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BENEFICIATION STUDIES OF DAU DAM (DISTRICT DADU, SINDH) SAND ON PILOT PLANT SCALE FOR MAKING COLOURLESS GLASS

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Six low grade glass sands of Dau Dam, district Dadu, have been beneficiated on laboratory as well as on pilot plant scale. Laboratory studies showed that none of the sand in its original form was suitable for melting colourless glass. However, three sands SQ_4, SQ_5, and SQ_6 after simple water washing were found suitable to be processed on sand washing plant. Sand SQ_4 and SQ_6 showed an iron content of 0.045 and 0.04% respectively after pilot plant washing treatment. These two sands can be utilized for the manufacture of colourless glass with the proper use of decolourizer mixture of selenium and cobalt. However, SQ_1, SQ_2, SQ_3 and SQ_5 sands after simple water washing can be used for making thin walled chemneys, electric shells, sheet glass and coloured glasses.

Key words: Beneficiation, Glass sand, Sand for making colourless glass.

Introduction

Silica sand is extensively used in metallurgy, ceramics, as a construction material and in the production of silicate based chemicals. However, glass industry is by far the largest individual consumer of silica sand. Other forms of silica sand as sand stone, crushed quartzite and ground flint can also be used but sand is preferred due to certain advantages presented by its physical nature.

Apart from the silicate and chemical industry, the monthly requirement of silica sand for flat and container industry of Pakistan is about 25,000 tonnes. Since major glass industry is situated in and around Karachi, therefore, the monthly requirement of silica sand in Sindh province is only 10,000 tonnes. As a result of this heavy demand, deposits of good quality sand are fast depleting. In view of this, efforts are being made to explore new deposits of sand to meet this requirement. At the same time, sand beneficiating equipment is being introduced to upgrade the low grade sands of Punjab and Sindh provinces. Presently there are two main deposits of silica sand, one of these is located around Thana Bolla Khan (Sindh) while the second biggest deposit is that of salt range (Punjab). Thana Bolla Khan sand is of low grade and needs special treatment for up-grading. Sand from Mianwali district is of good quality but high cost of transportation has forced the industrialists of Karachi to use the low grade sand of Thana Bolla Khan.

Present study is mainly concerned with the evaluation and up-grading of sand from Dau Dam district Dadu (Sindh). According to detailed geological survey, the total reserves are 1687 million tonnes and are stretched over an area of 4286 acres. Initially laboratory studies were made on six sand samples SQ_1, SQ_2, SQ_3, SQ_4, SQ_5 and SQ_6. As a result of these studies SQ_4, SQ_5 and SQ_6 were found suitable for pilot plant studies. Three tonnes of these sands were sent by Pakistan Mineral Development Corporation for pilot plant studies. This sand washing plant was designed and fabricated by PCSIR Laboratories Lahore. The plant consists of a conveyor belt, two spirals, one 18 feet long and other 14 feet long fitted with a shaker, and two rubber lines scrubbers arranged in series. It has been designed to beneficiate 80 tonnes sand/8 hrs but it can be up-scaled to any desired capacity.

Scope of investigation. On preliminary examination, the sand samples were found to contain the impurities in three distinct forms: (a)Ferruginous clayey materials, (b) Heavy mineral particles, (c) Coated sand grains.

In view of the previous sand beneficiation studies [1-3] following steps for the evaluation and improvement of these sands have been included in the present investigation.

(i) *Grading.* To separate the coarse and clayey (finer sand) fraction containing most of the colour imparting impurities and also if these sand conform to the standard specifications.

(ii) *Water washing.* To remove ferruginous clayey fraction and loosely held coating of Fe_2O_3 on the sand grains.

(iii) *Pilot plant studies.* To carry out water washing studies on commercial scale.

Experimental

Chemical analysis. Ten grams of the raw as well as washed sand samples were taken by coning method and ground to a fine powder for chemical analysis. The chemical analysis was done using the standard methods of chemical analysis [4]. The results are shown in Table 1.

Grading. Hundred grams of washed samples were sieved through 25 and 120 B.S. test sieves. The amount passing and retained on these meshes were weighed and the results are given in Table 3.

Water washing. In order to remove the iron coating from sand grains and clayey fraction, 500 g of the raw sand was stirred vigorously with water in a 2 litre beaker and allowed to settle for 30-40 sec. The dirty water was decanted off: washing was continued until there was no change in the colour of the freshly added water on subsequent stirring. The loss due to washing has been given in Table 3.

The manual washing of the sand is not effective because it removes only the ferruginous clayey material and the iron associated with it. The iron oxide present in the heavy minerals and especially in the form of coated grains still remains in the manually washed sand. In view of this mechanical washing of the sand is necessary to make the sand suitable for making good quality table wares and containers.

Pilot plant sand washing. A significant reduction in iron content (40-52%) was noted (Table 1 and 2) in samples SQ_4, SQ_5 and SQ_6 by simple water washing as compared to other sand samples. In view of this, these samples were selected for thorough investigation on pilot plant scale. The sand washing plant consists of a conveyor belt, a sieve shaker, 18 feet long spiral, two rubber lined scrubbers arranged in series and another 14 feet long spiral (Fig. 1). Two density separators and one magnet separator can be attached to this unit to increase its efficiency. The working of the plant is clear from Fig 1 and 2. The belt conveyor carried the raw sand to the sieve shaker where water is showed on the sand. The over size sand (+25 mesh size) is removed while below 25 mesh size goes to the first spiral where a counter flow of water carries away the ferruginous clayey material and to some extent loosely held iron coating on sand grains are removed. After this the sand is scrubbed at a speed of 300 rpm in two scrubbers and during this operation, iron coated on sand grains is removed. The residence time in the scrubbers was approximately 4-6.5 mins.

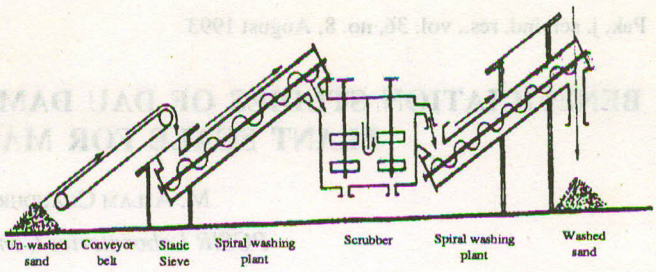

Fig. 1. Flowsheet for the sand beneficiation plant.

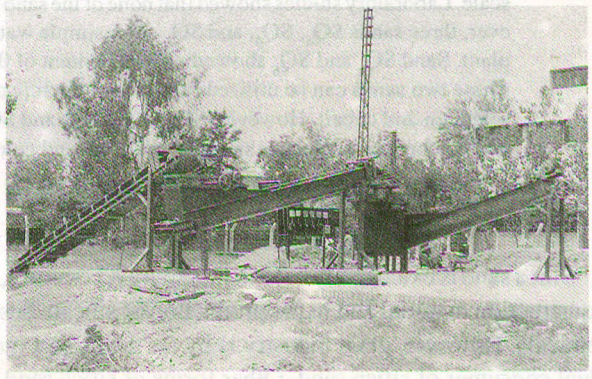

Fig. 2. Sand washing plant

Then the sand enters the second spiral and here again due to counter flow of water the left over ferruginous clayey material and the iron removed during scrubbing are removed. The chemical analysis of sand beneficiated on pilot plant is given in Table 4.

Results and Discussion

Silica sand constitutes about 70-75% of all the glass raw materials and therefore, its quality determines the end product.

TABLE 1. CHEMICAL COMPOSITION AND PHYSICAL CHARACTERISTICS OF ORIGINAL AND WATER WASHED GRADED SANDS OF DAU-DAM DISTRICT DADU (SINDH).

S. No.	Chemical constituents	SQ_1 Raw	SQ_1 Washed graded	SQ_2 Raw	SQ_2 Washed graded	SQ_3 Raw	SQ_3 Washed graded	SQ_4 Raw	SQ_4 Washed graded	SQ_5 Raw	SQ_5 Washed graded	SQ_6 Raw	SQ_6 Washed graded
1	I/L	0.78	0.36	0.69	0.65	0.73	0.38	0.56	0.42	0.78	0.36	0.52	0.45
2	SiO_2	96.64	97.49	96.43	97.20	96.32	97.14	97.03	97.53	95.33	97.50	96.29	98.33
3	Al_2O_3	1.77	1.63	1.64	1.50	2.04	1.96	1.81	1.62	2.99	1.65	2.58	0.77
4	Fe_2O_3	0.13	0.10	0.34	0.24	0.19	0.14	0.10	0.06	0.19	0.09	0.12	0.06
5	CaO	0.52	0.34	0.64	0.33	0.37	0.20	0.26	0.24	0.56	0.02	0.35	0.27
6	MgO	0.13	0.03	0.12	0.05	0.17	0.04	0.12	0.03	0.10	0.02	0.05	0.05
7	%Retained on mesh No. (-25+120) (washed)	93		92.5		91		94		91		90	
8	Bulk density lb/ft³(washed)	>95		>98.5		>95		>96		>97		>95	
9	Grains	Angular-round		Angular-round		Angular-round		Angular-round		Angular-round		Angular-round	

A glass sand finding use in the glass industry must conform to the BSS 2975 (1958). According to this, optical glass requires the purest sand (minimum silica 99.5% maximum iron content 0.008%) and at the lower end of the scale is the sand for general colourless container and flat glassware (minimum silica, 98.5%, maximum iron content 0.03%). It should be noted that many flat window glasses are actually green if viewed from an oblique angle but are, for practical purposes, regarded as colourless. An iron content of 0.1% may therefore, be acceptable for such glasses. The minimum silica content as is practised in Pakistani sheet glass industry may also be waived off if the silica is practically replaced by nonharmful or even beneficial impurity such as alumina. The second most important characteristic of the sand is its grain-size distribution. The best and suitable for glass industry must have the useful sand fraction (-25+120 mesh) more than 86.0%. All these sands conform to this specification (Table 3). Further the loss due to water washing is not significant (<3.5%). However, the loss in weight due to fine sand (4.0-9%) can be compensated if the sand fraction below 120 mesh sieve is sold at the site to consumer industries such as abrasive and silicates.

The results of chemical analysis of raw as well as washed graded sands on laboratory scale are given in Table 1. In the light of standard specifications none of the raw as well as washed sand is suitable for making good quality table wares and containers. The iron content in the raw sands varies from 0.1-0.34%. After simple water washing there is considerable reduction in the iron content of SQ_4, SQ_5 and SQ_6 sand samples. The iron content has reduced from 0.1-0.06%, 0.19-0.09% and 0.12-0.06% respectively. The average iron reduction in these samples is 47.5% while in the case of first three samples reduction is 27.2%. In view of this SQ_4, SQ_5 and SQ_6 sand samples were selected for pilot plant studies. However, SQ_1, SQ_2 and SQ_3 sands can be used for making beverage bottles, sheet glass, electric bulb shells, green and amber glass.

It seems that in case of SQ_4, SQ_5 and SQ_6 most of the iron is coated on the outer surface of the sand grains and therefore, it is removed by simple water washing where as in case SQ_1, SQ_2 and SQ_3 it is within the latex of the sand grains and cannot be removed without chemical treatment. The chemical treatment is an expensive process and adds heavily to the cost of the finished product, hence not feasible for making ordinary glass.

TABLE 2. IMPROVEMENT IN THE IRON CONTENTS OF THE SANDS AFTER GRADING AND WATER WASHING.

Sample No.	%Fe_2O_3 in raw sands	%Fe_2O_3 in the water washed graded sand	%Reduction in Fe_2O_3
SQ_1	0.13	0.10	23.0
SQ_2	0.34	0.24	29.4
SQ_3	0.19	0.14	26.3
SQ_4	0.10	0.06	40.0
SQ_5	0.19	0.09	52.6
SQ_6	0.12	0.06	50.0

TABLE 3. GRAIN SIZE DISTRIBUTION OF DAU DAM WASHED SANDS.

Sample No.	Retained on mesh No. +25 %	Through mesh No. –120 %	Sieving loss %	Useful fraction (-25+120) mesh (washed) %	Water washing loss of graded sands(–25+120) %	Water washing loss of original sand samples sand samples %
SQ_1	1.83	5.0	0.10	93.06	2.50	3.50
SQ_2	2.0	5.13	0.30	92.56	2.65	3.00
SQ_3	2.73	5.80	0.16	91.30	2.00	2.75
SQ_4	0.90	4.53	0.10	94.46	1.50	2.25
SQ_5	0.73	7.83	0.10	91.33	2.00	3.00
SQ_6	0.66	8.73	0.24	90.36	2.50	3.25

TABLE 4. RESULTS OF PILOT PLANT CHEMICAL ANALYSIS OF ORIGINAL AND WASHED SANDS (WT. %).

Sample	L/I	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	%Retained in Fe_2O_3
SQ_4 Original	0.54	96.95	1.82	0.100	0.26	0.12	—
Washed	0.41	97.50	1.63	0.045	0.25	0.02	55.00
SQ_5 Original	0.80	95.40	2.91	0.190	0.57	0.12	—
Washed	0.38	97.55	1.67	0.065	0.20	0.03	65.78
SQ_6 Original	0.54	96.34	2.55	0.120	0.37	0.04	—
Washed	0.43	98.30	0.85	0.040	0.28	0.03	66.66

From chemical analysis of SQ_4, SQ_5 and SQ_6 sands processed on the sand washing plant (Table 4), it can be seen that as a result of this treatment, the iron oxide content has reduced from 0.1-0.045%, 0.19-0.065% and 0.12-0.04% in SQ_4, SQ_5 and SQ_6 respectively. The total reduction in iron content is 55-66.5% which is quite significant on this unit. The improvement is considerable as compare to simple water washing. It shows that manual washing of the sand is not effective because it removes only the ferruginous clayey material and the iron associated with it. The iron oxide present in the heavy minerals and in the form of coated grains remains in the manually washed sand and for this mechanical washing of the sand is necessary. It may be noted that SQ_5 (0.065% Fe_2O_3) is unfit for making colourless glass even after mechanical washing where as SQ_4 (0.045%) and SQ_6 (0.04%) can be utilized for making good quality table wares. Sand containing iron oxide upto 0.05% [5] can be decolourised with the proper adjustment of decolourising mixture of selenium powder and cobalt oxide. The sheet glass industry may use the sands, provided the Fe_2O_3 content does not exceed 0.1%. If these industries desire to manufacture good quality table wares and containers, they must include modern techniques of washing sand in their units.

Glass manufacture. The sand obtained from the washing plant was used for melting soda-lime-silica containers glass with proper amount of decolouriser selenium and cobalt oxide. The glass obtained was colourless and seed free. The glass composition was SiO_2 (73.58%), CaO (10.5%), Na_2O (14.8%) and Al_2O_3 (1.2%). The melting temperature was 1450±10°. The results have been verified on a five tonne furnace.

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