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Industrial Utilization of White Silica Sandstone in Riyadh Area, Saudi Arabia

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ABSTRACT. There are many potential sources of white silica sandstone deposits in Saudi Arabia. One of them is Biyadh Formation east of Riyadh city. To evaluate the possible utilization of such natural resource, 221 samples were collected and analyzed mineralogically (19 samples), physically (221 samples) and chemically (135 samples). Mineralogically, the sandstone is quartz arenite (> 95% quartz), and the remaining includes feldspar, mica and stable heavy minerals (opaque, tourmaline, zircon and rutile). Physically, it is medium size, moderately well sorted. Chemically, it has a high silica content (> 94% SiO_2). The conducted chemical and physical analyses revealed that the white silica sandstone in Riyadh area (untreated) is favorable for use in the manufacture of glass. For sand filtration process in water purification, the effective size of untreated sand is below the lower limits specified for such use.

A demand for proper utilization of natural resources in industry is increasing in Saudi Arabia. In general, sand and sandstones form roughly one fourth of the total sedimentary rocks (Pettijohn *et al.* 1984). Beside their volumetric importance, sand and sandstones are considered an economical resource. They could be used and utilized to produce glass, silicon chips, construction and building materials, paper filler, catalyst, as well as filtering material in water purification plants. Previous geological and industrial studies indicate a number of potential sources of white silica sandstone deposits in Saudi Arabia. Most of the studies were general and dealt with utilization of white silica sandstone in glass manufacturing (Bhutta 1961a, 1961b, 1964, Villalard *et al.* 1987). A comprehensive, detailed study was carried out with the aim of evaluating the characteristics of white silica sandstone for possible utilization in glass making and as filtering material in drinking water purification plants. This paper presents the results of mineralogical, physical and chemical analysis of white silica sandstone in Riyadh area. Discussion relevant to possible utilization in glass making and as filtering material in drinking water purification processes is also presented.

Geologic Setting

The white silica sandstone occurs in the Riyadh area as a part of Early Cretaceous Biyadh Formation (Fig. 1). The area under investigation is more than 1880 km^2, forming a flat surface interspersed with locally prominent hills. The Biyadh Formation consists of at least 400 m thick of mineralogically and texturally mature white sandstone (> 96%) of fluvial and lacustrine environments, with intercalated lenses of white, pure kaolinitic clay and white discontinuous clayey

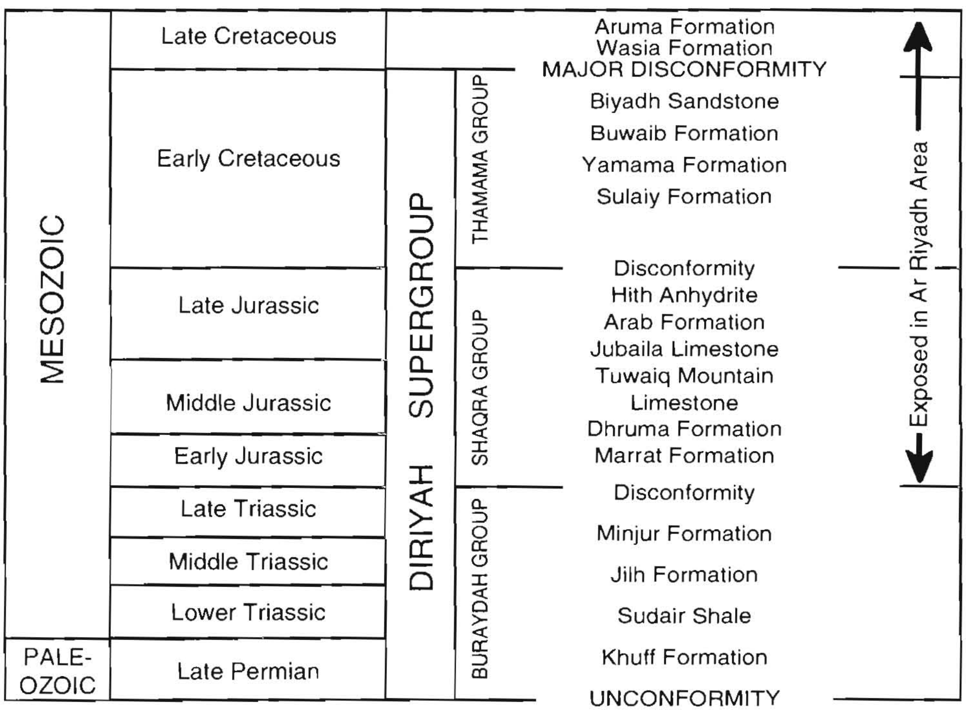

Fig. 1. Lithostratigraphy of the central Saudi Arabian Mesozoic succession (Vaslet *et al.* 1991)

sandstone. Beds of hard sandstone or quartzite crop out, capping outliers or escarpments. The Biyadh Formation is contained in a homocline dipping 1° to 2° to the east, with a general strike in the north-south direction (Moshrif 1980, Vaslet *et al.* 1991).

Materials and Methods

The study area has been divided into two sub-areas, viz Ad-Dughum and Southeast of Riyadh. The area of study lies between long. 46° 52' to 47° 38'E and lat. 24° 20' to 24° 58'N) (Fig. 2). Field traverses using E-W grid were used during the sampling process of the field investigation. The distance between each sample

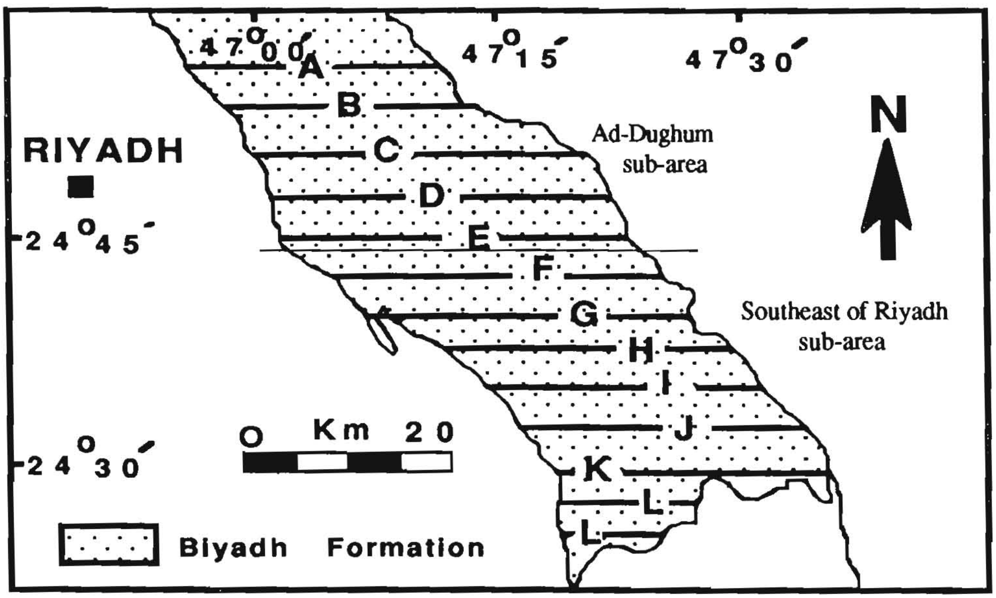

Fig. 2. Location map of white silica sandstone of Biyadh Formation - Riyadh area.

location was 1 km and between each traverse distance was 4 km. Samples were taken from the subsurface (Pits). A total of 221 samples were collected along 12 traverses, namely A, B, C, D, E, (Ad-Dughum sub-area), and F, G, H, I, J, K, L, (Southeast of Riyadh sub-area, Amjad *et al.* 1994a. Mineralogical, physical and chemical analyses were carried on 19, 221, and 135 samples, respectively.

1. Mineral analysis.

Nineteen thin sections were examined on the basis of 300-grain counts per thin section using a petrographic polarized microscope. The technique of Galehosue (1971) was used where grid spacing slightly exceeded the average grain-size, so that individual grains were not counted more than once. The samples of traverse "D" are not considered for mineralogical studies due to friable nature of sandstones.

2. Physical analysis

Grain-size analyses were performed on 221 samples and carried out with a Ro-tap sieve shaker. A 0.5ø interval was employed to provide maximum accuracy. Grain-size parameters (mean size and sorting) were obtained from values intercepted at specific percentiles on the cumulative curves (Folk and Ward 1957). The effective size and uniformity coefficient were calculated to evaluate possible utilization of white silica sandstone in water purification (Amjad *et al.* 1994b).

3. Chemical analysis

Acid solubility, loss on ignition (LOI), and chemical composition of the white silica sandstone were determined. Colorimetric and Flame Atomic Absorption Spectrometer (AAS) were used to determine the major oxides: SiO_2, Al_2O_3, Fe_2O_3, CaO, TiO_2, MgO, Na_2O, K_2O, MnO, and P_2O_5, in accordance with ASTM C 146-89 standard, American Society for Testing Materials Standard (ASTM 1989). Acid solubility was carried out according to ANSI-AWWA B100-89 standard for filtering material, American Water Works Association (AWWA 1989).

Results and Discussions

1. Mineral content

The white silica sandstone of Biyadh Formation in Riyadh area is petrographically homogeneous and mineralogically mature; the sandstone is mainly a quartz arenite over the entire area. The main mineral constiuent is quartz, which forms more than 96% of the total volume of the rock. The remaining detrital grains are feldspar, chert, mica, rock fragments and stable heavy minerals (opaques, zircon, tourmaline and rutile), Table 1. The sandstone contains restricted minerals such as quartz (chemically and physically stable mineral), which could be attributed to a lot of destruction and reduction of parent minerals during their long history of transportation and multicyclic sedimentation (Amjad *et al.* 1995).

2. Physical parameters

The average values for grain size, sorting, effective size and uniformity coefficient of each traverse have been determined and shown in Table 2. Most samples are medium sized (0.25 - 0.50 mm), and moderately well sorted. The average values of effective size(mm) and uniformity coefficient of Ad-Dughum and Southeast Riyadh sub-areas are 0.17 and 2.07, and 0.17 and 2.01, respectively.

Table 1. Average mineral content of white silica sandstone - Riyadh area

Trav.	No.	Quartz %	Feldspar %	RF %	Mica %	HM %	Cement %				Total %
							Silica	Carb.	Clay	Iron	
A	2	97.08	0.33	0.17	0.16	0.17	1.16	0.17	0.49	0.17	99.9
B	1	94.03	0.33	0.33	1.33	0.66	2.33	–	0.99	–	100
C	2	96.69	–	–	0.49	0.17	1.66	–	0.99	–	100
E	2	94.85	–	–	0.17	0.33	2.83	0.33	1.33	0.17	100
F	2	95.70	–	–	0.66	1.33	0.99	0.83	0.49	–	100
G	2	95.73	0.17	–	1.33	0.49	1.16	–	0.17	0.99	100
H	1	96.30	–	0.33	0.99	1.33	0.66	–	0.33	–	99.9
I	2	96.53	0.17	0.33	0.17	0.82	0.49	–	1.49	–	100
J	2	96.18	–	0.17	–	0.83	0.33	–	0.83	1.66	100
K	1	94.03	0.33	–	0.99	1.66	1.66	–	1.33	–	100
L	2	96.05	0.49	–	0.49	1.32	1.16	–	0.49	–	100

Trav. = Traverse No. = Number of samples RF = Rock Fragments Carb. = Carbonate
HM = Heavy Minerals

Table 2. Average of physical parameters of white silica sandstone - Riyadh area

Traverse	Physical Parameters				No. of samples
	Mean-size (mm)	Sorting	Effective size (mm)	Uniformity coefficient	
A	0.35	0.64	0.20	1.99	21
B	0.29	0.56	0.14	2.45	8
C	0.29	0.66	0.17	1.97	15
D	0.26	0.64	0.15	1.99	12
E	0.30	0.65	0.17	1.94	35
F	0.32	0.66	0.18	1.93	22
G	0.26	0.64	0.14	2.13	28
H	0.29	0.66	0.17	1.90	24
I	0.30	0.69	0.18	1.82	18
J	0.30	0.61	0.16	2.22	10
K	0.30	0.64	0.17	1.95	14
L	0.39	0.63	0.21	2.17	14

3. Chemical composition

The average values of the major oxides and loss on ignition (LOI) have been calculated, Table 3. The average percentage of total silica (SiO_2) of Ad-Dughum and Southeast Riyadh sub-areas are 95.55%, and 94.79%, respectively. Generally the sandstone in Ad-Dughum sub-area have a slightly higher SiO_2 content than Southeast Riyadh sub-area. It is evident from the chemical analysis that there is no significant trend of variation in the distribution of SiO_2 throughout the study area. However, there is slight increase in silica content in the West as compared to the East (Al-Warthan *et al.* 1994, Amjad *et al.* 1994b). The fluctuation of Al_2O_3 in the Ad-Dughum and Southeast Riyadh sub-areas is due to variation in the presence of clay and mica minerals.

Table 3. Average of chemical composition of white silica sandstone - Riyadh area

Traverse	No.	SiO_2 (%) Max.	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	TiO_2 (%)	CaO (%)	MgO (%)	Na_2O (%)	K_2O (%)	MnO (%)	P_2O_5 (%)	L.O.I (%)
A	12	98.4	97.11	0.77	0.06	0.08	0.15	0.05	0.06	0.05	0.05	0.05	0.54
B	5	94.8	89.09	3.22	0.37	0.19	1.83	0.22	0.16	0.07	0.02	0.02	3.65
C	8	99.2	97.48	1.30	0.07	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.59
D	7	99.5	96.91	1.73	0.08	0.23	0.05	0.05	0.07	0.05	0.05	0.05	0.74
E	20	99.6	97.19	1.01	0.09	0.15	0.23	0.05	0.08	0.05	0.05	0.05	0.083
F	18	99.8	98.77	0.41	0.07	0.05	0.07	0.05	0.08	0.05	0.05	0.05	0.33
G	15	99.5	97.04	1.21	0.14	0.21	0.26	0.06	0.05	0.05	0.05	0.05	0.70
H	17	98.4	95.75	1.63	0.23	0.15	0.26	0.05	0.08	0.05	0.05	0.05	1.09
I	11	99.6	97.92	0.77	0.10	0.15	0.51	0.50	0.10	0.05	0.05	0.05	0.67
J	4	99.0	97.17	0.93	0.17	0.65	0.08	0.05	0.05	0.05	0.05	0.05	0.44
K	10	99.2	84.82	1.98	0.12	0.17	0.10	0.05	0.14	0.06	0.05	0.05	0.88
L	8	99.5	92.10	1.28	0.09	0.12	0.07	0.05	0.08	0.05	0.05	0.05	0.55

No. = Number of samples   Max. = maximum   L.O.I. = Loss on Ignition

Utilization of White Silica Sandstone

1. Glass making

For glass manufacturing purposes sand should pass through No. 30 sieve (0.55 mm) and be retained on No. 140 sieve (0.15 mm). Excessive fines are undesirable because they tend to contain impurities. Coarse sands are usually rejected, as they may produce scum in the furnace. More ever, they require a high temperature and more time for fusion. According to the British Standard (BSI 1988), the sand being used for glass making should be 0.25% maximum retained in sieve of nominal aperture 0.71 mm and pass through the sieve of nominal aperture 0.125 mm upto 5% maximum.

The frequency percentage of sands (untreated) useful for glass making in Ad-Dughum and Southeast Riyadh sub-areas are 25.27% and 30%, respectively.

With regard to chemical analysis of the sandstone, the useful fraction of SiO_2 for glass making is in the range of 95.74% to 99.74%, and the acceptable fraction of Al_2O_3, Fe_2O_3, TiO_2, CaO, and LOI are in the range of 0.68% to 2.03%, 0.14% to 0.27%, 0.03% to 0.87%, 0.02% to 0.05%, and 0.12% to 0.47%, respectively. The total SiO_2 useful fraction for glass making in Ad-Dughum and Southeast Riyadh sub-areas are 72.68% and 70%, respectively. The acceptable fraction of Al_2O_3, Fe_2O_3, TiO_2, CaO and LOI in the white silica sandstone of the Ad-Dughum and Southeast Riyadh sub-areas are 70.02%, 9.16%, 72.72%, 60.06%, and 43.48% and 79.42%, 74.2%, 20.6%, 18.18%, and 57.04, respectively. Taking into consideration both physical and chemical specifications, it is found that the percentage of useful sand (untreated) for glass making in Ad-Dughum and Southeast Riyadh sub-areas are 24.17% and 27.69%, respectively.

2. Water purification

The most commonly used effective size and uniformity coefficient in filter media in water purification plants are in the range of 0.35 to 0.45 mm and 1.20 to 1.70, respectively. The white sand deposits of the study area are not suitable to be utilized in their natural condition as filtering media in water purification plants. The grain size analysis indicate that the sand deposits contain fraction that need to be separated in order to make use of such sand in water filtration.

The obtained data from sieve analysis of natural media were treated to determine the fraction that could be considered as filtering material. Treatment consisted of elimination of all media with size of 0.25 mm (No. 60 sieve) or less, which resulted in changing the overall average values of effective size and uniformity coefficient. The values of uniformity coefficient were within the recommended values, while as the effective size values revealed that the media is still fine and close to the minimum standard value. The average media fraction that need to be separated was found to be 41.9% for both Ad-Dughum and Southeast Riyadh sub-areas. This would indicate that more elimination might be carried out and a reasonable fraction can still be utilized. This would increase the effective size values to meet the standards.

Conclusions

Riyadh areas contains white silica sandstone that can be utilized in glass making. Based on physical and chemical consideration, more than 22% of the sands (untreated) can be used for such purpose. The sand in its natural condition is not suitable for utilization as filtering media in water purification plants. The average media fraction that need to be eliminated to have media with size > 0.25 mm, was found to be 41.9% in both Ad-Dughum and Southeast Riyadh sub-areas.

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الإستخدامات الصناعية للحجر الرملي الأبيض الغني بالسيليكا في منطقة الرياض – المملكة العربية السعودية

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ص .ب (٦٠٨٦) – الرياض ١١٤٤٢ – المملكة العربية السعودية

تتواجد العديد من المصادر المحتملة لرواسب الحجر الرملي الأبيض الغني بالسيليكا في المملكة العربية السعودية ، وإحدى هذه المصادر تكوين البياض شرق مدينة الرياض . ومن أجل تقويم إمكانية الإستفادة من تلك الثروة الطبيعية فقد تم جمع ١٢٢ عينة وتم تحليلها ، معدنياً (١٩ عينة) وفيزيائياً (٢٢١ عينة) وكيميائياً (١٣٥ عينة) . فمن الناحية المعدنية فإن أحجار الرمل الأبيض يتكون أساساً من معدن الكوارتز بنسبة تصل إلى أكثر من ٩٥٪ وبقية المعادن الفتاتية عبارة عن لفدسبار ومايكا وبعض المعادن الثقيلة (ماجنتيت ، تورمالين ، زركون وروتيل) . ومن الناحية الفيزيائية فإن أحجام حبيبات الحجر الرملي متوسط الحجم . ومن الناحية الكيميائية فإن ا لحجر الرملي الأبيض (الغير معالج) يحتوي على نسبة عالية من ثاني أكسيد السيليكا والتي تصل إلى أعلى من ٩٤٪ . وقد دلت نتائج التحاليل الفيزيائية والكيميائية لأحجار الرمل الأبيض الغير معالج في منطقة الدراسة إمكانية إستخدامها في صناعة الزجاج . وبالنسبة لإستخدامها في عمليات تنقية المياه فإن الحجم المؤثر للرمل الأبيض في حالته الطبيعية يجعلها غير مناسبة لتلك الإستخدامات .