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Determination Of The Suitability Of Sand Deposit In The Production Of Soda Lime Container Glass

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ABSTRACT
This study evaluated the suitability of silica sand from Marke Town, Makoda Local Government Area of Kano State, for the production of soda-lime silica container glass. The research employed a combination of sieving, X-ray fluorescence (XRF) analysis, and batch formulation to characterize the sand sample. The results revealed that the silica sand is suitable for glass production due to its high SiO_2 content ($\geq$ 90%) and low concentrations of Fe_2O_3, limestone, soda ash, and MgO. Notably, the alumina content in the silica sample eliminated the need for feldspar addition; instead, Na_2O was introduced as a flux. The findings demonstrate the potential of this silica sand deposit for glass manufacturing.
Keywords: silica sand, soda-lime glass, container glass, suitability, XRF analysis, batch formulation.

INTRODUCTION

Silica, a group of minerals composed of silicon and oxygen, is the most abundant element combination in the Earth's crust. Silica predominantly occurs in crystalline form, rarely in an amorphous state, with the chemical formula SiO_2, comprising one silicon and two oxygen atoms (Ariffin, 2004). There are three primary crystalline forms of silica dioxide:

1. Quartz: thermodynamically stable below 870°C
2. Tridymite: stable between 870°C and 1470°C
3. Cristobalite: stable above 1470°C

All three forms occur naturally, with tridymite and cristobalite being thermodynamically unstable (Muhammad, 2014). The low-temperature form, quartz, has a density of 2.65 g/cm³, whereas cristobalite, stable at high temperatures, exhibits a density range of 2.20-2.32 g/cm³, approaching that of supercooled silicon dioxide or vitreous silica (Ralph, 1955).

Glass has been a vital material for thousands of years, existing in two primary forms: natural and man-made. Natural glass forms when silica-rich rocks melt at high temperatures and cool rapidly, preventing crystallization. Volcanic glass is a prominent example of naturally occurring glass. Man-made glass, on the other hand, is produced by combining silica sand, soda ash, and lime. The addition of metallic oxides like iron, cobalt, and manganese imparts various colors to the glass. The diverse applications of glass in daily life, including window panes, light bulbs, mirrors, tableware, and packaging, have established glass manufacturing as a significant industrial sector.

Glass possesses desirable properties, such as: Inertness, high compressive strength, hardness, chemical compatibility, low permeability, and workability, all these characteristics make glass an versatile material for various uses (Gopissetti, 2008).

Glass Components and Their Roles

Glass formation relies on the combination of various oxides, which can be categorized into five primary groups: network formers, network modifiers, stabilizers, intermediate oxides, and colorants.

Network Formers: Network formers, such as SiO2, B2O3, and P2O5, are the primary glass-forming species. They create the three-dimensional network structure of glass, characterized by strong chemical bonds between oxygen anions and silicon cations (Rebecca, 1997). These oxides exhibit high melting points, viscosity, surface tension, chemical durability, and mechanical strength.

Network Modifiers: Network modifiers, including Na2O (from Na2CO3) and K2O (from K2CO3), cannot form glass independently but are combined with network formers to alter glass properties. They lower the melting temperature of network formers and are referred to as fluxes (Ajayi, 1986).

Stabilizers: Stabilizing oxides, primarily CaO and MgO, are introduced to counterbalance the effects of network modifiers. They improve glass properties and are typically added as carbonates (e.g., CaCO3) (Ajayi, 1986).

Intermediate Oxides: Intermediate oxides, such as Al2O3, exhibit amphoteric properties and octahedral structures. They cannot form glass alone but enhance chemical durability when added to soda-lime silicate glass. Al3+ ions replace Si4+ ions, forming AlO4 tetrahedra and maintaining electro-neutrality (Fatai, 1985).

These categories of oxides interact to determine the final properties of glass. Understanding their roles is crucial for producing high-quality glass with desired characteristics.

Cullet: They are broken glass and are important constituents of all glass batches. The actual amount used varies considerably. The addition of 10-15 % of cullet into the batch speeds up the melting of the batch. They are available either as rejected ware in the factory (in plant cullet) or procured from the vendors (foreign cullet) (Muhammad, 2014).

Fining agents: they are also minor additives of less than 1wt% employed to help promote bubble removal e.g. potassium nitrate (KNO_3), sodium nitrate ($NaNO_3$), sodium chloride (NaCl). They have minor effect on bulk properties, but important processing additive for large scalar production (Rebecca, 1997)

Oxidizing and reducing agents: these are introduced in the glass batch to attain precise condition in the glass melt, especially during coloration and for certain carbon materials that may be present in then batch material. Reducing raw material includes tartaric oxide while oxidizing raw materials are barium peroxide, manganese, etc. (Ajayi, 1986)

Opalizing agents: these are introduced to glass batch when transparency is not needed in glass, they are used to give the glass a milky appearance, example of these are fluorides and phosphates (Ajayi, 1986)

Colorants: they are essentially oxides with 3-dimensional (3D), 4f electric structure. They are minor additives of less than 1wt% (Rebecca, 1997)

Decolorizing agents: these are used to counter the effect of green coloration in glass as a result of impurities such as iron (ii) oxides. There are two methods of decolorizing, chemical and physical method (Ajayi, 1986)

Properties of glass

- Density
- Mechanical properties
- Viscosity
- Thermal conductivity
- Chemical durability
- Optical properties (Varshenya, 1994)

Types of glass

Soda lime glasses: Soda lime glasses or soda lime silicate glasses is perhaps the least expensive and the most widely used of all glasses made, incandescent and fluorescent lamps envelops are made from soda lime glass. It has a good chemical durability, high electrical resistivity and good spectral transmission in the visible region. Because of its relatively high coefficient of thermal expansion, is prone to thermal shock failure and prevent its use in a number of application (Khanna, 1999)

Table 1.1 Soda lime glass composition (container and float glass)

Oxides	Typical container glass (%)	Typical float glass (%)	Approximate limits (%)
SiO_2	74.42	71.86	63-81
Al_2O_3	0.75	0.08	0-2
MgO	0,30	5.64	0-6
CaO	11.27	9.23	7-14
Li_2O	0.00	0.00	0-2
Na_2O	12.9	13.13	9-15
K_2O	0.19	0.02	0-1.5
Fe_2O_3	0.01	0.04	O-0.6
Cr_2O_3	0.00	0.00	0-0.2
MnO_3	0.00	0.00	0-0.2
Co_3O_4	0.00	0,00	0-0.1
TiO_2	0.01	0.01	0-0.8
SO_3	0.16	0.00	0.-0.2
Se	0.00	0,00	0-0.1

Borosilicate glasses: Small amount of alkali added to silica and boron oxide makes a family of glasses which are utilized for their low thermal expansion coefficient and a high resistance to thermal shock. Laboratory glassware, household cooking utensils and automobile headlamps are examples of their usage. Glasses can be made commercially in a manner similar to the soda lime glasses but require slightly higher temperatures. The high cost of boron oxide (B_2O_3) makes them much less competitive compared to the soda lime glasses for common products (Khanna, 1999)

Lead silicate glasses: This family of glass contain lead oxide (PbO) and silica (SiO_2) as the glasses are utilized for their high degree of brilliance (crystal) large working range (useful to make art objects and intricate shapes without frequently reheating the glass), and high electrical resistivity. Lead oxide additions increase the fluidity of glass and its wet ability to oxide ceramics. Hence high lead silicate glasses are used extensively in microelectronics (Varshneya, 1994)

Phosphate glasses: Most types of glasses are good insulators at room temperature, although those with substantial alkali content May well be conductors in the molten state. This is because the conductivity depends mainly on the ability of the alkali ions in the glass to migrate in an electric field. However some glasses that do not contain alkali conduct electrons which jump from one ion to another. These are known as semi conducting oxides glasses and are used particularly in the construction of secondary electron multipliers. Typically they consist of mixtures of vanadium pentoxide (V_2O_5) and phosphorus pentoxide (P_2O_5) (Khanna, 1999)

METHODOLOGY

Collection of sample: The sample of silica sand was obtained from Marke, Makoda local Government Area of Kano State.

Experimental procedures

Sieve analysis: 4100g of the sample was weighed, 5g of the sample was retained in a no 600m mesh size, 266g was retained in a no 300 µm mesh size and 3820g was retained in a no 150µm mesh size, below is the table obtained from the sieve analysis.

Overall weight of sand = 4100g

Table 1.2 Sieve analysis

Sieve no	Weight of retained sand (g)	Weight of pass sand(g)	% of pass sand
600 µm	5g	4100-5=4095	99.38%
300 µm	266g	4095-266=3829	93.39%
150 µm	3820g	3829-3820=9	0.22%

Beneficiation: This is the process of improving the quality of the sand. This is important to find out the degree of improvement of sand quality after washing, the portion of the representative sample was subjected to continuous washing with water, the method is the simplest, cheapest and very effective method of beneficiation. Washing was repeated until clean water starts to flow out. After washing, the sample was dried at room temperature.

Chemical analysis: The essence of the chemical analysis is to find the percentage of iron impurities and the amount of silica as well as other oxides in the sample.

The analysis was carried out using the Mini pal equipment on an x-ray spectrometer which is an energy dispersive microprocessor controlled analytical instrument design for the detection and measurement of elements in a sample (solid, liquid and powders).

The sample (silica) was weighed and ground in a mortar and a binder was added to the sample and then carefully mixed and pressed in a hydraulic press into a pellet. The pellet was then loaded in a sample chamber of the spectrometer and maximum voltage 30kv and a maximum current of 1mA was applied to produce the x-ray to excite the sample for a preset time (10 minutes). The spectrum from the sample was analyzed and the quantity of each and every oxide was recorded.

Table 1.3 Marke silica sand sample analysis

Compound	Al_2O_3	SiO_2	P_2O_3	Cl	CaO	TiO	V_2O_5	Cr_2O_3	MnO
Conc unit	2.2%	95.5%	0.1%	0.14%	0.30%	0.28%	0.067%	0.045%	0.032%

Compound	Fe_2O_3	NiO	CuO	ZnO	ZrO_2	BaO
Conc unit	0.437%	0.05%	0.030%	0.422%	0.03%	0.34%

Batch calculation: Glass batch calculation or glass batching is used to determine the correct mix of raw materials (batch) for a melt. The raw materials mixture of glass melting is termed batch. The batch must be measured properly to achieve a given desired glass formulation ng

Table 1.4 Basis for calculation

Oxides	% Weight	Approximate range
SiO_2	74.42%	(63-81)
Al_2O_3	0.75%	(0-2)
MgO	0.30%	(0-6)
CaO	11.27%	(7-14)
Na_2O	12.9%	(9-15)
K_2O	0.19%	(0-1.5)

(Yang Z 2003)

Table 1.4 Chemical compositions of the raw materials

Compounds	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O
100g of Marke sand	95.5%	2.2%	0.30%			
100g of limestone			98.0%			
100g of MgO				96%		
100g of soda ash					89.89%	
	64.42	0.75	0.30	11.27	22.9	0.19

Table 1.5 Formulated batch

Compounds	SiO_2	Al_2O_3	CaO	MgO	Na_2O
64.84g of Marke sand	64.42	1.42	0.19		
11.31g of Limestone			11.08		
0.31g of MgO				0.30	
25.47g of soda ash					22.9
Total batch= 101.92g	64.42%	1.42%	11.27%	0.30%	22.9%

Test melting

The batch was formulated based on the result of the analysis and basic calculation. A batch consisting of 64.42% silica, 22.9% sodium oxide, 11.27% calcium oxide and 0.30% magnesium oxide was weighed and mixed thoroughly in a crucible and placed in an electrical furnace (Carbolite HTF 1800) at a temperature of 1300^0C and the temperature was held for 2hrs until homogenous mixture was obtained. After the batch has completely melted, the heating source was quenched the batch was gradually cooled.

RESULT AND DISCUSSION

The grain-size distribution and chemical analyses were carried out on the silica sand samples taken from Marke, makoda local government area of kano state. Chemical analysis showed that the sands contained more than 95% silica and low content of Fe, Al, Ca, Mg, Na, and K. The concentration levels of these components in the samples confirms with international acceptable standard for glass production. The quartz sand used the spiral classifier to improve the properties of the quartz sands to meet the standard specifications are mostly located in many areas of Makoda local government area. It can be concluded that most of the quartz sand deposits in Makoda sand investigation shows well-sorted grain-size with considerable purity, i.e. high-grade quality. The advanced works resulted in that these raw quartz sands can be used as raw material for fabrication of soda-lime, lead crystal, and lead-free high refractive index glasses. The colorless and various colored glass products have been satisfactorily used in the domestic art and glass manufactures.

CONCLUSION

This report examines the pivotal role of silica sand in glass manufacturing, highlighting its significance in producing various commodities and exploring prospects for future availability. With high demand for silica sand, this report emphasizes the need to test alternative sand types to reduce dependence on silica sand. Results indicate that the high iron oxide content (Fe2O3: 0.437%) in the silica sand sample imparted a greenish coloration to the glass. Scum formation on the glass surface was attributed to:

1. Devitrification: prolonged exposure to high temperatures, causing crystal nucleation.
2. Foreign residues: dust and unmelted batch particles.
3. Silica remnants: floating on the molten glass due to low density.

This study underscores the importance of optimizing batch composition and processing conditions to minimize defects and ensure high-quality glass production.

REFERENCES

Ajayi, S. F. (1986). Availability and exploration of sand deposits (a local and essential glass making raw material) in Bendel State.

Ariffin, K. S. (2004). What is silica? EBS 425-Mineral Preindustrial.

Arun, K. V. (1994). Fundamentals of inorganic glasses.

Khanna, O. P. (1999). Material science and metallurgy. Faridabad.

Fatai, O. A. (1985). The exploration of local raw materials and determination of their suitability for glass production in Oyo State of Nigeria. ABU Zaria.

Gopisetti, S. (2008). Cost model for a small glass manufacturing enterprise. College of Engineering and Mineral Resources at West Virginia University.

Muhammad, A. (2014). Analysis of 'Yargamji sand deposit and its suitability for glass making, using atomic absorption spectrophotometer (AAS).

Rebecca, A. K. (1997). Kubacha sand deposit in Kagarko Local Government Area of Kaduna State. ABU Zaria.

Ralph, K. I. (1995). The colloid chemistry of silica and silicates.

Yang, J. Z. (2003). Chemical interactions of barium-calcium-aluminosilicate based sealing glasses with oxidation resistance alloys. *Solid State Ionics*, 160.