of the increase in the manufacturing of products, such as ceramics, glass and chemical products, the use of this sand allows the manufacturing of products which contain an enormous potential of using silica sand as raw material. This type of sand can be used even for the manufacturing of flat-glass, because specifications indicate that <0.05% of Fe(III) can be used in the glassmaking process.

Moreover, the subproducts that contain titanium and iron in sand can be exploited. Some processes are able to accept this sand as raw material in the glass and ceramics industries. Thus, it is not necessary to remove some minerals, such as impurities in glass, including iron- and titanium-based quartz. For example, in the glass-ceramics process, a quartz-based product may contain 3% iron oxide and 2% titanium oxide.[15] ■

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