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# Sand Dune Characterization for Preparing Metallurgical Grade Silicon

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Abstract: Dune sand, from Biskra, Algeria which is in the Great Algerian huge desert attracts tourists from all over the world. Dune sand composes around 80% of the total area of the desert. To date only a few studies have been conducted on this sand. The purpose of the present study is to shed light on the textural and physico-chemical characteristics of this sand using several characterization methods, and to understand the potential for using for photovoltaic applications. The chemical composition of Biskra sand indicated a high purity quartz with 97.6% silica, and a presence of others oxides. Granular analysis enabled the determination of the size of the sand grains which was found to be fine to medium. On the other hand, a Scanning Electron Microscopy and optical observations were carried out, the micrographs observations indicated the presence of different shapes of sand grain, some rounded whereas others are angular edged or elongated. X-ray diffraction indicates the highly crystalline nature of the Biskra sand.

**Keywords:** photovoltaic, Sand dune, silica, Physicochemical characteristic, Biskra.

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#### 1 Introduction

Biskra is located at latitude 34.48 and longitude 5.44, in the north-east of Algeria [1,2]. The city lies about 400 km from Algiers, 115 km southwest of Batna and 222 km north of Touggourt. გ

**Photovoltaics** are able to convert sun rays into electricity. Photovoltaic solar energy has several advantages. First, it is relatively well distributed on the surface of the globe and readily available, which makes it particularly suitable for isolated areas. Secondly, the modular nature of the photovoltaic panels allows a simple and adaptable assembly to various energies needs [3]. The obstacle encountered in the production of solar electricity is related to the increased cost in comparison with conventional energy sources. This high cost is a result of The cost of production of solar panels due to the cost of manufacturing the solar cells that constitutes them. These solar panels are made from different types of semiconductors, the most common of which is crystalline silicon or amorphous silicon [4].

The first stage to make silicon is to react  $SiO_2$  (sand, quartz, quartzite, sandstone) and carbon in an arc furnace which results in metallurgical grade silicon. A



Figure 1: Geographic situation of Biskra [1].

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new developed working process for silicon production in a microwave furnace was developed, where some researchers investigate in the production of silicon using a high pure raw material such as pellets or powders (silica sand) [5,6]. Silica sand contains a high proportion of silica (more than 95%) [7,8]. It is used for a wide range of applications and can be purchased from different suppliers around the world. Silica sand is frequently used in different industrial processing [9]. The composition of silica sand is largely quartz arenite which is a sedimentary clastic rock with grain size between 0.0625 mm and 2 mm [10]. There are several varieties of sand in the world, each with their own composition and unique qualities. The white-sand beaches of tropical destinations, for example, consist primarily of limestone that has broken down, while many black sands are either volcanic in origin or contain magnetite. Other sands have high levels of iron in them and are therefore rich and yellow in colour [11]. Up to now, considerable efforts have been devoted to characterize sand from several regions of the earth and for its different applications. For example some researchers have determined the geomorphology and mineralogy of different dune types in the eastern part of Abu Dhabi in United Arab Emirates [12]. Others [13] determined the crystallographic phase, degree of crystallinity, crystal system, and space group and unit cell parameters of quartz in the Ouargla region (Algeria) sand dunes. María G.M. Elipe et al. characterized Aeolian sand for its potential use in construction [14]. Christine Scott et al. determined the original shapes of quartz sand grains [15]. Trabelsia and al determined the physico chemical proprieties of Douiret sand for the production of silica sand [16]. Guettala et al. studied the effect of addition the dune sand powder on development of compressive strength and hydration of cement pastes [17]. Alaa M.Kh. Mustafa et al. characterised a sample from Ardhuma silicasand deposit in the Iraqi Western Desert to provide a raw material for silicon industries [18], Perruchoud et al. work in the same field and produced a high-purity composite briquette for direct Upgraded metallurgical grade silicon production in arc furnaces using silica sand raw materials [19]. Dune sand is a material widely available in Algeria. This material is not practically exploited, in spite of the possible characteristics which it presents. The Solar Sahara Breeder SSB is a Japan-Algeria joint project and is the first technology project investigating converting desert sands to solar grade Si, with a focus on new silicon technology to enable large scale and low cost PV system and on preliminary data collection for PV operation in the desert [20,21]. For this purpose and to support the SSB project, the focus of the present study is to shed light on

the textural and mineralogical characteristics of Biskra sand dunes for its eventual use for the silicon production for photovoltaic application.

#### 2 Methodology

### 2.1 Particle size analysis and colour of Biskra Dune Silica Sand

The particle size analysis determines the size range and the relative weight percentages of the particles .We use a series of sieves with decreasing apertures to obtain a particle size distribution. The analyzed material is placed in the upper sieve and grading is obtained by vibrating the whole sieve column. All the sieves should be clean and brushed before use. The masses of the different refusals (the amount of material that is retained on the sieve) and sieves (the amount of material that passes through the sieve) are related to the initial mass of the material. The percentages obtained are used in graphical form. Each sand has it specific colour and grain appearance, the colour of the Biskra dune silica sand was observed.

# 2.2 Measuring of moisture content by oven drying

The knowledge of the moisture concentration of a powder (or water contained in this powder) determines an essential variation of the characteristics of different materials. The moisture content of particular sand will determine the diffusion or storage characteristics of the water in that sand. There are different techniques for measuring sand moisture. In our work we used the gravimetric method which consists of drying the sand samples at 105°C and weighing them before and after drying.

#### 2.3 Determination of Fines contents

The test consists of pouring a sample of sand and a small amount of flocculant solution into a graduated cylinder and shaking so as to detach the clay coatings in the sample. The sand is then filled using the remaining flocculant solution in order to raise the fine particles suspended above the sand. After 20 minutes the height of the products are measured. The sand equivalent is the ratio of sand height to total height, expressed as a percentage.

#### 2.4 X ray Fluorescence Analysis of Biskra Sand

A X-ray fluorescence instrument type Axios Panalytical in the Department of Geology of the National Office of Research in Geology and Mineralogy (ORGM, Boumerdes, Algeria) was used.

We use the X ray Fluorescence Analysis for determining the chemical composition of Biskra dune silica sand. This analysis determines the concentration of all the components present in our sand. Samples were first milled in a laboratory disc mill to approximately 40 µm before being pressed to pellets (approx. 5g sample material) and analyzed.

#### 2.5 Microscopy Observations of Biskra Sand

We first analyzed the material using a petrographic microscope under reflected light, to define the morphology of the sand grains. For our optical observations of Biskra sand, we used petrographic microscopy with transmitted and reflected light Axio Scope A1. The SEM observations were conducted using JSM-5500LV/JSM-5500 in the laboratory of sciences materials at the Department of Materials Science of USTHB University / Algeria.

#### 2.6 X-ray diffraction analysis of Biskra Silica Sand

All the samples were characterized by X ray diffraction using a PHILIPS PW 1800 X-ray diffraction device using Cu-Ka radiation, at the advanced technology research center CDTA, Algeria. Samples were scanned with 2  $\theta$  step sizes of 0.02°. The phase identification of the samples studied consisted of comparing the diagram of our silica sand with those of the reference materials.

Ethical approval: The conducted research is not related to either human or animal use.

#### 3 Results and DiscussionN

#### 3.1 Particle size analysis and colour of Biskra sand

The particle-size distribution characteristics of the sample were determined by conducting the sieve analysis, as per ASTM D 422-63, and results are presented in Figure 2.

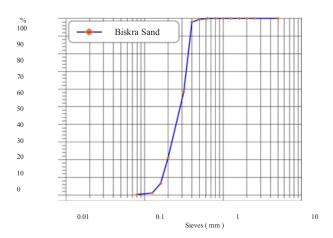


Figure 2: Granulometric analysis of Biskra Sand Dune (cumulative).

Table 1: Granulometric proprieties of Biskra Silica Sand.

parameter	value
D10 (mm)	0.180
D30 (mm)	0.225
D60 (mm)	0.325
cu	1.805
СС	0.865

Subsequently, D10, D30 and D60 corresponding to the size fraction finer than 10%, 30% and 60%, respectively, the uniformity coefficient, cu, and the coefficient of curvature, cc, were determined and the results are listed in Table 1.

Based on the USCS (ASTM D 2487-93, 1994), this sand can be classified as poorly-graded sand (SP) and according to the cumulative curve represented in Figure 2, the grain size of Biskra sand is fine grain of light brown colour.

#### 3.2 Determination of fines, Moisture Content of Biskra Sand

The percentage of moisture content of Biskra sand is about 0.5%, this value is good according to ISO 15512 and the percentage of clay content of Biskra sand is about 2%. According to the results, we affirm that Biskra sand presents good properties for its future use in carboreduction [22].

#### 3.3 X Ray Fluorescence Analysis of Biskra Sand

According to the results presented in Table 2, we show that Biskra sand is rich in silica containing 97.6% and has

#### Optical Microscopy Observation

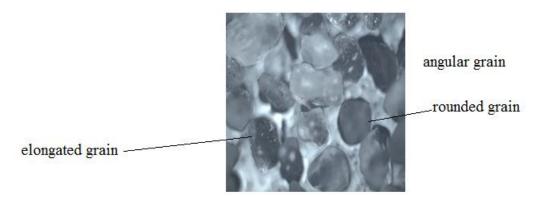


Figure 3: Micrograph of Biskra Dune Sand.

#### Scanning Electron Microscopy Observation

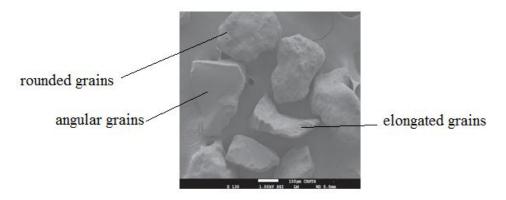


Figure 4: Scanning electron Micrograph of Biskra Dune Sand (lower magnitude).

a low percentage of aluminum oxide and iron oxide and lower levels for the others oxides which were also found in the raw material.

## 3.4 Microscopy Observations of Biskra Dune Silica Sand

The microscopy indicates the presence of different shapes of sand with irregular morphologies, for example Figure 3 shows some rounded grains, whereas others are angular or elongated.

The scanning electron micrographs confirm the optical microscopy observations and that Biskra sand has several irregular morphologies (Figure 4).

As the sand is a quartz component, we observe in Figure 5 some specific features, for example conchoidal fracture.

Table 2: X-ray fluorescence of the Biskra Silica Dune Sand.

Oxides	Concentration (%)
SiO <sub>2</sub>	97.6
$Al_2O_3$	0.4
$Fe_2O_3$	0.5
CaCO <sub>3</sub>	1
Na <sub>2</sub> O	0.06
MgO	<0.05
TiO <sub>2</sub>	<0.05
K <sub>2</sub> O	<0.05
MnO	<0.05
P <sub>2</sub> O <sub>5</sub>	<0.05

#### 3.5 X ray diffraction of Biskra Dune Silica Sand

Figure 6 confirms the high crystallinity of Biskra sand and reveals the presence of alpha quartz peaks. This result confirms the latest result found by XRF analysis. The crystallographic parameters of Biskra sand have been determined through X-ray diffraction analysis. Biskra silica sand has a hexagonal crystal system, its group space is P<sub>2</sub>221 and crystallographic parameters are: a = b = 4.9030 Å, c = 5.3999 Å.

#### 4 Conclusion

This study deals with physico-chemical characterization of dune sand from Biskra, Algerian desert. The sand from

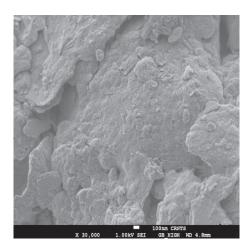


Figure 5: Scanning electron micrograph. of Biskra Dune Sand (higher magnitude).

Biskra has a high SiO, concentration but not sufficient for direct use for solar-grade silicon production. It needs enrichment by acid leaching for the best result in the briquetting process for producing silicon for photovoltaic applications. The granulometric analysis of Biskra sand indicates that this sand can be classified as poorlygraded sand (SP) with a high concentration of fine grain. The percentage moisture content of Biskra silica sand is about 0.5% and the fines percentage content is about 2% with grey to light brown coloration. XRF analyses show maximum silica contents on the order of 97-98%, with presence of others oxides in small quantities.

The micrographics observations of silica sand illustrate several irregular morphologies of Biskra sand grain. By using X Ray Diffraction analysis; we determinate that Biskra silica sand reveal a high crystallinity with specific crystallographic parameters. Finally, we can certify that Biskra sand has good proprieties for its future use in photovoltaic applications after its enrichment, for getting the best proprieties in the briquetting process.

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Conflict of interest: Authors declare no conflict of interest.

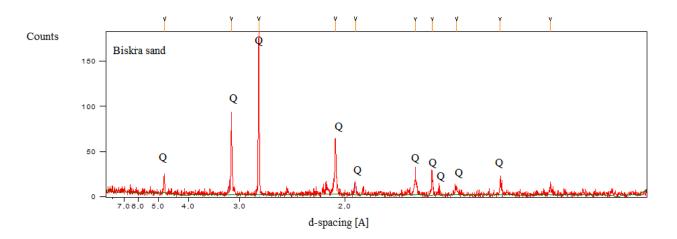


Figure 6: XRD spectrum of Biskra sand.

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