EVALUATION OF SANDS FROM DIBDIBBA FORMATION IN AL-NAJAF PLATEAU, CENTRAL IRAQ, FOR COLORED GLASS MANUFACTURING

Abdul Wahab A. Al-Ajeel*, Nawfal A. Hammodi, Suhair Z. Abdulla*** and Baha'a A. Sabbar******

Received: 18/ 2/ 2009, Accepted: 28/ 1/ 2010
Key words: Beneficiation, Silica sand, Glass sand, Scrubbing

ABSRTACT

Silica sand samples collected from Dibdibba Formation in Al-Najaf Plateau (NW Al-Najaf and Al-Kifil areas). Their chemical properties and grain size distribution were studied and evaluated for possible utilization in colored glass manufacturing. The overall results revealed, that the sands are not suitable, and required upgrading to provide them as raw material acceptable for the glass industry. In this work, techniques involving screening and attrition scrubbing have been utilized for this purpose. The results obtained indicated that the sands can be beneficiated to the grade that satisfies the requirements of colored glass industry.

تقييم رمال تكوين الدبدبة في هضبة النجف، وسط العراق، لصناعة الزجاج الملون

عبد الوهاب عبد الرزاق العجيل، نوفل عبد الرسول حمودي، سهير زكريا عبد الله وبهاء عبد المجيد صبار

المستخلص

أجريت هذه لدراسة على نطاق مختبري ومنضدي في مختبرات البحث والتطوير في الشركة العامة للمسح الجيولوجي والتعدين، وهي تعنى بتقييم رمال تكوين الدبدبة لموقعين مختلفين (شمال غرب النجف ومنطقة الكفل) من الترسبات الرملية لهضبة النجف لأغراض صناعة الزجاج الملون. وقد أشارت نتائج هذه الدراسة إلى إمكانية الحصول على منتج للرمل يصلح لصناعة هذا النوع من الزجاج وذلك بمعاملة الرمل الخام بالطرق الفيزيائية (الغربلة، ألرج والحك ألميكانيكي). بينت نتائج التحليل الكيميائي للرمل الناتج (- 0.6 + 0.106 ملم) من عملية الغربلة الجافة لرمال الكفل صلاحيتها لإنتاج الزجاج الملون، حيث أنها تحتوي على 0.2% Fe_2O_3 و 98% SiO_2. أما بالنسبة لرمال شمال غرب النجف فان الجزء الحجمي (- 0.6 + 0.106 ملم) الناتج من عملية الغربلة الجافة تحتوى على 0.4% Fe_2O_3 و 95% SiO_2. وبعد معاملة هذا الجزء بعملية الرج والحك الميكانيكي تم الحصول على رمل يحتوي على 0.27% Fe_2O_3 و 97.5% SiO_2 وهذه المواصفات تتيح إمكانية استخدام الرمال في صناعة الزجاج الملون وفق المواصفة القياسية البريطانية رقم 2975 للعام 1988.

* Expert, S.C. of Geological Survey and Mining, P.O.Box986, Baghdad, Iraq,
e-mail: wahabalajeel@yahoo.co.uk
** Expert (deceased)
*** Chief Engineer, S.C. of Geological Survey and Mining, P.O.Box986, Baghdad, Iraq.
**** Senior Engineer, S.C. of Geological Survey and Mining, P.O.Box986, Baghdad, Iraq.

INTRODUCTION

Silica sand in the form of quartz is the essential and major raw materials for glass making industry. The most commercial glass, however, in everyday use, such as colorless containers (bottles and jars), flat glass (windows, mirrors), and colored glass, uses silica sand that contain SiO_2 between (97 – 99) %. The required iron oxide (Fe_2O_3) level is of less than 0.035% for colorless glass, (0.06 – 0.1) % for flat glass and (0.2 – 0.3) % for colored glass. The grain size distribution, preferably, ranges from (0.6 – 0.1) mm (Murphy, 1960; BS. 2975, 1988; Al-Maghribi, 2004; Ushie *et al*., 2005 and British Geological Survey, 2006). Succinct, the criteria for evaluating a sand deposit as a source of glass sand are principally concerned with the chemical composition and to some extent the grain size of the sand.

Generally, silica sand deposit will require some form of processing to fulfill glass type requirements. Processing of silica sand is of varying degree of complexity, and depends on the nature of the raw materials, and the ease with which the impurities can be removed, together with the end use of the sand. At most operation processes involve washing, attrition scrubbing and sizing to remove coarse and fine fractions, and to obtain clear sand with desired particle size range. For the production of colorless glass grades, additional more sophisticated processing may be required to remove contaminating impurities from the sand.

Silica sand deposits are mostly distributed in the Western Desert of Iraq. Except for Ardhuma deposit, all other sand deposits are invariably of low grades. Ardhuma deposit, however, contain low iron oxide (0.08 – 0.1 % Fe_2O_3), and it is mainly utilized for flat glass production (glass mill in Al-Ramadi region, Western Iraq). It has been claimed (Jajjoo *et al*., 1977) that by froth flotation and attrition scrubbing, the iron oxide in Ardhuma sand can be lowered to the required level (0.027% Fe_2O_3) for the production of colorless containers, according to BS. 2975 (1988).

Other available sand deposits in Kilo 160, Kilo 180 and east Rutbah, which are located in the Western Desert, were also evaluated, and subjected to physical beneficiation techniques to achieve the desired glass sand requirements for flat glass production (Isa, 1985 and Al-Ajeel *et al*., 1988).

The present work, however, was predominantly undertaken to evaluate the sand deposit of Dibdibba Formation in Al-Najaf Plateau, located in the central part of Iraq, for colored glass making.

MATERIALS AND METHODS

▪ **Materials**

Two sand samples of Dibdibba Formation collected from different locations in Al-Najaf Plateau deposit were received, in the Ore Dressing Laboratory, Research and Development Division of GEOSURV. The first sand sample (S1) is of minus 1 mm grain size, obtained by screening raw sand (for removal of major feldspar proportion) from a quarry located about 25 Km NW of Al-Najaf town. The sand deposit of this area was investigated and selected for feldspar utilization (Al-Kabi and Abdulla, 1999). The feldspar occurs mostly as free grains of sodium and potassium type, and mainly concentrated in the coarse size fraction**.** The second sample (S2) was collected from the vicinity of Al-Kifil region, about 35 Km to the north of Al-Najaf town and 4 Km to the west of the paved road, which connects between Al-Najaf and Karbala towns.

▪ **Methods**

– **Sample Preparation**: Each sand sample (S1 and S2), as received, was thoroughly mixed, and representative specimens were drown for chemical, mineralogical (XRD) and size distribution analysis. Subsequently, the sand samples were separately screened on 0.6 and

0.106 mm sieve to remove undesirable size fractions, represented by the + 0.6 mm and – 0.106 mm, and to obtain the desired size range (– 0.6 + 0.106 mm) required by the glass industry. The yielded (S1C and S2C) sand fraction of the size range (– 0.6 + 0.106 mm) from each sample (S1 and S2) was, then divided into identical samples for further tests.

– **Sand Processing:** The technique implemented for the processing of the sand was attrition scrubbing, followed by washing and de-sliming on 0.106 mm sieve. Each sand fraction (S1C and S2C) of the size range (– 0.6 + 0.106) mm, produced from the sizing operation of samples S1 and S2, respectively, was separately treated in a Denver laboratory attrition scrubbing unit. Based on previous work (Al-Ajeel *et al.*, 2006), the sand sample was introduced into the scrubber cell and just enough water was added to make thick slurry having a solid content of (70 – 75) % wt and the machine was then operated for 15 minutes at 950 rpm. The sand was then removed from the cell and agitated in a tank for 5 minutes with water at a ratio of 1: 3 by weight (sand: water). Next screening was conducted on 0.106 mm sieve for de-sliming; the sand products (S1Cp and S2Cp) were dried, chemically analyzed and used for preparation of a glass sample for further evaluation.

– **Glass Preparation:** A glass sample was prepared by mixing a quantity of the sand (S1Cp) with appropriate additives in alumina crucible and, fused at 1400^{o} C in electrical muffle furnace. The melt was then, allowed to cool in the furnace to room temperature, removed from the furnace and then a thin glass specimen (75 × 25 × 1 mm) was cut for visible light transmission test.

– **Visible Light Transmission Test:** This test indicates the percentage of the visible light (light that corresponds to a wavelength range of (400 – 700) nanometers (nm) and, color range of violet through red) that can be transmitted through the glass (Atmospheric Science Data Center, 2008).The test was carried out by the Department of Applied Science, University of Technology.

RESULTS

▪ Chemical and Mineralogical Compositions

The chemical and qualitative mineralogical analysis of sand samples from Dibdibba Formation, collected from different locations, in Al-Najaf Plateau, are shown in Table (1).

Table 1: Results of chemical and mineralogical analysis of the studied sand samples (S1 and S2) of Dibdibba Formation from Al-Najaf Plateau (in wt %)

Sample No.	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	L.O.I
S1	93.5	0.47	2.36	<1	0.25	0.13	0.45	0.85	0.75
S2	96.3	0.29	1.5	<1	0.12	<0.07	0.2	0.41	0.5
Mineralogical composition									
Quartz, Feldspar, Iron oxide, and trace of Clay									

It can be seen from the data of Table (1), that the two samples are of different grades. Sample S1, have lower silica content (93.5% SiO_2) and higher iron oxide (0.47% Fe_2O_3), as compared with that of sample S2. Both samples, however, are of a low grade and can not be used in glass manufacturing; unless they are upgraded to the acceptable level of glass production industry, where by the colored glass production was taken in consideration, in this work the mineralogical composition however, is the same for both samples (S1and S2).

- **Size Analysis**

The size analysis results of the two raw sand samples (S1 and S2) are shown in Table (2).

Table 2: Results of size analysis of the sand samples (S1and S2)

Sieve opening (mm)	Sample (S1)		Sample (S2)	
	wt% retained	Cumulative wt% pass (under size)	wt% retained	Cumulative wt% pass (under size)
0.85	10	89.9	9.97	90.03
0.6	23.5	66.4	8.12	81.91
0.3	47.6	18.8	79.61	2.3
0.106	17.1	1.7	1.89	0.41
– 0.106	1.7	–	0.41	–

It is obvious from Table (2) that both sand samples (S1 and S2) contain appreciable amounts of undesirable oversize particles (+ 0.6 mm). The amount of the sand that passed through 0.6 mm sieve was of 66 wt% and 82 wt% for sample S1 and sample S2, respectively. Therefore, the sand samples were screened on two decks screen to remove both oversize (+ 0.6 mm) and undersize (– 0.106 mm); size fractions, to arrive at the grain size range requirements for glass manufacturing industry. The yielded sand fractions (S1C and S2C), which are in the size range of (– 0.6 + 0.106) mm from the sand samples (S1 and S2), respectively were chemically analyzed. The results are shown in Table (3).

Table 3: Results of chemical analysis of the sand range (– 0.6 + 0.106 mm) fraction of S1C and S2C (in wt %)

sample No.	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	L.O.I
S1C	95.0	0.4	2	1	0.25	<0.07	0.26	0.65	1
S2C	97.7	0.2	0.87	<1	0.15	<0.07	0.09	0.24	0.16

It can be observed from Table (3), that the classified sand fraction (S2C) obtained from the sand sample S2 was of a better grade than that of S1C obtained from the other sand sample (S1), in Al-Najaf Plateau deposit. The data of Table (3), however, also showed that, the chemical composition of the sand sample S1C does not yet met the requirements of glass manufacturing. On the other hand, it perceive that, the classification (screening) operation increased the SiO_2 and decreased Fe_2O_3 content of the sand fraction (S2C), producing sand acceptable for colored glass-making.

- **Attrition Scrubbing Tests**

The chemical analyses results of the sand products (S1Cp and S2Cp) obtained from the scrubbing experiments are shown in Table (4). These results indicate that using scrubbing technique increases the silica content and reduces the iron content of the classified sand (SIC), producing sand (SICp) containing 97.5% SiO_2 and 0.27% Fe_2O_3, acceptable for colored glass industry (BS. 2975, 1988). The data of Table (4) showed also, that the silica content of the scrubbed sand product (S2Cp) increased only slightly than that of the classified sand fraction (S2C).

Table 4: Results of chemical analysis (in wt %) of the scrubbed sand products

Test Run	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	L.O.I
S1Cp	97.5	0.27	1.58	<1	0.08	nil	0.27	0.52	0.36
S2Cp	98.1	0.1	0.73	<1	0.06	nil	0.1	0.24	0.13

▪ **Visible Light Transmission Test**

This test was carried out for further evaluation of the scrubbed sand product (S1Cp), due to its iron content (Table 4), which is slightly less than the maximum level (0.3% Fe_2O_3) that is permissible for colored glass production (BS. 2975, 1988 and Al-Maghribi, 2004).

The results of the transmission of the visible light waves test, which was conducted on: **a)** a glass specimen obtained from the glass sample that was prepared from the scrubbed sand product (S1Cp) and **b)** an Iraqi manufactured window glass specimen, are shown in Fig. (1). It can be clearly observed from this figure that the mode of the light transmittance through the prepared glass specimen is of a high resemblance to that of the Iraqi window glass. The data of Fig. (1), however, shows that, the visible light transmitted through the prepared glass sample was of about 64%, compared with about 85% of the ordinary Iraqi manufactured window glass. Obviously, this difference is due to the presence of iron oxide, which imparts a green tint color to the glass. However, it was stated (Björnsson, 1998), that visible light intensity of about 50% is considered to give sufficient natural light level; inside a building.

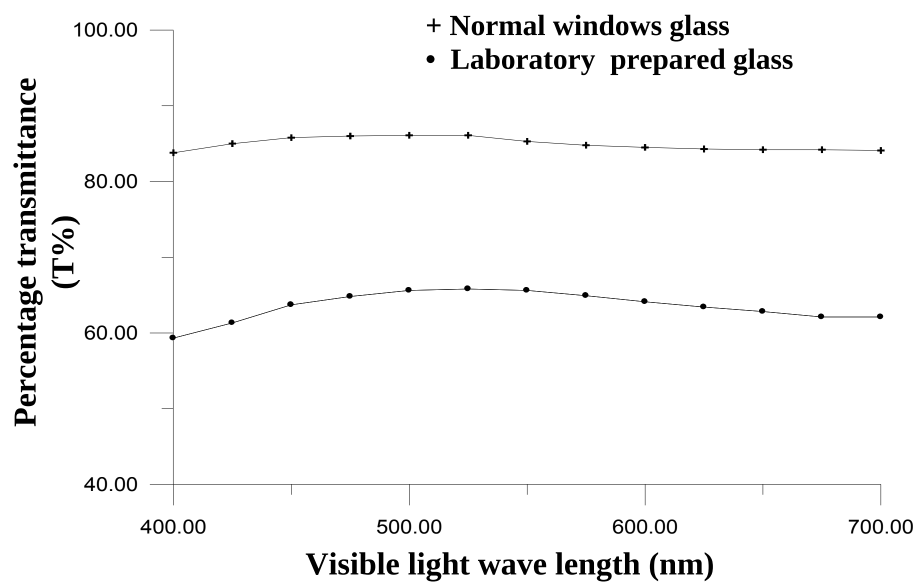

Fig.1: Transmission of visible light through normal windows glass and laboratory prepared colored glass

DISCUSSION

Silica sand deposit as a raw material for glass manufacturing industry is principally concerned with the chemical composition and to some extent the grain size distribution of the sand. Chemically, the sand that can be used for colored glass manufacturing must have a minimum of 97% SiO_2 and (0.2 – 0.3) % Fe_2O_3 (BS. 2975, 1988 and British Geological Survey, 2006). It is clear from the results of the chemical analyses (Table 1), of the sands under study that this important criterion does not met for both sands. Also the results of their size distributions (Table 2) showed, that the sands contain appreciable amounts of undesirable particle sizes, particularly that which retained on 0.6 mm screen opening. This, as a first measure, necessitates the classification of the sands to the preferable size range (– 0.6 + 0.106 mm) for glass industry (Al-Maghribi, 2004 and British Geological Survey, 2006).

Using screening alone for the classification of the sands resulted in: **a**) a suitable product for the colored glass industry from that of Al-Kifil region, it contains 97.7% SiO_2 and 0.2% Fe_2O_3**. b**) unacceptable sand product from the raw sand of NW Al-Najaf area, the sand product contains 95% SiO_2 with 0.4% Fe_2O_3.

Scrubbing the classified sand product from NW Al-Najaf led to upgrading the silica content from 95% to 97.5% SiO_2 and reduced iron content from 0.4% to 0.27% Fe_2O_3. The test performed on the classified sand product of Al-Kifil region resulted in slightly increase of the silica. It increased from 97.7% to 98.1% SiO_2, but the iron was appreciably decreased from 0.2% to 0.1% Fe_2O_3. In both cases, however, the resulting product is considered suitable for colored glass manufacturing.

CONCLUSIONS

According to the experimental results of this work the following conclusions can be drawn:

- The chemical and physical characteristics of the silica sand of Dibdibba Formation in Al-Najaf Plateau, does not satisfy the requirements of the glass making unless treated by suitable means.
- Screening of the raw sand from NW Al-Najaf, followed by attrition scrubbing can upgrade the sand, resulting in a product contains 97.5% SiO_2 and 0.27% Fe_2O_3, which is suitable for colored glass manufacturing
- Subjecting the raw sand from the vicinity of Al-Kifil to screening only, will upgrade the sand to the level required to colored glass manufacture and to colorless; if followed by scrubbing, respectively. The sand product obtained contains 97.7% SiO_2 and 0.2% Fe_2O_3., and 98.1% SiO_2 and 0.1% Fe_2O_3.

REFERENCES

Al-Ajeel, A., Daykh, B., Isa, R., 1988. Beneficiation of Kilo 180 and East Rutbah sand deposits for use in glass making. GEOSURV, int. rep. no. 1716.

Al-Ajeel, A., Abdulla, B., Al-Ka'abi, A. and Khaled, D., 2006. Beneficiation of feldspar from Dibdibba Formation sand deposit in Al-Najaf area. Iraqi Bull. Geol. Min., Vol.1., No. 2, p. 77 – 85.

Al-Ka'abi, A. and Abdulla, W., 1999. Discovery of feldspathic sand within Dibdibba Formation at northwest Al-Najaf area. GEOSURV, int. rep. no. 2517, (in Arabic).

Al-Maghribi, Mohammed-Noor. N.H., 2004. Improvement of low grade silica sand deposits in Jeddah area. JKAU: Eng. Sci., Vol.15, No.2, p. 113 – 128 (2004 A.D./ 1425 A.H).

Atmospheric Science Data Center, 2008. What wave length goes with a color. http:// eosweb.Larc.nasa.gov/.

British Geological Survey, 2006. Silica sand. www.thebgs.co.uk/ mineralsuk/ Down loads/ mpfsilica sand. pdf.

British Standard, 1988. Recommended chemical composition of glass-making sands, BS. 2975.

Björnsson, O.B., 1998. Compromise between day light visibility and thermal comfort. www2.Fjarhitun. is/ pdf.

Jajoo, Y.R., Al-Dejaili, Y., Isa, R. and Hassan, B., 1977. Beneficiation of Iraqi silica sand of Ardhuma area. GEOSURV, int. rep. no. 883.

Isa, R., 1985. Upgrading of Iraqi sand from Kilo 160 region for glass making. GEOSURV, int. rep. no. 1464.

Murphy, J.D., 1960. Distribution of silica resources in the Eastern U.S.: U.S. Geol. Survey. Bull. 10721, p. 657 – 665. Cited in: Geological study of sand deposits in the state of Michigan Technological University, Houghton, Michigan, 1977.

Ushie, F.A., Esu, E.O. and Udom, G.J., 2005. A preliminary evaluation of Otamiri River sands for the production of plain glass. Jour. Appl. Sci. Environ. Mgt, Vol.1, p. 65 – 68.