Geo-Chemical and Beneficiation Studies of Yakhtangi (Swat) Silica Sand for Industrial Utilization

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Summary: Present study is an attempt to describe geochemical and industrial potential of Yakhtangi (District Swat) sand deposits, which are exposed within a distance of several hundred meters along the metalled road. Chemical composition, grain size distribution and physical characteristics of sand samples were investigated in order to check their suitability for utilization in glass industry. Samples were subjected to physical treatment to minimize iron content. About 60 % reduction of Fe_2O_3 content has been achieved as a result of grading and water washing. The sand was found suitable for the manufacturing of ordinary container glass. Some simple upgradation techniques enhance its ability to be utilized for high quality container glass manufacturing. The Yakhtangi silica sand deposits occur along the metalled road at 33 km distance from Alpuri towards Shanglapar. These deposits are exposed within the area of several hundred meters at a height upto 1189 m from mean sea level and within 1.5 to 61 m from the metalled road. The deposits are easily accessible.

Introduction

The industrial minerals found in Pakistan have been categorized broadly into two groups based on economic workability toward the viable end uses: (a) the deposits which may be determined showing viz-a-viz the size and grade as well as the feasibility, and (b) the large and feasible (both economically and technically) deposits [1]. Silica sand deposits belong to second category and hence could play an important role in the industrial development of the country.

Silica sand occurs in all the four provinces of the country. In Punjab the major deposits lie at Daudkhel, Mianwali. Two significant deposits of silica sand occur in Khisor and Marwat Ranges near town Pezu and Paniala districts Bannu and D.I. Khan. The glass sand deposits of Manda Kuchha, Hazara [2] is also a large silica sand deposit in NWFP. The other comparatively small deposits of silica sand in North West Frontier Province are those of Mohmand Agency and Bande Sadiq of Hazara district. In Sindh the silica sand deposits occurs in Hyderabad, while several deposits of glass sand have been reported from Loralai, Quetta and Zhob districts of Balochistan [3].

Annual production of silica sand in the country during 2003-2004 was 2,59,009 tons, while the same figure for NWFP during 2003-2004 was 30,155 tons only [4], which indicates that either the quality of the silica sand deposits of NWFP is not up to desired specification or the deposits are not easily accessible. This makes the evaluation and development of new deposits of silica sand imperative.

The present study is one such effort. The Yakhtangi silica sand was firstly reported by Afridi and Khan [5]. A small-scale production 250 tonn of silica sand from the same area has also been reported in 1999-2000 [6]. The deposit occur along the metalled road at 33 Km distance from Alpuri towards Shangla Par from the glass manufacturing point of view only pure quartz is required and other minerals, like iron oxide, clay, feldspar, mica etc, if present are considered as impurities. Silica sand having 85-99 % SiO_2 contents are considered to be suitable for glass manufacturing, provided its Fe_2O_3 content is less than 0.08 % [7]. The permissible iron content of the raw silica sand vary with the type and quality of glass. The sand for chemical glassware should contain ferric oxide below 0.02 % while for optical glass it should not more than 0.008 %. For high grade domestic and decorative glassware the maximum limit for Iron oxide is 0.013 % [8].

Beside silica sand, sandstone, quartz and quartzite could also be used for glass manufacturing provided they have iron content within specifications.

Results and Discussion

Geology

The Yakhtangi area is located between longitude 72' 50' and 34' 37'. Exposed within the

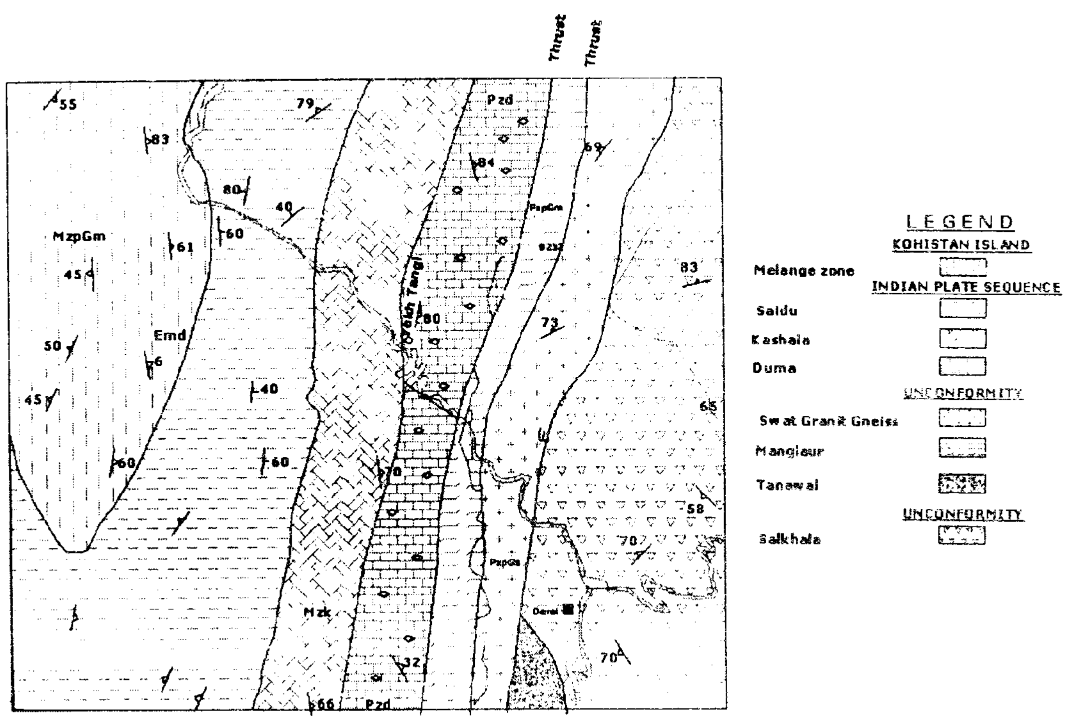

Fig. 1: Stratigraphic setting of Yakhtangi Silica sand Kohistan Island arc sequence

area of several hundred meters at a height upto 1189 m. The deposits are large, approximately 200 m in length and 150 m in height with varying thickness from 70 to 90 meters. It is soft, weathered, white to gray in colour and banded in nature. Quartz veins are also common. The area is generally underlain by Kashala and Duma formations (Fig. 1). These Silica sand deposits are a weathering product of the Silica dominated rocks comprising mostly of schists and gneiss belonging to Kashala and Duma formations (Table- 1). The Silica Sand outcrops occur at the contact of these two formations in the form of lenses and pockets. The deposit of Yakhtangi is hard, soft and loose. The rocks exposed in the area include phyllites, quartzite, schist and gneiss, which are porous, permeable and fine to medium grained. The cement in these rocks is ferruginous and variable. The reserve is large but remain unestimated. The accessibility of these deposits is easy and overburden is minimum. The sand is generally white to light brown in colour and medium to coarse grained in size.

Chemical Analysis

Results of the chemical analysis given in (Table- 2 and 3) along with graphic representation (Fig. 2) shows that SiO_2 content varies from 91.08 % to 97.88 % in sand while from 90.78 % to 95.08 % in quartz samples besides both silica sand and quartz contain some feldspar, calcite and mica impurities. The Al_2O_3 concentration of quartz samples (Table- 3) is high in some samples while that of sand samples (Table- 2) is comparatively low (0.69 - 2.81 %). The alkalies, calcium and magnessium concentrations are

Table-1: Lithologic setting of Yakhtangi Silica sand in the Kohistan Island arc sequence

Mesozoic to tertiary	MMT melange zone	Asemblage of serpentine and greenschist
Indian plate Sequence		
Mesozoic to late Paleozoic	Saidu formation	Graphitic phyllite
Late Paleozoic	Rashala formation	Garnet bearing calcareous schist with phyllite
	Duma formation	Amphibolite, calcareous schist
Unconformity		
Paleozoic to Precambrian	Swat Granite formation	Granite and gneiss
	Manglur formation	Granite and biotite schist
	Tanawal formation	Quartz-Feldspar schist and Quartzite
Unconformity		
Proterozoic	Salkhala formation	Chlorite, Quartz and mica schist

Table- 2: Average Chemical composition of Yakhtangi Silica sand samples.

Parameters	Sample Numbers Silica Sand					
	SLS-1	SLS -4	SLS -5	SLS -6	SLS -14	SLS -15
SiO_2	96.14 ± 0.185	95.82 ± 0.062	94.68 ± 0.314	96.42 ± 0.268	97.88 ± 0.301	91.08 ± 0.241
TiO_2	Nil	Nil	Nil	Nil	Nil	Nil
Fe_2O_3	0.07 ± 0.004	0.06 ± 0.005	0.14 ± 0.004	0.06 ± 0.003	0.11 ± 0.004	0.07 ± 0.002
Al_2O_3	1.83 ± 0.191	1.78 ± 0.171	2.52 ± 0.139	1.69 ± 0.044	0.69 ± 0.040	2.81 ± 0.092
CaO	1.47 ± 0.147	1.12 ± 0.125	0.90 ± 0.139	0.16 ± 0.021	0.80 ± 0.047	1.46 ± 0.075
MgO	0.31 ± 0.035	0.72 ± 0.029	0.53 ± 0.022	0.54 ± 0.35	Nil	3.91 ± 0.041
Na_2O	0.14 ± 0.052	0.15 ± 0.631	0.26 ± 0.010	0.19 ± 0.026	0.13 ± 0.026	0.24 ± 0.036
K_2O	0.20 ± 0.030	0.25 ± 0.038	0.50 ± 0.050	0.35 ± 0.031	0.21 ± 0.023	0.39 ± 0.031
Loss on ignition	Nil	0.22 ± 0.025	0.42 ± 0.025	0.39 ± 0.036	Nil	0.43 ± 0.037
Total	100.16 ± 0.092	100.12 ± 0.060	99.95 ± 0.087	99.80 ± 0.058	99.82 ± 0.073	100.39 ± 0.069

Table- 3: Average Chemical composition of Yakhtangi Quartz samples.

Parameters	Sample Numbers Quartz			
	SLS -2	SLS -3	SLS -8	SLS -9
SiO_2	93.70 ± 0.258	95.08 ± 0.212	90.78 ± 0.223	92.28 ± 0.347
TiO_2	Nil	Nil	Nil	Nil
Fe_2O_3	0.09 ± 0.004	0.14 ± 0.004	Traces	0.14 ± 0.008
Al_2O_3	3.59 ± 0.093	2.08 ± 0.072	2.78 ± 0.143	4.14 ± 0.139
CaO	1.64 ± 0.119	1.48 ± 0.076	2.46 ± 0.154	1.68 ± 0.102
MgO	0.56 ± 0.025	0.45 ± 0.050	1.18 ± 0.029	0.65 ± 0.045
Na_2O	0.32 ± 0.025	0.27 ± 0.032	0.22 ± 0.033	0.31 ± 0.017
K_2O	0.58 ± 0.025	0.51 ± 0.021	0.16 ± 0.016	0.33 ± 0.031
Loss on ignition	Nil	0.29 ± 0.031	1.90 ± 0.360	0.65 ± 0.030
Total	100.48 ± 1.077	100.30 ± 0.062	99.48 ± 0.136	100.26 ± 0.089

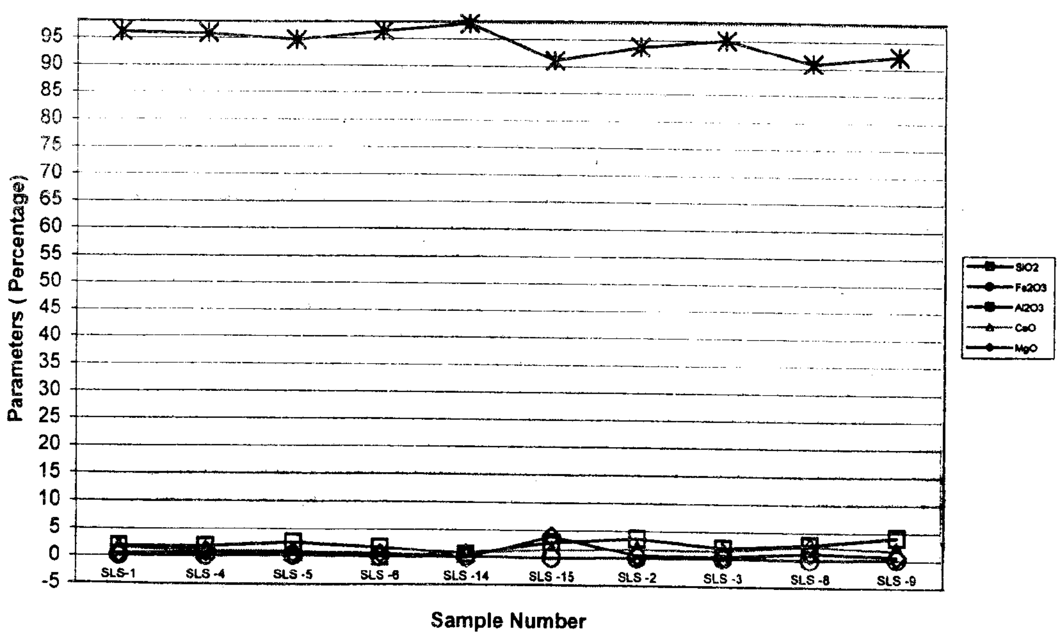

Fig. 2: Graphic presentation of Chemical composition of Silica sand samples.

Table-4: Grading (sieve analysis) of Yakhtangi silica sand

Sample Number	Mesh size									
	+25 Mesh (%)	-25 Mesh (%)	-36 Mesh (%)	-52 Mesh (%)	-72 Mesh (%)	-100 Mesh (%)	-120 Mesh (%)	Total (%)	Sieve losses (%)	Useful fraction -25 to +120 (%)
SLS-1	41.18 ± 0.15	15.47 ± 0.04	3.41 ± 0.01	13.51 ± 0.03	2.83 ± 0.01	6.52 ± 0.06	16.59 ± 0.05	99.51 ± 0.05	0.49 ± 0.01	44.74 ± 0.03
SLS-4	42.60 ± 0.10	22.89 ± 0.07	3.85 ± 0.01	12.70 ± 0.02	2.03 ± 0.005	5.32 ± 0.008	10.07 ± 0.025	99.46 ± 0.034	0.54 ± 0.009	46.79 ± 0.023
SLS-5	20.70 ± 0.05	23.53 ± 0.054	4.70 ± 0.015	18.55 ± 0.022	3.35 ± 0.010	8.55 ± 0.018	20 ± 0.045	99.38 ± 0.031	0.62 ± 0.01	58.68 ± 0.024
SLS-6	23.26 ± 0.06	24.23 ± 0.066	4.40 ± 0.015	16.59 ± 0.07	3.04 ± 0.009	8.59 ± 0.028	19.67 ± 0.08	99.78 ± 0.047	0.22 ± 0.005	56.85 ± 0.038
SLS-14	34.17 ± 0.07	20.57 ± 0.050	3.91 ± 0.012	15.07 ± 0.03	2.71 ± 0.007	7.41 ± 0.011	14.95 ± 0.042	99.69 ± 0.032	0.31 ± 0.004	49.67 ± 0.022
SLS-15	23.47 ± 0.06	14.94 ± 0.035	4.68 ± 0.015	18.58 ± 0.04	3.12 ± 0.009	8.36 ± 0.01	26.40 ± 0.033	99.55 ± 0.029	0.45 ± 0.005	49.68 ± 0.022

well between the limits [9]. The most objectionable impurity of glass sand is the oxide of iron, which imparts colour to the glass. Iron in ferrous form produces green colour, while its presence as ferric oxide imparts yellow colour to the glass, which is not visible [10]. The Yakhtangi silica sand have up to 0.14 % Fe_2O_3, which indicates that the sand in its original form could be used for the manufacturing of window and plate glass [2].

Beneficiation and Upgradation

The quality of silica sand was found to be improved after water washing and grading (sieve analysis). Data in Table- 4 shows that the useful fraction (- 25 to + 120) for the glass industry of Yakhtangi silica sand varies from 44.74 to 58.68 % which is comparatively low, as for a good quality sand this fraction should constitute about 80 % of the original raw material [9], and hence may not be economically beneficial for a glass factory at a away distance, due to high transport charges. However, since a large portion of this sand is + 25 mesh, a small grinding unit at the mining side could overcome this problem very well.

On the other hand portion of the sand passing through – 120 mesh comprises about 10.07 to 26.40 % of the Yakhtangi sand and consists of ferrogenous clay. Simple water washing of the sand either at the mining or factory site will not only enhance the useful fraction of the sand by removing the ferrogenous clay but will also upgrade the quality of sand by reducing its Fe_2O_3 content (Table- 5).

Result given in table 4 shows the effect of grading and water washing on this silica sand. The Fe_2O_3 concentration in the water washed dried samples as well as the graded (useful fraction) sand was determined spectrophotometrically [11]. The reduction of iron oxide content in the useful fraction varies from 26.69 to 65.71 %, while the same was found to lie between 16.67 to 60.00 % in water washed samples.

The above results indicate that the quality of Yakhtangi silica sand can be improved by simple physical treatments which make the silica sand suitable for the manufacturing of high quality container glass. Beside the glass industry the sand from yakhtangi can also be utilized by abrasive and sodium silicate industries [7].

Experimental

Twenty samples were collected (in March 2001) from the close lateral and vertical distances from Yakhtangi deposits for studying their physicochemical characteristics to determine their industrial uses. Ten samples, six silica sand and four quartz samples were selected for detailed physical and chemical analysis (April-June 2001) in the laboratory.

Chemical Analysis

100 g of the original sample was ground to a fine powder (-100 + 120) and analyzed using standard method of chemical analysis [11-13]. The

Table-5: Effect of water washing on iron content of silica sand samples

Sample Number	% Fe_2O_3 in original sample	% Fe_2O_3 after water washing	% Reduction in Fe_2O_3 content due to water washing	% Fe_2O_3 in useful fraction (- 25 + 120)	% Reduction of Fe_2O_3 due to grading
SLS-1	0.07 ± 0.004	0.052 ± 0.002	25.71	0.036 ± 0.002	48.57
SLS-4	0.06 ± 0.005	0.050 ± 0.002	16.67	0.044 ± 0.002	26.67
SLS-5	0.14 ± 0.004	0.065 ± 0.003	53.54	0.062 ± 0.003	55.71
SLS-6	0.06 ± 0.003	0.032 ± 0.001	46.66	0.028 ± 0.001	53.33
SLS-14	0.11 ± 0.004	0.065 ± 0.004	40.90	0.062 ± 0.003	43.64
SLS-15	0.07 ± 0.002	0.028 ± 0.001	60.00	0.024 ± 0.001	65.71

constituents determined were SiO_2, Al_2O_3, TiO_2, CaO, MgO, Na_2O, K_2O and loss on ignition. Results are given in Table- 2, Wet methods of analysis were used for SiO_2 combined oxide, CaO and MgO while Fe_2O_3 and TiO_2 were determined spectrophotometrically by (Schimadzu double beam spectrophotometer UV-200S). For spectrophotometric and flame photometric determinations solution were prepared by decomposing the sample with HF / $HClO_4$ and diluted with water to 250 ml each. 2 ml of this solution was used for Fe_2O_3 and 10 ml for TiO_2 determination. The reagents for iron were 0.25 % 1, 10 Phenanthroline, 0.2 M Sodium acetate and 2 M Hydroxylamnnoniumchloride. Absorbance was measured at 523 nm using blank as reference.

For TiO_2 determination 10 ml of the reagent (500 ml), comprising 50 ml of 50 % H_2SO_4, 50 ml of syrupy phosphoric acid and 50 ml 30 % H_2O_2 was used for colour development and the absorbance was measured at 400 nm. Sodium and potassium contents were determined using corning 400 flame photometer.

Grading

100 g of each of the six sand samples (originally in coarse powder form) was taken and sieving was done by means of ASTM standard sieves of 25, 36, 52, 72, 100 and 120 mesh. Each sample was shaken for 5 min in a mechanical shaking machine and the amount retained on every mesh was weighed [10]. From these weighed quantities the percentage retention on a particular sieve and the useful fraction for glass industry (-25 - + 120) were calculated and are given in Table- 4.

Magnetic Separation

In order to remove the ferromagnetic particles the sand samples were subjected to magnetic separation. A strong permanent magnet was passed over a sand bed on a glazed paper. No particles were attracted by the magnet in anyone of the ten samples indicating all samples free from ferromagnetic particles.

Water Washing

Samples were also subjected to water washing in addition to grading. For this purpose sand and water (100 g/ 2.5 L) were taken in a 3 liter beaker and stirred for 15 minutes with a glass rod. The resulting dirty liquid carrying ferruginous clay particles were decanted after 1.5 min. The process was repeated till the washing was clear and transparent. Iron content of the washed samples were determined, after drying, by the same spectrophotometric method as mentioned above for original samples. Effect of water washing on removal of iron oxide was calculated and given in Table- 5.

Conclusion

Yakhtangi (Swat) silica sand- deposit if developed could be a good addition as the high quality raw material source for glass, ceramics and silicate industries. For high quality glass making, the quality of the sand may be improved by simple physical processes like water washing and sieve analysis, reported in this paper.

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