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CHARACTERISTICS OF GLASS MAKING SANDS OF MUNDA KUCHHA, DISTRICT MANSEHRA AND THEIR BENEFICIATION AND UTILIZATION FOR THE PRODUCTION OF COLOURLESS CONTAINER GLASS

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Large deposits of silica sand occur at a distance of 50km to the northeast from Mansehra town, near Munda-Kuchha village along the Siran river. Estimated reserves upto a workable depth of 300 feet are 57 million tons. Twelve representative samples were collected from the area for studying their suitability for glass industry. The chemical composition and grain size distribution of these samples were determined. Beneficiation studies by physical and chemical methods were undertaken to remove colour imparting impurities which are a factor for producing the glass of inferior quality. The objective of this study was to upgrade the quality of silica sand to the acceptable limits for the production of colurless container glass. Using physical methods a maximum of 41.66% of the iron, the most undersirable impurity, was removed; by chemical treatment seven of the twelve samples can be brought into the specification for colourless container glass, five can be brought into, or very near, the specification for optical glass.

Key words: Evaluation, Glass sand, Mansehra.

Introduction

Silica sand deposits are widespread and extensive throughout Pakistan but todate there has been no systematic assessment of reserves. In NWFP, a large silica sand mining area is Pezu-Paniala (Kishore-Marwat Range) in district Dera Ismail Khan. Other significant glass sand producing areas include Punjab and Sindh. The Pakistan silica sand industry is currently buoyant, the principal consumer being the glass, sodium silicate and foundary industries in relative order of importance [1].

This investigation aims at delineating the characteristics of large silica sand deposits occurring near Munda Kuchha village, district Mansehra, NWFP (Toposheet No. 43F/6). Munda Kuchha village is linked with Mansehra town by a 50km metalled road. The Munda Kuchha silica sand outcrops occur within elevations of 1000 to 5000 feet. These deposits are naturally exposed making them easily accessible and extractable (Fig. 1).

Previously several studies were conducted on Munda Kuchha sand deposits, which included the reporting of large quantities of silica sand at Munda Kuchha [2-4]. The first geological map of Munda Kuchha area was prepared by Offield and Abdullah [5]. Later, Husain [6] estimated silica sand reserves of these deposits as 57 million tons upto a depth of 300 feet.

This work is an extension of the efforts of PCSIR Laboratories, Peshawar to locate suitable glass sands in the region which can be used in local glass industries after beneficiation. In NWFP, there is a paucity of suitable silica sand deposits for the production of quality glass wares, [7,8].

Large silica sand deposits of Kishore-Marwat Range, district Dera Ismail Khan, NWFP are being utilized without purification by a number of local industries for the production of sheet glass. However, after beneficiations, some of the samples were upgraded to meet the specifications of colourless container glass industries [9].

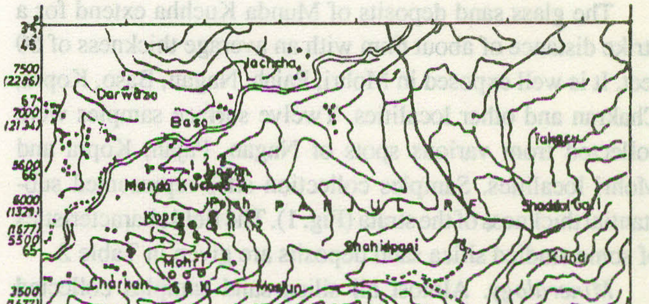

Fig. 1. Location map of silica sand deposits of Munda Kuchha, area district Hazara, N.W.F.P.

The glass and bulb industries of NWFP are getting their bulk supply of silica sand from Daudkhel, district Mianwali, Punjab, but the source is far away from the glass industries of NWFP and the transportation cost of silica sand is very high.

The specific objectives of this study were to investigate the characteristics of Munda Kuchha silica sand and its suitability for manufacturing glass products. Efforts were also made to remove all objectionable impurities from these samples by physical and chemical methods of beneficiation.

Materials and Methods

General geology. The silica sand deposits of Munda Kuchha are located on the western limb of Hazara - Kashmir syntaxis and deformation in the area could be the part of Himalayan orogenic events which are considered to be post middle Miocene in age [10]. A major part of the Munda Kuchha area is underlain by Tanawal Formation. The rocks belonging to Abbottabad Formation are also extensively exposed in the area (Fig. 2). The lithology of this area is briefly summerised in Table 1.

The silica sand deposits of Munda Kuchha area occur in quartzose sandstone beds which are the metamorphose equivalents of Abbottabad Formation of early Cambrian age. The quartzose is snow-white to brownish-white, and weathers to white or dirty white quartz sand. The compaction, cementation and composition of quartzose sandstone is the area slightly variable and a large portion is friable, which provides an excellent source of silica sand.

The glass sand deposits of Munda Kuchha extend for a strike distance of about 6km with an average thickness of 60 feet. It is well exposed in Mohri, Pajah, Nagan, Baso, Kopra, Chakran and other localities. Twelve surface samples were collected from various spots of Nagan, Pajah, Kopra and Mohri localities. Samples collection sites represented substantial thickness of the strata (Fig. 1). The field characteristics of some studied silica sand deposits are given in Table 2.

Mineralogy. Almost all silica sand samples collected from Munda Kuchha area show uniform characteristics – a minimum of 90% subangular to subrounded and mostly fine to medium grains of quartz with accessory muscovite, phlogopite, feldspar, limonite and goethite. Micaceous minerals occur as white coloured flakes, while fine and amorphous grains of limonite are randomly distributed throughout the sample. Yellowish and reddish brown stainings of ferruginous material are common along joints and fracture partings [10].

The mineralogical character of the sands is quite favourable as they contain minimum 90% quartz and total silica of 93% (Table 3) making them quite pure variety that could selectively be used in manufacturing various grades of glass products. The ferruginous matter occurs mostly as pigmenta-

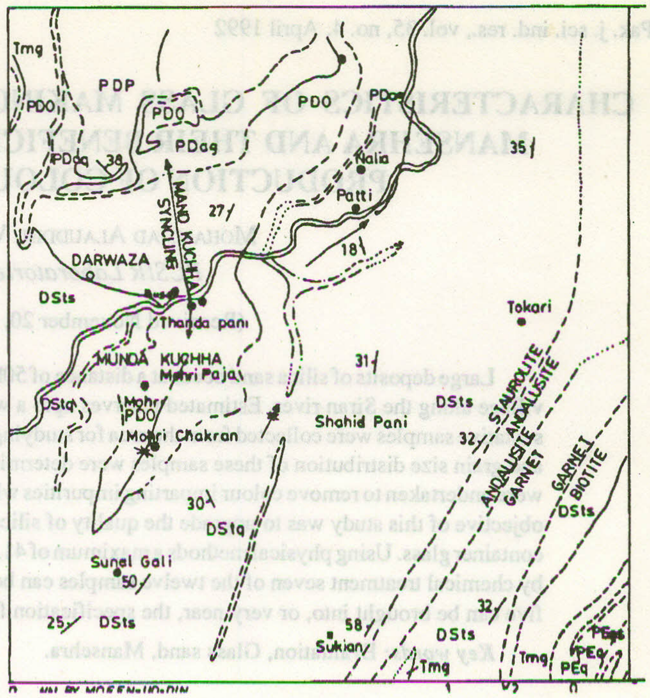

Fig. 2. Geological map of Munda Kuchha area district Hazar N.W.F.P. (After T. W. Offield and J. A. Calkins, 1963).

Alluvium	Qal Alluvium	
Mansehra Granite	Tmg	Mansehra granite
Abbottabad Formation	PDO	Abbottabad formation mostly dolomite
	PDag	Abbottabad formation quartzite
	PDp	Panjal formation volcanic greenstone
Tanawal Formation	DSts	Quartzose Schist
	DStq	Quatzite lenses
Salkhala Formation	PEq	Quartzo feldspathic unit
	PEqs	mica quartz Schist and quartz phyllite in south

Dashed where contact approximately located, dotted where concealed.

TABLE 1.

Formation	Alluvium	Age
Abbottabad	Marble Amphibolite. Quartzite and quartzose Sandstone. Quartz schist.	Early cambrian
UNCONFORMITY		
Tanawal	Quartzose schist with interbedded quartzite lenses and bands.	Late Pre-cambrian
Salkhala	Schist, phyllite Quartzite and slate.	Pre-cambrian

tion and separate grains, which is reduced significantly after washing these sand samples (Table 4).

Chemical analysis. Twelve silica sand samples from the study area were analysed for their chemical composition. 100 Grams of the sand was ground to a fine powder (-100 +120 mesh) and analysed using standard methods of chemical analysis [11]. The constituents determined were SiO_2, Fe_2O_3, Al_2O_3, CaO, MgO etc. The results of chemical analysis of the original and water washed silica sand samples are given in Table 3 and 4.

Water washing. In order to remove the iron coating from sand grain and clay fraction, the sand was subjected to vigorous washing. The washing treatment was given to both graded and ungraded samples. 700 Grams of the sand was stirred with 1 litre water in a 2 litre beaker and was allowed to settle for 1 min. and the washings were decanted off. The washing of sand was continued with 1 litre water everytime until there was no change in colour in the freshly added water on subsequent stirring. The washed sand was ground to pass 100 mesh sieve for chemical analysis. The rest was used for other treatment.

TABLE 2.

Site	Geomorphology 1. Elevation (feet) 2. Cause of outcrop	Lithology-texture 1. Rock type 2. Hardness 3. Texture 4. Cement	Structure 1. Bedding 2. Discontinuities.	1. Thickness (feet exposed) 2. Strike length of exposed silica sand (feet)	Estimated reserves (m. tonnes) exposed	1. Accessibility 2. Overburden	Extraction method
Pajab	1. 2500 2. Natural	1. Quartzose sandstone. 2. Friable 3. Fine medium loose. 4. Minimal	1. Interbedded with white, hard and medium bedded quartzite. 2. Jointed.	1. Sixty. 2. Two thousand.	2.4	1. Easy. 2. Vegetation & quartzite.	Buldozer explosive.
Mohri	1. 1000 2. Natural	1. Quartzose sandstone. 2. Friable. 3. Fine medium. 4. Minimal.	1. Thin bedded 2. Highly jointed and fractured.	1. Thirty. 2. Two thousand.	1.4	1. Easy. 2. Vegetation & quartzite.	Buldozer explosive.
Nagan	1. 5000 2. Natural	1. Quartzose sandstone. 2. Soft. 3. Fine medium. 4. Minimal.	1. Thin bedded 2. Jointed and fractured.	N.D. N.D.	N.D.	1. Easy. 2. Only vegetation.	Buldozer.
Kopra	1. 2100 2. Natural	1. Quartzose sandstone. 2. Soft. 3. Fine medium loose. 4. Minimal.	1. Thin bedded. 2. Jointed.	N.D. N.D.	N.D.	1. Easy. 2. Only vegetation.	Buldozer.

TABLE 3. CHEMICAL ANALYSIS OF SILICA SAND (RAW) FROM MUNDA KUCHHA, MANSEHRA.

Chemical composition%	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	93.10	92.49	92.76	94.58	92.26	92.27	90.94	92.01	92.02	86.72	86.93	47.24
Fe_2O_3	0.11	0.14	0.08	0.10	0.11	0.12	0.09	0.08	0.12	0.18	0.05	0.45
Al_2O_3	5.99	3.32	3.18	3.29	5.26	1.92	4.69	4.69	5.17	4.06	3.59	7.75
TiO_2	Nil	Nil	Nil	Nil	–	–	–	–	–	–	–	–
CaO	0.80	2.48	2.52	0.82	0.80	5.56	2.60	1.30	1.80	7.66	8.10	16.58
MgO	Traces	1.46	1.42	1.12	0.71	0.25	0.89	0.15	0.65	0.42	0.22	0.75
Na_2O	0.03	0.02	0.08	0.07	0.09	0.02	0.05	0.07	0.05	0.06	0.03	1.10
K_2O	0.24	0.22	0.20	0.22	1.35	0.07	0.17	0.12	0.13	0.47	0.42	4.70
I.O.I.	0.44	0.38	0.23	0.54	0.22	0.23	1.43	0.06	0.21	0.03	0.42	22.35
Total	100.70	100.51	100.74	100.80	100.41	100.86	98.54	100.66	99.66	99.60	99.57	98.92

Magnetic separation. In order to remove the ferromagnetic particles, the washed and raw sand were subjected to manual magnetic separation. A strong permanent magnet was passed over a sand bed in a glazed paper. No particle was attracted from any one of the silica sand samples. All the samples were found free from ferromagnetic particles.

BENEFICIATION BY CHEMICAL TREATMENT

(a) Adam's process. Adam removed the iron coating [12] of the sand by treating the samples with a solution of sodium acid oxalate containing some $FeSO_4 . 7H_2O$. The solution was prepared by mixing the following and making the volume to 100ml. 1.0gm sodium oxalate, 6.0ml H_2SO_4 1:1, 0.2gm $FeSO_4 . 7H_2O$.

20 Grams of the sample in each case was put into 20 ml of Adam's solution which was heated to 65 ±5°. The reaction was extremely slow at room temperature. The period of reaction was allowed for 30 min. with constant stirring and washed thoroughly with hot water till the solution became free from

TABLE 4. CHEMICAL COMPOSITION OF SILICA SAND (WATER WASHED) FROM MUNDA KUCHHA, MANSEHRA.

Chemical composition%	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	95.74	97.86	95.08	97.90	97.18	97.16	89.80	96.80	97.12	97.74	97.60	53.26
Fe_2O_3	0.09	0.12	0.07	0.08	0.07	0.07	0.06	0.07	0.07	0.11	0.50	0.28
Al_2O_3	2.98	0.84	4.15	0.98	1.55	1.95	4.76	2.08	1.65	0.56	0.91	3.23
TiO_2	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
CaO	0.48	0.56	0.53	0.47	0.15	0.12	2.62	0.66	0.38	0.12	0.76	13.76
MgO	0.29	0.02	0.63	Traces	0.43	0.54	0.18	Traces	0.60	0.21	0.24	8.31
Na_2O	0.02	0.01	0.02	0.02	0.04	0.02	0.04	0.02	0.29	0.02	0.03	0.36
K_2O	0.16	0.13	0.17	0.07	0.80	0.52	0.25	0.26	0.12	0.52	0.30	1.50
L.O.I.	0.09	0.09	0.09	0.72	0.12	0.16	2.92	0.27	0.20	0.46	0.93	18.72
Total:	99.82	99.66	100.74	100.24	100.34	100.54	100.63	100.25	100.43	99.74	100.82	99.42

TABLE 5. GRAIN SIZE ANALYSES OF MANSEHRA SILICA SAND (RAW AND WATER WASHED).

Sample No.	Raw sand or water washed	+25 mesh %	-25 mesh %	-36 mesh %	-52 mesh %	-72 mesh %	-100 mesh	-120 mesh	Sieve loss	Useful fraction -25+120 mesh %
1	Raw	27.88	15.91	3.66	9.01	15.63	10.34	17.80	1.23	54.32
	Water washed	27.56	15.58	3.05	19.29	5.79	12.77	15.51	0.45	56.93
2	Raw	29.87	20.72	4.40	19.37	5.31	8.51	11.55	0.27	58.64
	Water washed	21.44	21.80	4.99	23.93	5.55	11.44	10.22	0.63	68.34
3	Raw	35.05	17.93	3.43	17.78	4.06	7.01	14.06	0.68	60.89
	Water washed	37.33	20.94	4.18	18.30	3.77	8.26	7.27	0.05	45.40
4	Raw	1.68	8.48	3.44	25.05	10.26	16.64	33.21	0.24	65.11
	Water washed	0.25	5.80	3.24	30.41	10.53	23.27	25.81	0.69	73.94
5	Raw	11.57	13.98	3.47	17.75	6.95	12.81	32.72	0.93	55.71
	Water washed	8.87	17.55	8.34	19.70	7.36	16.90	20.80	0.48	70.33
6	Raw	26.28	7.84	1.73	11.88	5.23	12.84	33.74	0.46	39.98
	Water washed	24.04	10.26	2.64	17.72	9.71	17.42	17.33	0.88	58.63
7	Raw	15.40	9.93	2.49	14.89	7.05	15.03	34.75	0.46	49.85
	Water washed	7.90	10.04	2.85	19.40	6.69	18.03	34.82	0.27	57.28
8	Raw	33.15	15.89	3.79	17.53	5.10	12.40	11.35	0.70	55.50
	Water washed	17.03	18.05	4.92	23.16	6.43	12.74	17.56	0.11	65.61
9	Raw	30.54	15.52	3.68	17.53	5.54	9.98	17.08	0.15	52.38
	Water washed	29.38	16.34	4.33	20.23	5.29	10.79	13.46	0.18	57.16
10	Raw	19.37	21.48	4.68	17.86	4.69	10.57	19.92	0.43	60.71
	Water washed	19.07	23.01	5.75	20.24	5.96	11.04	14.92	0.51	66.01
11	Raw	28.01	9.40	2.02	11.45	11.54	23.16	14.16	0.24	57.83
	Water washed	15.64	9.92	2.36	14.80	5.28	15.84	35.38	0.76	48.98
12	Raw	12.95	9.77	2.14	10.81	3.46	10.43	50.43	0.01	38.62
	Water washed	4.17	9.40	3.25	17.42	5.66	15.41	44.24	0.45	51.59

TABLE 6. PERCENTAGE IRON OXIDE (Fe_2O_3) IN RAW AND BENEFICIATED SILICA SAND.

Sample No.	%Fe_2O_3 in raw silica sand	%Fe_2O_3 in water washed sand	%Fe_2O_3 after Adam's process	%Fe_2O_3 after NaOH process
1	0.11	0.09	0.017^{+}	0.017^{+}
2	0.14	0.12	0.037	0.038
3	0.08	0.07	0.008^{x}	0.0085^{x}
4	0.10	0.08	0.045	0.045
5	0.11	0.07	0.068	0.068
6	0.12	0.07	0.07	0.08
7	0.09	0.06	0.008^{x}	0.008^{x}
8	0.08	0.069	0.0081^{x}	0.008^{x}
9	0.12	0.07	0.008^{x}	0.008^{x}
10	0.18	0.11	0.0085^{+}	0.0084^{x}
11	0.05	0.05	0.031^{+}	0.031^{+}
12	0.45	0.28	0.14	0.071

+ = below limit for colourless container glass, x = below limit for optical glass.

TABLE 7. PERCENTAGE REDUCTION OF IRON OXIDE (Fe_2O_3) IN SILICA SAND AFTER VARIOUS TREATMENTS.

Sample No.	%Fe_2O_3 in raw sand	%Fe_2O_3 reduced after water washing	%Fe_2O_3 reduced after Adam's process	%Fe_2O_3 reduced after NaOH treatment
1	0.11	18.18	84.54	84.54
2	0.14	14.28	73.57	72.85
3	0.08	12.50	90.00	89.37
4	0.10	20.00	55.00	55.00
5	0.11	36.36	29.09	29.09
6	0.12	41.66	41.66	33.33
7	0.09	33.33	91.11	91.11
8	0.08	13.75	90.00	90.00
9	0.12	41.66	93.33	93.33
10	0.18	38.88	95.27	95.33
11	0.05	Nil	38.00	38.00
12	0.45	37.77	71.11	84.22

oxalic acid and iron. Later, it was filtered and dried in an oven at 110°. The iron content in the sand was determined spectrophotometrically and the percentage of iron removed was also detected (Table 6).

(b) Sodium hydroxide process. The sodium was wet with 4% sodium hydroxide solution and heated to 160° on sand bath with constant stirring to convert iron oxide to sodium ferrite [13]. The above mass was then stirred with sufficient water to hydrolyze the ferrite, allowed to stand for sometime to separate the liberated iron oxide and the supernant liquid decanted off. The sand was further washed with 2% H_2SO_4 to remove the traces of free iron left over and it was also washed with water. The dried sand was then analysed for iron content by spectrophotometer (Table 6).

Results and Discussion

The chemical data show that the iron content (Fe_2O_3) in silica sand samples varies from 0.05% (lowest) in sample No. 11to 0.45% in sample No. 12 (Table 3). In sample No. 11, the percentage of iron remains unchanged even after water washing indicating that the sample is free from ferruginous and clay material. Most of the samples (*viz.* samples Nos. 4,5,6,7,9,11 and 12) show varying degrees of improvement in iron content indicating presence of clay minerals (Table 4). Sample Nos. 1 to 9 have more than 90% SiO_2 which was enhanced to a maximum of 97.90% after removing clay particles. Sample No. 12 has however, low silica content as it is a mixture of sand and limestone (e.g. CaO = 16.58% and loss on ignition 22.35%). Some of the samples (*viz.* sample Nos. 6, 10 and 11) contain 5.56% 7.66 and 8.10% CaO respectively. As CaO and SiO_2 are important constituents of glass, their presence is not objectionable. The presence of Na_2O and K_2O in small quantity in some of the samples is atributed to rare amount of

TABLE 8. PERCENTAGE REDUCTION OF IRON OXIDE IN SILICA SAND FROM MUNDA KUCHIA AFTER BENEFICIATION.

Sample No.	%Fe_2O_3 in raw sand	%Fe_2O_3 retained in water washed sand	% reduction of Fe_2O_3 after water washing	%Fe_2O_3 retained after Adam's process	%reduction of Fe_2O_3 after Adam's process	%Fe_2O_3 retained after NaOH process	% reduction of Fe_2O_3 after NaOH process
1	0.11	0.09	18.18	0.017	84.54	0.017	84.54
2	0.14	0.12	14.28	0.037	73.57	0.038	72.85
3	0.08	0.07	12.50	0.008	90.00	0.008	89.37
4	0.10	0.08	20.00	0.045	55.00	0.045	55.00
5	0.11	0.07	36.36	0.068	29.09	0.068	29.09
6	0.12	0.07	41.66	0.07	41.66	0.08	33.33
7	0.09	0.06	33.33	0.008	91.11	0.008	91.11
8	0.08	0.069	13.75	0.008	90.90	0.008	90.90
9	0.12	0.07	41.66	0.008	93.33	0.008	93.33
10	0.18	0.11	38.88	0.008	95.27	0.008	95.33
11	0.05	0.05	Nil	0.031	38.00	0.031	38.00
12	0.45	0.28	37.77	0.14	71.11	0.071	84.22

feldspar present in these sands. As alkali is added in raw mix in the form of flux for manufacturing glass, so the presence of Na_2O and K_2O in small quantities is not likely to have any adverse effect on glass products.

For economic consideration, useful fraction for glass manufacturing should be between -25 + 120 mesh size. Coarser fraction higher than 25 mesh is unsuitable as it melts with difficulty and results in seed formation. Fine particles pasing 120 mesh tend to form bubbles during glass melting as more air is trapped in finer sand particles and also possess dust control problem [14].

Grain size analysis (Table 5) shows that the useful fraction of six of the twelve samples (*viz.* sample Nos. 2,3,4,8,10 and 11) lies between 55.80 to 65.11%. After washing, it shows enhancement in the range of 65.11 to 73.94% and in two samples upto 68.34 and 70.33% (sample Nos. 2 and 5 respectively). The increase in grain size is due to removal of fine clay particles. However, for economic exploitation of silica sand, the useful fraction should be above 80%. But in the silica sand under study, the useful fraction is generally in the range of 55.50 to 65.11%. It is, therefore, advisable that the waste part should be discarded at the mine site through seiving.

In six of the twelve samples (*viz.* sample Nos. 3,4,5,6,7, and 9), Fe_2O_3 was reduced from 12.50 to 41.66% by water washing bringing them close to the permissible limit of iron content for glass making. The chemical treatment of sand (Adam's process and Na_2OH process) reduces the total iron by as much as 95% (Table 8) in five samples (sample Nos. 3,7,8,9 and 10) in which the residual iron is in the range of 0.008 to 0.0058%, while in three samples (sample Nos. 1,2 and11) Fe_2O_3 was brought down to 0.017 to 0.037% (Table 8). These samples are suitable for manufacturing the quality glassware. By NaOH process in six samples (sample Nos. 3,6,7,8,9 and 10) Fe_2O_3 was brought in the range of 0.008 to 0.0085%, while in other samples (*viz.* 1,3, and 11) the residual iron was in the range of 0.017 to 0.03%.

The chemical treatment of the silica sand samples was successfully experimented for purifying silica sand using simple methods and cheap chemicals and needs trial by glass industries provided is found cost-effective.

Conclusions

Sand sample No. 12 is a mixture of sand and limestone characterized by high iron content and is therefore unsuitable for glass manufacture. Sand sample Nos. 3,5,6,7,9,10 were found suitable for colourless glass manufacturing after washing as the Fe_2O_3 content left behind (0.07%) is within permissible limit. If the iron content is small decolourisation method may be applied provided the iron oxide content of glass does not exceed 0.1% of the batch [15,16]. For this purpose frequent use is made of selenium preferebly in combination with small amount of cobalt oxide. Only 1 part of selenium per 32000-64000 parts of sand and about 1/6 of this amount of cobalt oxide [14,17] is needed to decolourise most glasses. By chemical treatment five samples were brought into or very near to the specification of optical glass i.e. 0.008% Fe_2O_3. The silica content of most of the samples were enhanced to the required limit after removing clay particles through washing. The cost of silica sand and freightage can be lowered by separating the useful fraction at the mine site. The waste material of this silica sand can be used in pottery and abrasive industries.

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