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Review Article

Silica Sand and Feldspar Resources in Ethiopia: A Review of Their Occurrence, Characteristics, Industrial Applications, and Beneficiation

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Abstract

Silica sand/quartz and feldspar are strategic industrial minerals that play a vital role in glass, ceramic, foundry, construction, filtration, and chemical industries. Ethiopia has abundant occurrences of these minerals across diverse geological settings, yet their industrial potential remains underutilized due to limited systematic characterization and beneficiation studies. This review provides a comprehensive assessment of the geological occurrence, distribution, physicochemical characteristics, and industrial suitability of major silica sand and feldspar deposits in Ethiopia. Representative deposits including Mugher, Lemi, Fetra, Atsbi, Dire Dawa (Belewa), and Blue Nile Gorge for silica sand, and Kenticha, Shebelle, Negelle Borena, and Hamariesa for feldspar were evaluated using compiled physical parameters (grain size, shape, sorting, weathering, and bulk density) and chemical compositions (major oxides). The results indicate that Mugher, Fetra, and Lemi silica sand deposits exhibit high SiO_2 contents (>95%), favorable grain morphology, and low impurity levels, making them suitable for foundry applications, water filtration, construction, and amber and green glass production, with limited beneficiation. However, none of the studied deposits meet the stringent requirements for optical or float glass without advanced processing to reduce Fe_2O_3 and Al_2O_3. Feldspar deposits, particularly Shebelle and Kenticha, show promising alkali and alumina contents suitable for ceramic and glass industries, though iron removal is required to meet high-grade industrial specifications. Overall, Ethiopia possesses substantial potential to substitute imported industrial minerals and develop value-added mineral industries, provided that targeted beneficiation, infrastructure development, and systematic resource evaluation are implemented.

Keywords

Silica Sand, Quartz, Feldspar, Physiochemical, Beneficiation, Industrial Use, Ethiopia

1. Introduction

Quartz, silica sand, and feldspar are among the most significant industrial minerals essential to modern manufacturing and infrastructure development. These minerals serve as fundamental raw materials in the glass, ceramics, paint, refractory, oil and gas and geothermal drilling, metallurgy, cement and construction industries, owing to their desirable chemical purity, thermal stability, and mechanical properties [1, 2].

Globally, silica (SiO_2) forms the principal ingredient in glassmaking and foundry industries, while feldspar a group of aluminosilicate minerals rich in potassium (K), sodium (Na),

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and calcium (Ca) acts as a fluxing agent that lowers the melting temperature during ceramic and glass production and improve its mechanical strength and thermal endurance [3]. Quartz and silica sand are also indispensable in the manufacture of silicon-based materials, abrasives, fillers, and filtration media [4], whereas feldspar plays a crucial role in porcelain, enamel, and glaze formulations [5].

In Ethiopia, the demand for industrial minerals like quartz, silica sand, and feldspar has increased markedly over the past two decades due to the country's rapid industrialization, urbanization, and infrastructure expansion. Key driving factors include the expansion of construction, glass, ceramic, and cement industries, as well as government initiatives to promote import substitution and local resource utilization in line with the Ethiopian Industrial Development Strategy [6].

Extensive occurrences of quartz, silica sand, and feldspar have been documented by the Geological Survey of Ethiopia (GSE) and regional mineral exploration programs across diverse geological environments ranging from Precambrian basement terrains to Mesozoic and Quaternary sedimentary basins [7, 8]. These deposits occur in several distinct geological settings. Quartz and feldspar are primarily associated with pegmatite, granitic intrusions, and high-grade metamorphic rocks (gneiss, migmatite, and quartzite) within the Precambrian basement complexes of southern, eastern, western, and northern Ethiopia, notably the Adola-Kenticha Belt, Borena-Dawa zone, Dire Dawa, and Harer-Jigjiga basement [9, 10]. Silica sand deposits, on the other hand, are mainly derived from Mesozoic sandstones, Tertiary volcanic weathering profiles, and Quaternary alluvial and lacustrine environments, with significant accumulations in the eastern (Ogaden), central (Awash and Blue Nile basin), northern (Mekele basin), western (Gambella basin), and southern Ethiopia (Omo basin) [11, 12].

Despite the abundance of such occurrences, systematic evaluation, beneficiation, and quality assessment studies remain limited. Most deposits are still at reconnaissance or preliminary exploration stages, and further physicochemical and mineralogical characterization including X-ray fluorescence (XRF), X-ray diffraction (XRD), inductively coupled plasma (ICP) spectroscopy, scanning electron microscopy (SEM), and quantitative physical analysis (grain size and shape, grain size distribution) is required to assess their industrial suitability. The economic viability of these resources depends mainly on their chemical purity (SiO_2, Al_2O_3, and Fe_2O_3 contents), grain morphology and size, and proximity to infrastructure and markets [1].

The objectives of this review are summarized as follows: (1) to present a comprehensive overview of the geological occurrence, distribution, and mineralogical and physicochemical characteristics of quartz, silica sand, and feldspar deposits in Ethiopia; (2) to evaluate their chemical composition, impurity levels, and physical properties against international standards, and suggest possible beneficiation methods using representative analytical data; and (3) to identify challenges, opportunities, and strategies for enhancing the sustainable development of these mineral resources.

2. Geological Occurrence and Distribution in Ethiopia

2.1. Major Silica Sand Deposits in Ethiopia

Silica sand deposits in Ethiopia are widespread, reflecting the country's diverse geological settings, ranging from Precambrian basement rocks to Mesozoic sandstones and Quaternary alluvial sequences. These deposits are of significant industrial importance due to their high silica (SiO_2) content, low impurity levels, and suitability for applications in glass, ceramics, foundry, water treatment, oil and gas, paints and porcelain, cement and construction industries. Several major and minor silica sand deposits occurrences have been reported in different parts of Ethiopia by many academic researchers and GSE experts, as shown in (Table 1).

Table 1. *The geological and industrial characteristics of major silica sand deposits in Ethiopia.*

Deposit type	Exploration status	Reserve (tons)	Geological setting	mineralogy & physico-chemical characteristics	Industrial Applications	Reference
Lemisilica sand	Detailed	6.94 × 109	Mesozoic sandstone and Quaternary alluvial	Dominated by quartz, minor feldspar, clay minerals with Fe_2O_3 (<0.1%), Al_2O_3 ~1%, hard, angular to sub-rounded grains; specific gravity ~2.65 g/cm^3	Manufacturing of container glass, fiberglass, and foundry casting. For the highest grades of glass, such as clear float glass or optical glass, the alumina (Al_2O_3) and potassium oxide (K_2O) levels might require further beneficiation or blending.	[13]
Fetra silica	Detailed	5 × 106	Mesozoic sandstone and Quaternary alluvial	Quartz-rich sandstone, minor feldspar and clay,	all glass types except the high grade one and ceramic production,	[14]

Deposit type	Exploration status	Reserve (tons)	Geological setting	mineralogy & physico-chemical characteristics	Industrial Applications	Reference
sand			specifically hosted by Debire libanos sand stone (DLS)	sub-rounded grains, moderate purity	foundry sands, construction materials	
Mugher silica sand	Detailed	3.4 × 106	Mesozoic sandstone and Quaternary alluvial	Quartz (96-98%), feldspar (4%), muscovite (1-3%) and accessory minerals like magnetite, ilmenite, graphite and garnet	It is well-suited for the manufacturing of High quality glass (including clear sheet/float glass, container glass, and tableware) Fiberglass Specialty glass (e.g., for lighting, laboratory ware) Other high-purity applications in ceramics and chemicals	[15]
Enticho silica sand	Detailed	-	Paleozoic-Mesozoic sandstone and Quaternary alluvial	Extremely pure α-quartz, negligible impurities, fine-grained, chemically stable	Specialty glass, laboratory-grade silica, electronics, high-purity industrial applications	-
Atsbi/Sasada silica sand	Detailed (1: 5000)	5.95 × 108	Mesozoic sandstone and Quaternary alluvial	Quartz-dominated sand, minor feldspar and clay, with fine to medium grain and rounded to sub rounded grains, with white to yellowish and reddish color and bulk density of	Construction applications (concrete, mortar) Foundry sandformetal casting Medium-grade glass production and Water filtration media and others	[16]
Dire Dawa (Belewa) silica sand	Detailed	3.1 × 107	High grade metamorphic rocks and intrusive (granite and pegmatite) Mesozoic sediment and Quaternary alluvial	Dominantly Quartz and minor feldspar rich sand with moderate iron content (~1-2%), mixed grain sizes	Used for Construction materials, and all typesfiber glass industries, not suitable for high grade glass production and foundry industries unless its impurities (iron, titanium and alumina) are removed by advanced processing methods like floatation and acid leaching	[17]
BlueNile gorge (Amenti. A, 1973)	Detailed	-	Pre-Adigrant sand stone,	dominantly quartz and minor feldspar with lithic fragments	Unsuitable for flint glass due to high Fe_2O_3, Cr_2O_3 and Al_2O_3 in both chip and core samples but the SiO_2 is 96.1 and 89.5% respectively.	[18]
Harare - Jijiga (Somali region)	Reconnaissance	-	Paleozoic-Mesozoic sandstone and Quaternary alluvial	Quartz with variable purity, minor feldspar and clay, iron oxides	Construction aggregate, potential for industrial processing after beneficiation	-

2.2. Major Feldspar Deposits in Ethiopia

Ethiopia has significant feldspar deposits, which are critical raw materials for the glass, ceramic, and enamel industries. These occurrences are primarily associated with pegmatite bodies intruded into the country's basement complex. The most notable deposits are located at Kenticha, Shebele, Negelle, and in the Hamariesa area near Harare, each with distinct characteristics and potential (Figure 1). Feldspar has also been reported in western (Wollega and Assosa) and southern (Kaffa) Ethiopia [19].

2.2.1. Kenticha Feldspar Deposit

Kenticha deposit, situated approximately at 09°09'N, 38°38'E, is the most substantial known feldspar resource in Ethiopia and a strategically important asset for the national mining sector. With a significant estimated resource of 500,000 tons, it is the country's largest known deposit, hosted within a pegmatite formation containing both potassium feldspar and quartz and minor muscovite with accessory minerals like, apatite, beryl, garnet and biotite. Its industrial potential is clearly delineated by its chemical composition: thepure feldspar component, with a high potash (K_2O) content of 11.9% and a critically low iron oxide (Fe_2O_3) level of 0.17%, meets all requirements for 1st grade raw material in sheet glass production. In contrast, the mixed quartz-feldspar material is diluted, exhibiting a lower K_2O content (5.0%), a higher and industrially prohibitive Fe_2O_3 level (0.63%), and elevated silica (SiO_2 70.5%), rendering it non-conforming without further processing. It is conclusively established that the pure feldspar within the deposit meets the requirements for sheet glass production in both quantity and quality, making it a primary target for future large-scale industrial development [15].

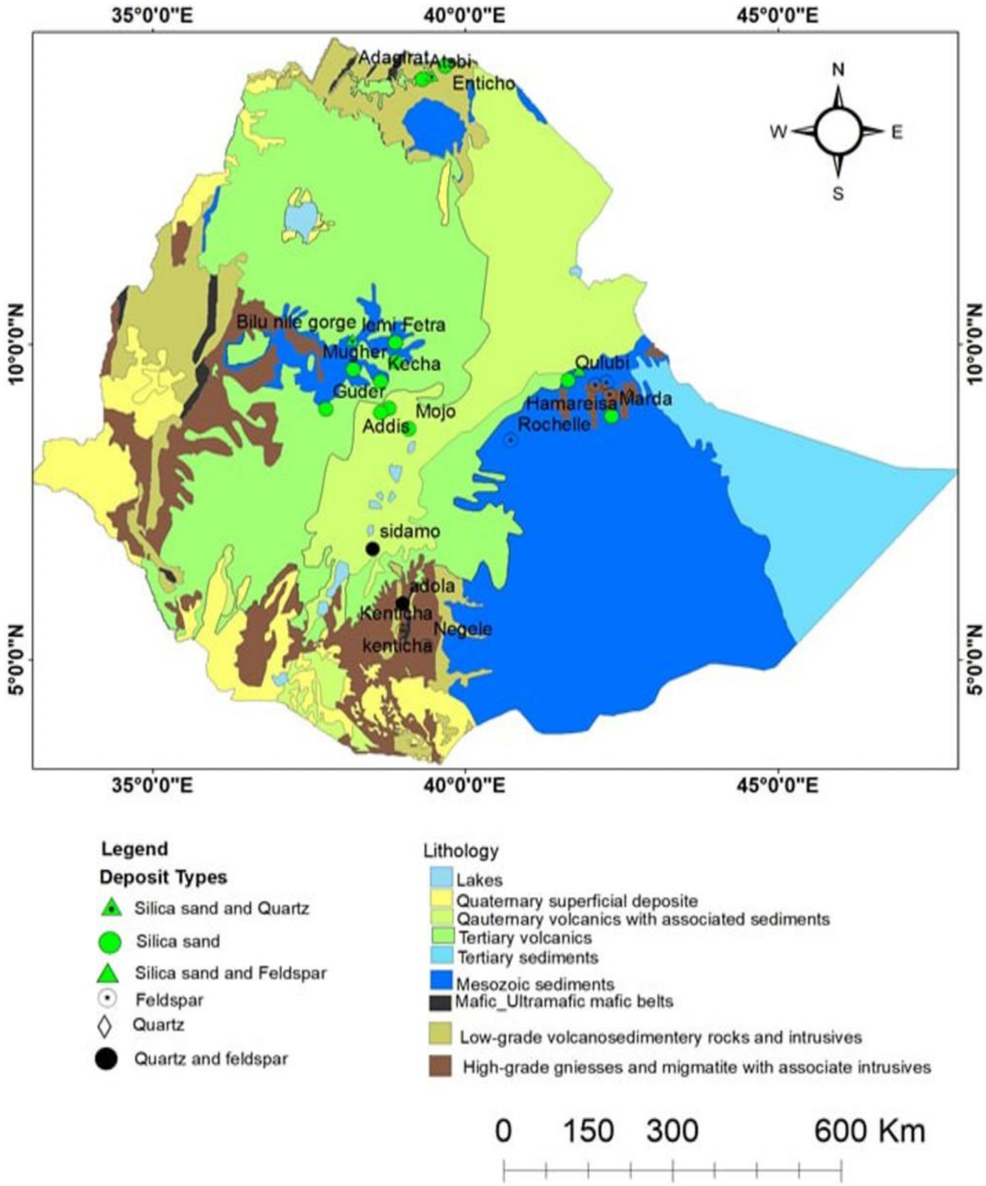

Figure 1. *Geological map showing the occurrences of silica sand, quartz and feldspar deposits in Ethiopia [21].*

2.2.2. Shebelle Feldspar Deposit

The Shebelle deposit, located approximately 80 km from Harar on the road to Jigjiga and it is relatively well-studied pegmatite field renowned for its high-quality potassic feldspar. With a preliminary estimated resource of 25,000 tons, its geology consists of coarse-grained pegmatite intruded into biotite schist and gneisses, with a primary mineral assemblage of Orthoclase (K-feldspar), quartz, and muscovite with accessory biotite, tourmaline, and garnet. The main impurity, iron, is introduced by accessory biotite. The deposit's exceptional quality is demonstrated by high-purity zones with an iron oxide (Fe_2O_3) content of just 0.07% to 0.08%, which meets strict industrial standards. Crucially, even the average ore, with a Fe_2O_3 content of approximately 0.24%, responds very well to beneficiation methods like magnetic separation and flotation without acid leaching that allowing it to be easily upgraded to a high-value concentrate containing less than 0.1% Fe_2O_3. Due to these characteristics, the Shebelle deposit is an excellent candidate for further exploration and development, with high potential to yield minable reserves of high-quality, alkali-aluminous raw material for the glass industry [19].

2.2.3. Negelle Feldspar Deposit

The Negelle-Borena deposit, situated in the Oromia region about 50 km from Kibremenghist near the town of Negelle, is a defined but lower-grade pegmatite occurrence. It is estimated to contain a resource of 14,500 tons, hosted within a single, wide pegmatite dyke composed of feldspar, quartz, and biotite. The primary challenge for this deposit is its inherently higher iron content, with Fe_2O_3 values in channel samples ranging from 0.27% to 0.89%, placing it at a significant qualitative disadvantage compared to other deposits. This elevated iron, attributed to the presence of magnetite and biotite, classifies the material as poor quality in its raw state. Consequently, its industrial potential is considered limited, as it would require effective and cost-efficient beneficiation methods to be utilized for premium applications like clear glass manufacturing [19].

2.2.4. Hamariesa Feldspar Deposit

The Hamariesa deposit, located in the Hamariesa area of the Oromia Region, contributes significantly to the mineral potential of eastern Ethiopia. Geologically, it occurred in granite intrusion and characterized by mineral assemblage, consisting primarily of Orthoclase (K-feldspar), quartz, and muscovite (white mica), with biotite (dark mica) occurring as the main accessory mineral. The rock is coarse-grained and generally non-differentiated; however, a key positive feature is the presence of localized segments that show valuable mineral concentrations, such as distinct streaks rich in orthoclase or muscovite. These concentrations significantly enhance the deposit's economic potential by increasing the feasibility of producing high-purity feldspar concentrates through selective mining or straightforward processing methods. While a specific resource estimate has not yet been established, these promising geological characteristics strongly warrant systematic prospecting and further evaluation to determine the full scale and commercial quality of the deposit [20].

3. Physiochemical Characteristics

3.1. Physical Characteristics

From an industrial perspective, Ethiopian silica sand and feldspar deposits exhibit a range of physical properties that determine their suitability for various applications. Atsbi silica sand, moderately weathered at the surface with a thin iron-stained overburden, is fine to medium-grained (0.1-0.5 mm), sub-rounded to rounded, and easily excavated, making it suitable for general industrial uses [16]. Lemi sand, moderately to intensively weathered, is well-sorted, rounded, and low in fines (1.18 %), ideal for applications requiring minimal processing [13]. Mugher and Fetra sands are low-weathered, high-purity, and well-rounded, making them suitable for proppants, filtration, and high-quality silica applications. According to [17] Dire Dawa (Belewa) sand, highly weathered and clay-rich with angular grains, requires significant washing before industrial use. Feldspar deposits including pure feldspar, feldspar-quartz, Shebelle, and Negelle Borena are coarse-grained, crystalline, and hard, largely unweathered, and are appropriate for ceramics, glass, and industrial fillers.

Table 2. The physical characteristics of silica sand and feldspar deposits in Ethiopia.

Deposit Type	Bulk Density (g/cm^3)	Degree of Weathering & Alteration	Grain Size	Grain Shape	%Fines (<0.075 mm)	Color	Remark
Atsbi Silica Sand	2.65	Moderate surface weathering: 0.5-0.7 m of iron-stained, brownish overburden. Minimal alteration at depth, becoming pure white.	Fine to medium (0.5 to 0.1 mm)	Sub rounded to rounded		White - yellow ish and brown ish	Massive, weakly cemented deposits; easily excavatable after removing thin overburden.
Lemi Silica Sand	1.9	Moderate to intensive weathering: loosely consolidated, suggesting chemical weathering has weakened cement.	0.34 - 0.50mm Sand (97.18%), gravel (1.93%), and Mud-sized (1.21%)	Dominantly rounded to well round, high to	1.18	Whit-ish	Well-sorted and unconsolidated; ideal for minimal processing.

Deposit Type	Bulk Density (g/cm^3)	Degree of Weathering & Alteration	Grain Size	Grain Shape	%Fines (<0.075 mm)	Color	Remark
				medium sphericity			
Mugher Silica Sand	1.6	Low weathering: derived from weakly cemented sandstone; retains high purity and rounded grains.	0.5 - 0.1 sand size (85.5%), >0.5 (0.66%) and <0.1 clay sized (14.82)	Rounded		White	High sphericity and roundness; excellent for proppants and filtration.
Fetra Silica Sand	1.8	Low weathering: similar to Mugher, with loose consolidation indicating minimal chemical alteration.	sand-size grains are predominant with (97.24%) 92.3% are found (0.60-0.15 mm, Gravel (0.99) and mud (1.17%) with D50 (0.34 - 0.50) with aver D50=041mm medium sizeSand grains.	Predominantly rounded with less spherical sand grain Cu=1.3>0.1-0.9, Cc=2.18	1	Whitish	Well-graded and uniform, suggesting for foundary, water treatment and filtration and proponants in oil and gas industry
Blue Nile Gorge Silica Sand	-	-	-	-		-	It requires investigation
Gelemso (Kulubi) Silica Sand	-	-	-	-		-	-
Sidamo Silica Sand	-	Unknown: not characterized; weathering profile unconfirmed.	-	-		-	It requires investigation
Dire Dawa (Belewa) Silica Sand	1.47-2.35	High weathering and alteration: surface is clay-rich and stained; high Al_2O_3 and LOI suggest significant alteration and impurity concentration.	Characterized by medium to fine grained size with 16.23% granule, 35.43% sand and 6.5% silt size	Sub rounded to sub angular	6.5	White (at depth)	Variable grain sizes and poor sorting due to weathering; requires significant washing.
Pure Feldspar	-	Low weathering (fresh rock): hosted in hard pegmatite; slight surface discoloration possible but largely unweathered.	Coarse (in pegmatite)	Crystalline / Anhedral		White, Pink	Hard, competent rock; requires blasting and crushing.
Feldspar-Quartz	-	Low weathering (fresh rock): crystalline rock, largely unweathered; quality variation is primary, not due to alteration.	Coarse (in pegmatite)	Crystalline / Anhedral		White, Mixed	Hard rock; “mixed” nature is primary feature, not due to weathering.
Shebale Feldspar	-	Low weathering (fresh rock): high-quality unweathered pegmatite; low Fe_2O_3 indicates minimal oxidative weathering.	Coarse (in pegmatite)	Crystalline / Euhedral		White, Pink	Coarse-grained with well-formed crystals; hard and competent.
Negelle Borena Feldspar	-	Low weathering (fresh rock): high iron content is primary (from biotite), not a result of surface weathering.	Coarse (in pegmatite)	Crystalline / Anhedral		White, Brownish	Hard rock; biotite content intrinsic, making it susceptible to iron staining when crushed and exposed.

3.2. Major Oxide Compositions

The economic value and industrial applicability of industrial minerals such as silica sand, quartz and feldspar are fundamentally determined by their chemical composition. Unlike metallic ores, the value of these industrial minerals is derived from the presence of desirable major oxides and the strict limitation of deleterious impurities, particularly iron and titanium oxides, clay content and heavy minerals which can cause lowering of the quality of glass and ceramic products [1]. The average major oxide compositions of key deposits are presented in Table 3.

As shown in Table 3, the Mugher silica sand deposit shows the highest chemical purity, with an average SiO_2 content of about 95.46% and minimal Fe_2O_3 (~0.44%), confirming its premium quality. However, the Lemi, Fetra, and Atsbi deposits showmoderate purity with acceptable value of silica and slightly higher iron values while the Belewa-Dire Dawa deposit represents a lower-grade material due to reduced silica and elevated alumina contents. Among the feldspar deposits, the Shebelle feldspar deposit is ideal for potassium feldspar production owing to its high K_2O and Al_2O_3 contents with very low Fe_2O_3. Conversely, the Negelle feldspar shows higher and inconsistent Fe_2O_3 levels, lowering its industrial suitability. The Kenticha feldspar, however, demonstrates variable but promising chemistry, with SiO_2 ranging from 65.7% to 70.5%, Al_2O_3 between 16.3% and 18.6%, and K_2O and Na_2O contents of 4.8-7.0% and 4.9-5.4%, respectively, indicating potential for use in both potassium and sodium feldspar industries despite moderate Fe_2O_3 levels (0.5-0.7%).

Table 3. *Average Major Oxide Composition of major Ethiopian silica sand, quartz and feldspar deposits (%) in Ethiopia.*

Deposit type	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	MgO	MnO	P_2O_5	Cr_2O_5	LOI
Atsbi Silica Sand	95.45	2.75	0.44	0.03	0.04	0.09	0.39	0.06	<0.01	<0.01	-	1.14
Lemi silica sand	95.66	1.94	0.95	0.17	0.49	0.02	0.02	0.03	0.01	0.01	<0.01	0.4
Mugher Silica Sand	96.48	1.46	0.19	0.1	0.5	0.06	-	-	-	-	<0.01	0.1
Fetra silica sand	96.65	1.35	0.85	0.13	0.06	0.04	0.06	0.03	-	-	<0.01	0.39
Blue Nile gorge silica sand	95.7	1.91	0.3	0.1	1.02	0.1	0.1	0.1	-	-	-	-
Gelemso (Kulubi) silica sand	93	-	-	-	-	-	-	-	-	-	-	-
Sidamo silica sand	95	-	-	-	-	-	-	-	-	-	-	-
Dire Dawa (Belewa) silica sand	91.1	6.25	0.18	0.06	0.08	<0.01	1.63	0.09	0.01	<0.01		2.55
Pure feldspar	65.7	18.6	0.5	-	4.9	7	0.2	0.1	-	-	-	0.7
Feldspar-quartz	70.5	16.3	0.7	-	4.8	5.4	0.6	0.2	-	-	-	2.7
Shebale Feldspar	70.96	18.04	0.24	0.002	9.45	1.41	0.56	0.15	-	-	0.018	-
Negelle Borena Feldspar	66.0	18.5	0.58	0.04	10.0	2.75	0.45	0.3	-	-	-	0.65

4. Industrial Applications and Specification Standards

4.1. Possible Industrial Applications of Silica Sand

Different silica sand, quartz and feldspar-consuming industries require different physicochemical attributes [22]. Assessing the physicochemical attributes and mineralogical character of these minerals is needed to ensure the suitability of industrial minerals for different industries.

4.1.1. Glass Industries

To establish the acceptability of silica sand deposits for the glass industry grain size, grain shape, and chemical composition are the major attributes examined [22, 23]. For example Silica sand deposits must have a substantial number of sand grains ranging in size from 0.5 mm to 0.09 mm to be useable in the glass industry. Glass sand's color, transparency, and melting qualities are all controlled by its chemical composition [23] SiO_2 is a desirable oxide for glass formation since it is used to make silicates, which make up the majority of the glass [24] Green glass, sheet glass, amber glass, and flint glass require a minimum of 95% SiO_2, whereas optical glass requires 99.8% SiO_2. The allowable iron concentration for the common varieties of glass is as follows: optical glass

(0.013%), float glass (0.1% ± 0.005), colored container glass (0.25% ± 0.03), and fiberglass (0.3% ± 0.03), in decreasing order of quality [25]. The inclusion of Al_2O_3 and TiO_2 raises the melting temperature of glass sand and reduces transparency [24, 26] recommended a maximum of 1.5% Al_2O_3 and 0.1% TiO_2 for sand deposits used in glass production. When the average silica percentage of Lemi silica sand samples (96.13%) is compared to British and Norton glass requirements, it is clear that the deposit has enough silica to produce green and sheet glass. The average quantity of Fe_2O_3 (0.95) limited the suitability of the studied silica sand deposit for the manufacturing of amber glass that tolerates Fe_2O_3 up to 1%. According to [27], fiberglass can be made with silica sand that contains less than 1% Fe_2O_3. The iron content of the analyzed sand is found to be within the acceptable range for fiberglass manufacture using this standard.

From the Table 4, Mugher, Lemi, Fetra, and Atsbi silica sands are most suitable for amber and green glass production, where higher Fe_2O_3 is acceptable for coloration. Fetra, with slightly higher purity and lower Fe_2O_3, is marginally better for flint or clear glass after beneficiation. In contrast, Belewa-Dire Dawa sand, with high Al_2O_3 (6.25%) and low SiO_2, is unsuitable for standard glassmaking but may be used in fiberglass or ceramics. Currently, no Ethiopian deposit meets optical or float glass standards due to low SiO_2 and elevated Fe_2O_3, necessitating advanced purification such as magnetic separation or acid leaching.

Table 4. Suitability of major Ethiopian silica sand deposits for glass manufacturing based on [24] specifications.

Glass Type	SiO_2 (min%)	Al_2O_3 (max%)	Fe_2O_3 (max%)	Mugher (95.46, 1.46, 0.44)	Lemi (96.13, 1.95, 0.96)	Fetra (96.65, 1.35, 0.85)	Atsbi (95.45, 2.24, 0.75)	Belewa-Dire Dawa (91.10, 6.25, 0.18)	Suitability
Optical glass	99.8	0.10	0.02	✗	✗	✗	✗	✗	Not suitable - Fe_2O_3 too high
Flint containers	98.5	0.50	0.035	✗	✗	✗	✗	✗	Not suitable - Fe_2O_3 exceeds limit
Flint glass	95.0	4.00	0.035	✓ (partially)	✓ (partially)	✓ (partially)	✓ (partially)	✗	Suitable after Fe_2O_3 reduction
Sheet /Float glass	98.5	0.50	0.06	✗	✗	✗	✗	✗	Requires beneficiation; Fe_2O_3 too high
Green glass containers	98.0	0.50	0.30	✗	✗	✗	✗	✗	SiO_2 below requirement; Fe_2O_3 too high
Green glass	95.0	4.00	0.30	✓ (partially)	✓ (partially)	✓	✓	✗	Suitable after minimal beneficiation
Amber glass containers	98.0	0.50	1.00	✓	✓	✓	✓	✓	Suitable for amber glass with high Fe_2O_3 tolerance
Amber glass	95.0	4.00	1.00	✓✓	✓✓	✓✓	✓✓	✓	Fully meets specification

✗: not feet, ✓: partially fit&✓✓: directly used.

4.1.2. Foundry Industry

Silica sand is utilized to make molds and cores for metal casting [28]. The sand should be sufficiently available at low cost and should possess appropriate physicochemical properties [29]. Grain size distribution, particle shape, refractories, and chemical composition are the critical properties studied from silica sand to determine its quality for foundry use. Grain size controls the permeability and the binder requirement of molding sand and the surface smoothness of metal [29]. Fine sands produce a binder. On the other hand, coarser sands have higher permeability and demand less binder volume. However, they value of Lemi silica sand (0.34-0.5 mm) suggest, that sand grains constituting the deposit are dominantly medium grain. Uniformly graded silica sand offers maximum permeability for the escaping of gas. According to Indian standard [30], high silica sand for foundry purposes shall have narrow grading with 70% or more grains and should retain only three consecutive sieves. According to Brown [29], a minimum of 95.0% of sand grains should be spread only on four or five subsequent screens to give sufficient permeability. Similarly, to the above specifications, 74.1% of Lemi silica sand grains are retained on three consecutive sieves (0.425 mm, 0.3 mm, and 0.15 mm), or 94.0% of sand grains are reserved on five consecutive screens having a diameter of 1.18 mm, 0.6 mm, 0.425 mm, 0.3 mm and 0.15 mm Table 6. Unwanted elements in Foundry sand include CaO, Fe_2O_3, Al_2O_3, Na_2O, K_2O, MgO, and organic materials reduce the quality of foundry sand [31]. CaO increases the acid demand values of the sand. [29] Stated that a maximum of 0.5% of the LOI should be used to choose a sand deposit for foundry use. Based on [29, 30] criteria, the chemistry of the Lemi silica sand deposit for foundry usage revealed that the deposit has a high potential for a source of high-quality foundry sand. The presence of grains smaller than 0.075 mm increases the requirement for binder and reduces the permeability of molding sand [32]. According to the Indian Standard [30], the recommended maximum fine content is 4%, whereas [29] specified that the fine content should be less than 2%. For selecting silica sand for foundry applications. Lemi silica sand has an average of 1.18 percent of grains below 200 meshes (Table 5).

Table 5. *Suitability of Major Ethiopian Silica Sand Deposits for foundry industries [29, 30].*

Deposit Type	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	Na_2O +K_2O (%)	LOI (%)	Grain Size (mm)	% Grains Retained (3 sieves)	% Grains Retained (5 sieves)	% Fines <0.075 mm	IS/Brown Standard	Compliance	Suitability
Lemi Silica Sand	95.66	1.94	0.95	0.02	0.03	0.51	0.40	0.34-0.50	74.1	94.0	1.18	$SiO_2 \geq 95\%$, $Fe_2O_3 \leq 1\%$, LOI $\leq 0.5\%$, fines <2%, 3-5 sieve retention >70%	✓	High-quality foundry sand
Fetra Silica Sand	96.65	1.35	0.85	0.06	0.03	0.10	0.39	0.30-0.48	72	92	1.0	Same as above	✓	Suitable
Mugher Silica Sand	96.48	1.46	0.19	-	-	0.56	0.10	-	-	-	-	Same as above	✓	Excellent
Atsbi Silica Sand	95.45	2.75	0.44	0.39	0.06	0.13	1.14	-	-	-	-	Same as above	⚠	Acceptable (LOI slightly high)
Dire Dawa (Belewa)	91.10	6.25	0.18	1.63	0.09	0.09	2.55	-	-	-	-	Same as above	✗	Not suitable

4.1.3. Water Filtration and Treatment

Chemical composition, grain size distribution, grain size and grain shape are the basic criteria for selecting silica sand for filtration and treatment purposes [32]. Chemical composition controls the inertness of the sand from reacting with toxic substances present in wastewater, for using high silica sand as filtering media specified a minimum of 80% of SiO_2 and a maximum of 90% of SiO_2 and a maximum of 2% of Fe_2O_3 for the lowest-grade and a maximum of 0.7% of LOI used as filter media sand (Table 5). A comparison of the SiO_2 content, Fe_2O_3 content, and LOI content in Lemi silica sand samples with the specifications shows that it is an ideal material for use in water filtration and treatment. Silica sand grain determines how fast water can be purified [33]. While finer sands provide slower filtration; they are more effective in producing high-quality water. Coarser sands provide speedier filtration but yield less quality water. Medium-size sand grains are ideally suited to be filtering media [32]. In addition to the actual grain size, uniformity of grain size also controls the suitability of sand for filtration use [33], set out the limits of the Cu, and effective grain size (D10) of silica sand used for filtration. Accordingly, silica sand having Cu up to 3 and D10 above 0.15 mm is appropriate as filtering media. If the Cu value is less than 1.50 and D10 is above 0.55 mm, the sand is used for rapid filtration. Whereas, if the coefficient of uniformity (Cu) is between 1.60 and 3.0 and D10 between 0.15 and 0.55 mm is used in slow filtration. The average value of Lemi silica sand D10 (0.24 mm), Cu (1.9), and coefficient of curvature (*Cc*) value is (1.30) reveal, that Lemi silica sand deposit is characterized by the abundance of medium size uniformly graded sand grains. Based on those specifications, the properties of the studied silica sand deposit make it an appropriate resource from which filter media sand particularly used for slow filtration can be extracted. The grain shape of silica sand chiefly determines the proportion of pore space available for the passage of water

[33]. Rounded and spherical sand grains offer more space for the efficient flow of water. In contrast, angular and elongated grains lock and inhibit flows in the filtering media. Lemi silica sand deposit is mostly rounded to well-rounded, less spherical sand grains. Except for the sphericity, the roundness of sand grains is found in the recommended range for use in water filtration and treatment (Table 6).

Table 6. Suitability of Major Ethiopian Silica Sand Deposits for water treatment and filtration.

Deposit Type	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	Na_2O $+K_2O$ (%)	Grain shape and uniformity	LOI (%)	D10	Cu	Grain size & uniformity (Chatterjee, 2009))	BS EN 12904 (2005): D10 >0.15 mm, Cu ≤3	BIS 8419 (1977): SiO_2 ≥90%, LOI ≤0.7%	Compliance	Suitability
Lemi Silica Sand	95.66	1.94	0.95	0.51	Rounded and well sorted	0.40	0.19 mm	2.25	Same as above	Same as above	Same as above	✓	suitable
Fetra Silica Sand	96.65	1.35	0.85	0.10	Rounded and well sorted	0.39	0.20 mm	Cu = 2.18	Same as above	Same as above	Same as above	✓	Suitable
Mugher Silica Sand	96.48	1.46	0.19	0.56	Rounded and well sorted	0.10	-	-	Same as above	Same as above	Same as above	✓	suitable
Atsbi Silica Sand	95.45	2.75	0.44	0.13	Rounded and well sorted	1.14	-	-	Same as above	Same as above	Same as above	⚠	Acceptable (LOI slightly high)
Dire Dawa (Belewa)	91.10	6.25	0.18	0.09	Sub rounded to rounded and	2.55	-	-	Same as above	Same as above	Same as above	✗	Not suitable

4.1.4. Summary of International Quality Standards for Silica Sand

The five major Ethiopian silica sand deposits Fetra, Lemi, Mugher, Atsbi, and Dire Dawa (Belewa) show varying suitability across different industrial applications based on international quality standards. For the foundry industry, Fetra, and Lemi meet [29, 30] specifications for grain size and Mugher also best suitable based on chemical purity, SiO_2 content, Fe_2O_3 levels, and rounded grain shape, making them highly suitable, while Atsbi is marginal due to slightly higher LOI, and Dire Dawa is not suitable due to lowervalue SiO_2. In water filtration, Fetra, Lemi, and Mugher also perform best, with medium-sized, well-graded, and chemically inert grains meeting [25, 34] criteria, whereas Atsbi is marginal and Dire Dawa is suitable only for rapid filtration due to its finer, poorly sorted grains. For high grade glass and ceramic applications, none of the deposits fully meet the high-purity requirements, though Mugher is the most favorable due to its low Fe_2O_3 content. Overall, Fetra, Lemi, and Mugher are the most versatile for industrial use, while Atsbi and Dire Dawa have limited suitability.

Table 7. The industrial suitability analysis of silica sand deposit for different industries.

Industry type	Specification / Standard	Fetra Silica Sand	Lemi Silica Sand	Mugher Silica Sand	Atsbi Silica Sand	Dire Dawa (Belewa)	Suitability / Remarks
Foundry Industry	Brown (2000): ≥95% on 4-5 consecutive screens	95.3% retained on 5 sieves	94.0% retained on 5 sieves	-	-	-	Both Fetra, and Lemi, suitable
	BIS 1987-2002: SiO_2 ≥95%, Fe_2O_3 ≤1.5%	SiO_2 = 96.65%, Fe_2O_3 = 0.85%	SiO_2 = 95.66%, Fe_2O_3 = 0.95%	SiO_2 = 96.48%, Fe_2O_3 = 0.19%	SiO_2 = 95.45%, Fe_2O_3 = 0.44%	SiO_2 = 91.10%, Fe_2O_3 = 0.18%	Fetra, Lemi, Mugher fully meet criteria; Atsbi slightly high LOI; Dire Dawa below SiO_2 standard

Industry type	Specification / Standard	Fetra Silica Sand	Lemi Silica Sand	Mugher Silica Sand	Atsbi Silica Sand	Dire Dawa (Belewa)	Suitability / Remarks
	Grain shape: Rounded preferred (Chatterjee, 2009)	Predominantly rounded	Moderately rounded	Rounded	Sub-rounded	Angular	Grain shape favors Fetra, Lemi, Mugher; Atsbi marginal; Dire Dawa less suitable
	BIS 8419 (1977): $SiO_2 \geq 90\%$, LOI $\leq 0.7\%$	SiO_2 = 96.65%, LOI = 0.39%	SiO_2 = 95.66%, LOI = 0.40%	SiO_2 = 96.48%, LOI = 0.10%	SiO_2 = 95.45%, LOI = 1.14%	SiO_2 = 91.10%, LOI = 2.55%	Fetra, Lemi, Mugher suitable; Atsbi marginal; Dire Dawa not suitable
Water treatment and Filtration	BS EN 12904 (2005): D10 >0.15 mm, Cu ≤3	D10 = 0.20 mm, Cu = 2.18	D10 ≈ 0.19 mm, Cu ≈ 2.25	-	-	-	Both Fetra, and Lemi, ideal for slow filtration;
	Grain size & uniformity (Chatterjee, 2009)	Medium, well-graded	Medium, fairly uniform	Medium, uniform	Medium, slightly variable	Fine to medium, poorly sorted	Fetra, Lemi, Mugher best for controlled filtration; Atsbi marginal; Dire Dawa less suitable
Glass, Tiles And Ceramics	For glass: Norton (1957) SiO_2 (min): 95%, Al_2O_3 (max): 4%&Fe_2O_3 (max): 1%	SiO_2 = 96.65%, Fe_2O_3 = 0.85%	SiO_2 = 95.66%, Fe_2O_3 = 0.95%	SiO_2 = 96.48%, Fe_2O_3 = 0.19%	SiO_2 = 95.45%, Fe_2O_3 = 0.44%	SiO_2 = 91.10%, Fe_2O_3 = 0.18%	None ideal for high-grade glass/ceramics; Mugher best due to lowest Fe_2O_3
Paints, Plastics, and Rubber	ISO 3262-19 / ASTM D6051): SiO_2>97%Fe_2O_3< 0.3%, Al_2O_3<2%, K_2O + Na_2O<0.5%, CaO+MgO<0.5%, TiO_2<0.1, LOI<1%, grain size 10-100 micron	SiO_2 = 96.65%, Fe_2O_3 = 0.85%	SiO_2 = 95.66%, Fe_2O_3 = 0.95%	SiO_2 = 96.48%, Fe_2O_3 = 0.19%	SiO_2 = 95.45%, Fe_2O_3 = 0.44%	SiO_2 = 91.10%, Fe_2O_3 = 0.18%	All deposits are generally suitable except Belewa silica sand
Oil And Gas	API RP 19 C: CR>6,000 psi, SP&rRD≥0.6, AS≤2.0%, TR<100 FTU, BD=1.55-1.7 g/cm^3, MS: 40/70, 30/50	Not determined	Not determined	Not determined	Not determined	Not determined	
	ISO1350-2: SiO_2:>95	SiO_2 = 96.65%,	SiO_2 = 95.66%,	SiO_2 = 96.48%,	SiO_2 = 95.45%,	SiO_2 = 91.10%	All deposits are suitable except Belewa silica sand
Paper and Packaging	ISO 3262-19 / ASTM D1534 / TAPPI T437, SiO_2>96%Fe_2O_3< 0.3%, Al_2O_3<2%, K_2O + Na_2O<0.5%, CaO+MgO<0.5%, TiO_2<0.1, LOI<1%, grain size <50 micronBrightness (TAPPIT437) ≥ 85%, Opacity (TAPPI T524) ≥ 80%Ash Content (TAPPI T524) 10-20%	SiO_2 = 96.65% Fe_2O_3 = 0.85%	SiO_2 = 95.66% Fe_2O_3 = 0.95%	SiO_2 = 96.48% Fe_2O_3 = 0.19%	SiO_2 = 95.45%, Fe_2O_3 = 0.44%	SiO_2 = 91.10%, Fe_2O_3 = 0.18%	Mugher, Fetra, Are Best Suitable While Lemi And Atsbi Moderately Suitable
Construction and Cement	Concrete Aggregate (ASTM C33 / EN 12620): SiO_2>90%, Fe_2O_3< 1-5%, Al_2O_3<5%, K_2O + Na_2O<1%, MgO<1%, TiO_2<0.5, LOI<3%	SiO_2 = 96.65%, Fe_2O_3 =0.85%	SiO_2 = 95.66%, Fe_2O_3 = 0.95%	SiO_2 = 96.48%, Fe_2O_3 = 0.19%	SiO_2 = 95.45%, Fe_2O_3 = 0.44%	SiO_2 = 91.10%, Fe_2O_3 = 0.18%	Mugher, Fetra, Lemi, and Atsbi are highly suitable, while Dire Dawa (Belewa) is suitable but less preferred due to its comparatively lower SiO_2 content

Industry type	Specification / Standard	Fetra Silica Sand	Lemi Silica Sand	Mugher Silica Sand	Atsbi Silica Sand	Dire Dawa (Belewa)	Suitability / Remarks
	Cement Raw Material (ASTM C114 / ISO 29581-1 / EN 196-2): SiO_2>80%, Fe_2O_3<4%, Al_2O_3<2-8%, K_2O + Na_2O<0.5-5%, MgO<5%, TiO_2<0.5, LOI<5%	SiO_2 = 96.65%, Fe_2O_3 =0.85	SiO_2 = 95.66%, Fe_2O_3 = 0.95%	SiO_2 = 96.48%, Fe_2O_3 = 0.19%	SiO_2 = 95.45%, Fe_2O_3 = 0.44%	SiO_2 = 91.10%, Fe_2O_3 = 0.18%	Mugher is the most suitable owing to its high SiO_2 and low Fe_2O_3 contents, followed by Fetra, Lemi, and Atsbi. Dire Dawa (Belewa) is suitable for general cement applications
	Mortar / Plaster Sand (ASTM C144 / EN 13139): SiO_2>85%, Fe_2O_3<3%, Al_2O_3<5%, K_2O + Na_2O<1%, MgO<1%, TiO_2<0.5, LOI<3%	SiO_2 = 96.65%, Fe_2O_3 =0.85	SiO_2 = 95.66%, Fe_2O_3 = 0.95%	SiO_2 = 96.48%, Fe_2O_3 = 0.19%	SiO_2 = 95.45%, Fe_2O_3 = 0.44%	SiO_2 = 91.10%, Fe_2O_3 = 0.18%	Fetra, Lemi, Mugher, and Atsbi are highly suitable, whereas Dire Dawa (Belewa) is suitable for generalconstruction applications but less preferred for high-quality products

4.2. Possible Industrial Applications and Standards of Feldspar

Feldspar represents a crucial group of aluminosilicate minerals that serve as fundamental raw materials across multiple industrial sectors due to their fluxing properties and chemical composition [2]. These minerals are categorized primarily into potassium-rich (K-feldspar) and sodium-rich and calcium (plagioclase) varieties, each with distinct applications based on their alkali content and impurity levels [35]. The primary value of feldspar lies in its ability to lower melting temperatures in manufacturing processes, thereby reducing energy consumption and improving product quality in ceramics, glass, and other industrial applications [3, 24]. This fluxing action occurs because feldspars melt incongruently over a range of temperatures, forming a viscous liquid phase that promotes vitrification and bonding between constituent particles in ceramic bodies and glass batches [1].

4.2.1. Ceramics Industry

From the Table 8, it is evident that all evaluated feldspar deposits contain adequate alkali content (K_2O + Na_2O) andalumina (Al_2O_3) within the desirable range for effective fluxing, vitrification, and structural reinforcement in ceramic production. However, the Fe_2O_3 content, which exceeds 0.2% in most deposits, indicates a risk of glaze discolorationandreduced whiteness, potentially affecting compliance with ASTM C1466 by increasing the likelihood of heavy-metal leach ability in ceramic glazes. Therefore, iron reduction through beneficiation techniquessuch as high-intensity magnetic separationoracid leaching is necessary to obtain ceramic-grade feldspar**.** Among the studied deposits, Shebale Feldspar deposit shows the most favorable composition and requires only minor processing to meet the required ceramic industry standards.

Table 8*. Ceramics industry compliance analysis using ASTM C1466 Standards.*

Deposit Type	K_2O + Na_2O (%)	Requirement (> 10%)	Fe_2O_3 (%)	Requirement (< 0.2%)	Al_2O_3 (%)	Requirement (16 - 19%)	Compliance Status
Pure Feldspar	11.9	Meets	0.50	Above limit	18.6	Meets	Partial - Requires Fe reduction
Feldspar-Quartz	10.2	Meets	0.70	Above limit	16.3	Meets	Partial - Requires Fe reduction
Shebale Feldspar	10.86	Meets	0.24	Slightly above limit	18.04	Meets	Near compliance - Minor Fe treatment needed
Negelle Borena	12.75	Excellent	0.58	Above limit	18.5	Meets	Requires significant Fe beneficiation

4.2.2. Glass Industry

All feldspar types possess adequate alkali oxides (K_2O + Na_2O**)** and alumina to act as efficient fluxes and stabilizers in ceramic production, ensuring vitrification and mechanical strength. However, iron oxide (Fe_2O_3) **c**ontents above 0.3% in all deposit types except Shebale Feldspar can cause undesirable glaze coloration, reduce whiteness, and affect translucency. Thus, beneficiation processes such as high-intensity magnetic separationoracid leaching are required for achieving ceramic-grade feldspar quality, particularly for Pure Feldspar and Negelle Borenadeposits.

Table 9*. The general glass industry suitability analysis using ISO3262-19 standards.*

Deposit Type	K_2O + Na_2O (%)	Requirement (≥ 10%)	Fe_2O_3 (%)	Requirement (≤ 0.3%)	Al_2O_3 (%)	Requirement (15 - 19%)	Compliance Status (ISO 3262 Based)
Pure Feldspar	11.9	Meets	0.50	Above limit	18.6	Meets	Partial - Fe reduction required for ISO grade
Feldspar-Quartz	10.2	Meets	0.70	Above limit	16.3	Meets	Partial - Fe reduction needed
Shebale Feldspar	10.86	Meets	0.24	Acceptable (near limit)	18.04	Meets	Near-compliant - Minor Fe polishing needed
Negelle Borena	12.75	Meets	0.58	Above limit	18.5	Meets	Requires Fe beneficiation - for ISO use

4.2.3. Filler Industry Applications

Table 10*. The filler industry suitability analysis using ISO3262 standard.*

Filler Application	ISO 3262 Requirements	Shebale Feldspar	Pure Feldspar	Negelle Borena	Feldspar-Quartz
Paints & Coatings	Fe_2O_3<0.5%, Whiteness >85%, LOI <1.0%	Excellent	Good	Limited	Poor
Plastics & Polymers	Low moisture, chemical inertness, Fe_2O_3<0.8%	Excellent	Good	Good	Limited
Rubber Compounds	LOI <1.0%, Consistent particle size, Fe_2O_3<0.6%	Excellent	Good	Good	Poor
Adhesives & Sealants	Brightness >75%, Fe_2O_3<0.5%	Excellent	Good	Moderate	Poor
Construction Fillers	LOI <2.0%, Fe_2O_3<1.0%, consistent grading	Excellent	Excellent	Good	Fair

5. Impurity Types and Beneficiation Methods Selection

The beneficiation of silica sand, quartz, and feldspar is established to remove specific impurities and is guided by the physiochemical and mineralogical characteristics of the deposit. The process for silica sand and quartz typically commences with attrition scrubbing and desliming to dislodge and remove coatings and fine particles [3]. This is critically followed by magnetic separationto extract iron-bearing minerals such as magnetite and ilmenite, a vital step for achieving the low Fe_2O_3 content demanded by the glass industry [36]. For feldspar beneficiation, the primary objective is separation from quartz, which is efficiently accomplished through froth flotation [3]. When premium-grade purity is required, acid leaching used as an effective final chemical purification stage to dissolve residual iron and alumina [37]. The sequence for all these minerals culminates in drying and grading to ensure a consistent, marketable product that meets precise industrial specifications [1]. Based on the physiochemical and mineralogical data, the impurity types and the recommended beneficiation methods for each deposit types have been summarized on the Table 11 below and the possible beneficiation flow sheet of each deposit is prepared.

Table 11. Impurities and the beneficiation methods of silica sand/quartz and feldspar deposits in Ethiopia.

Impurity type	Deposit types	Recommended Beneficiation Method	Reason for Selection
Clays & coatings	All Silica Sands, especially Dire Dawa	Attrition Scrubbing & Desliming	Liberates and physically removes fine coatings that increase LOI and Al_2O_3.
Magnetic Minerals (Magnetite, Ilmenite, Garnet)	Mugher, Lemi, Fetra, Atsbi, Feldspar deposits	High-Intensity Magnetic Separation	Highly efficient for removing Fe and Ti oxides that cause discoloration in glass.
Feldspar & Mica	Lemi, Fetra, Dire Dawa, Feldspar ores	Froth Flotation	Effective for separating minerals with similar density (e.g., quartz and feldspar).
Quartz	Kenticha, Shebelle Feldspar	Froth Flotation	Separates valuable feldspar concentrate from quartz gangue.
High Iron/Biotite Content	Negelle Borena Feldspar	Multi-Stage Magnetic Separation + Flotation acid leaching	Essential for this low grade deposit; requires advanced processing to achieve marketable grade.

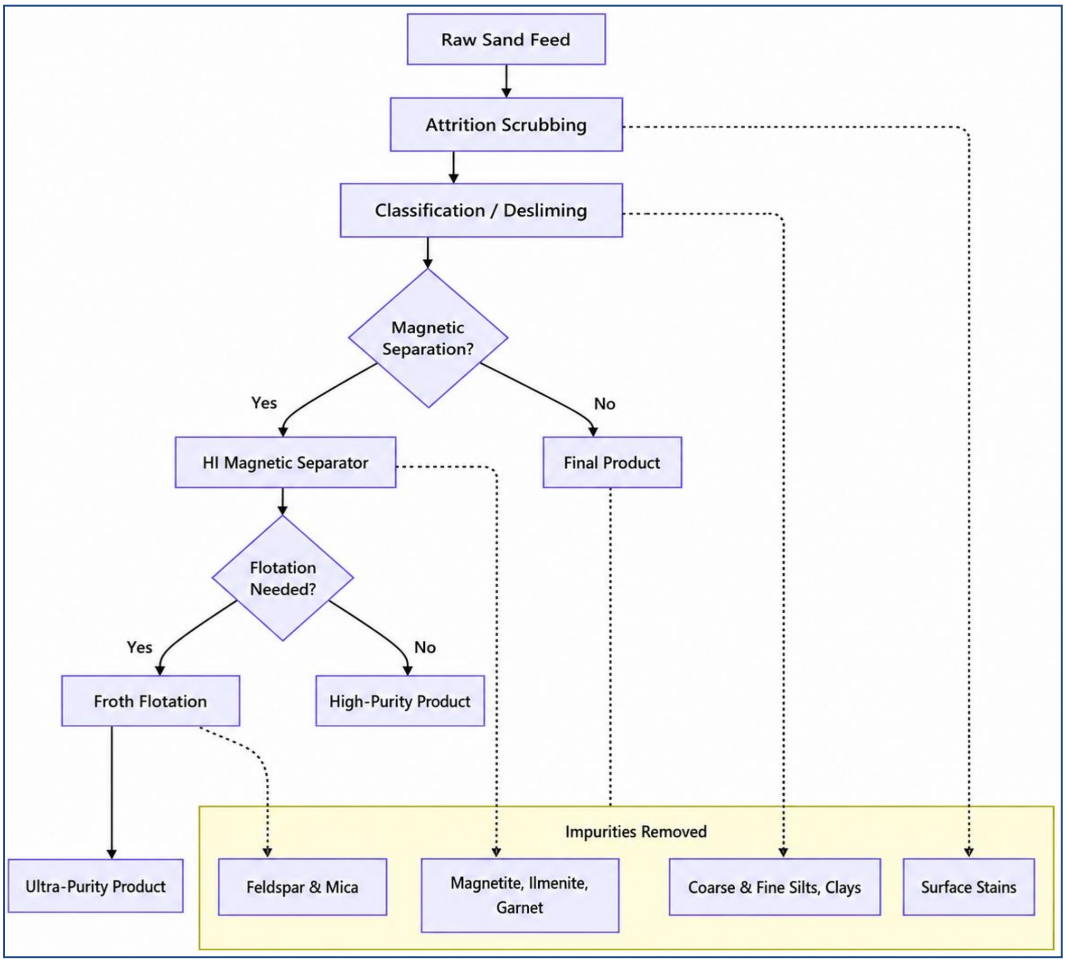

Figure 2. Beneficiation flowsheet for high-grade silica sand deposit (Mugher and Fetra).

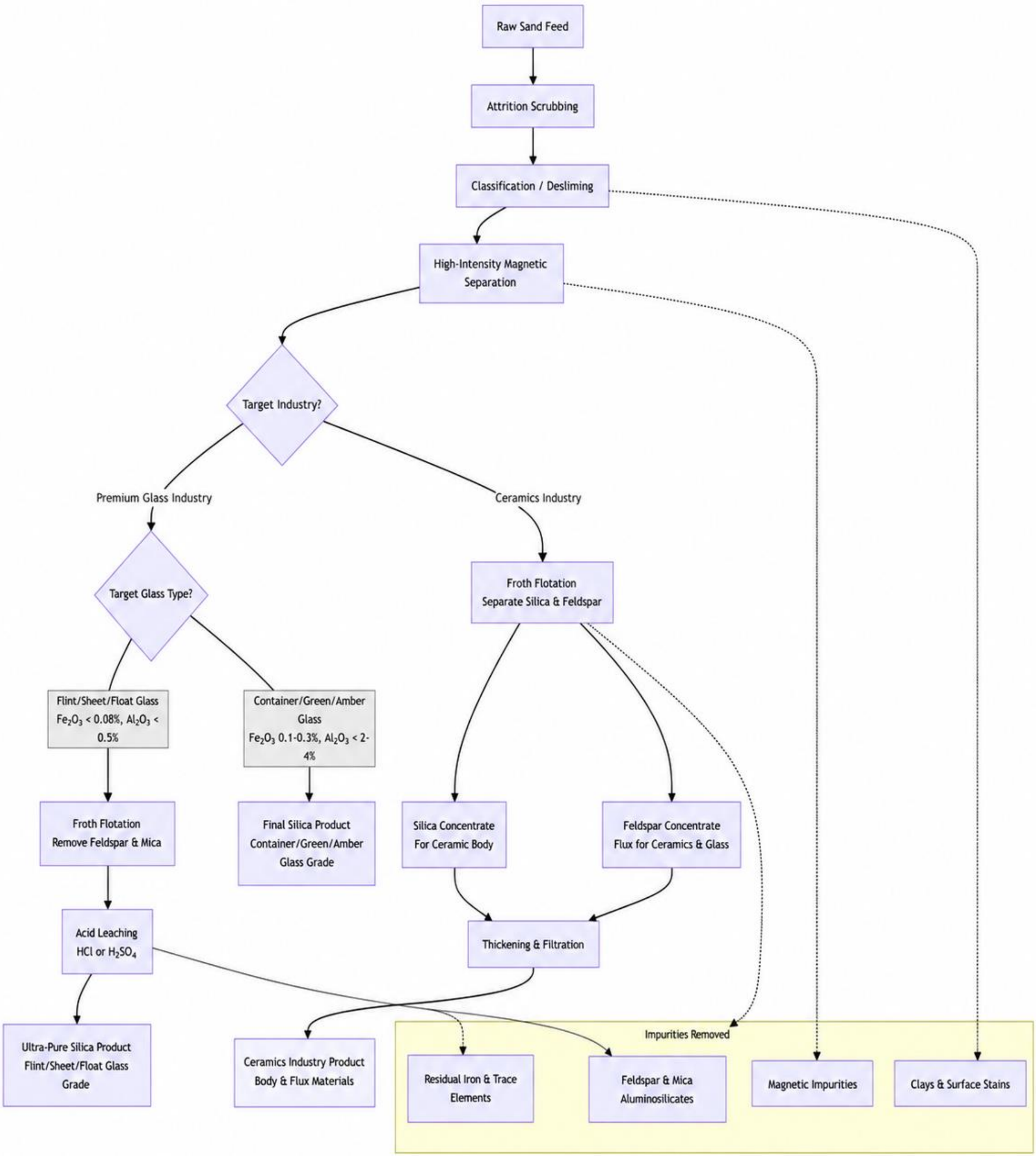

Figure 3. *Beneficiation flowsheet for medium-grade silica sand deposit (Atsbi and Lemi).*

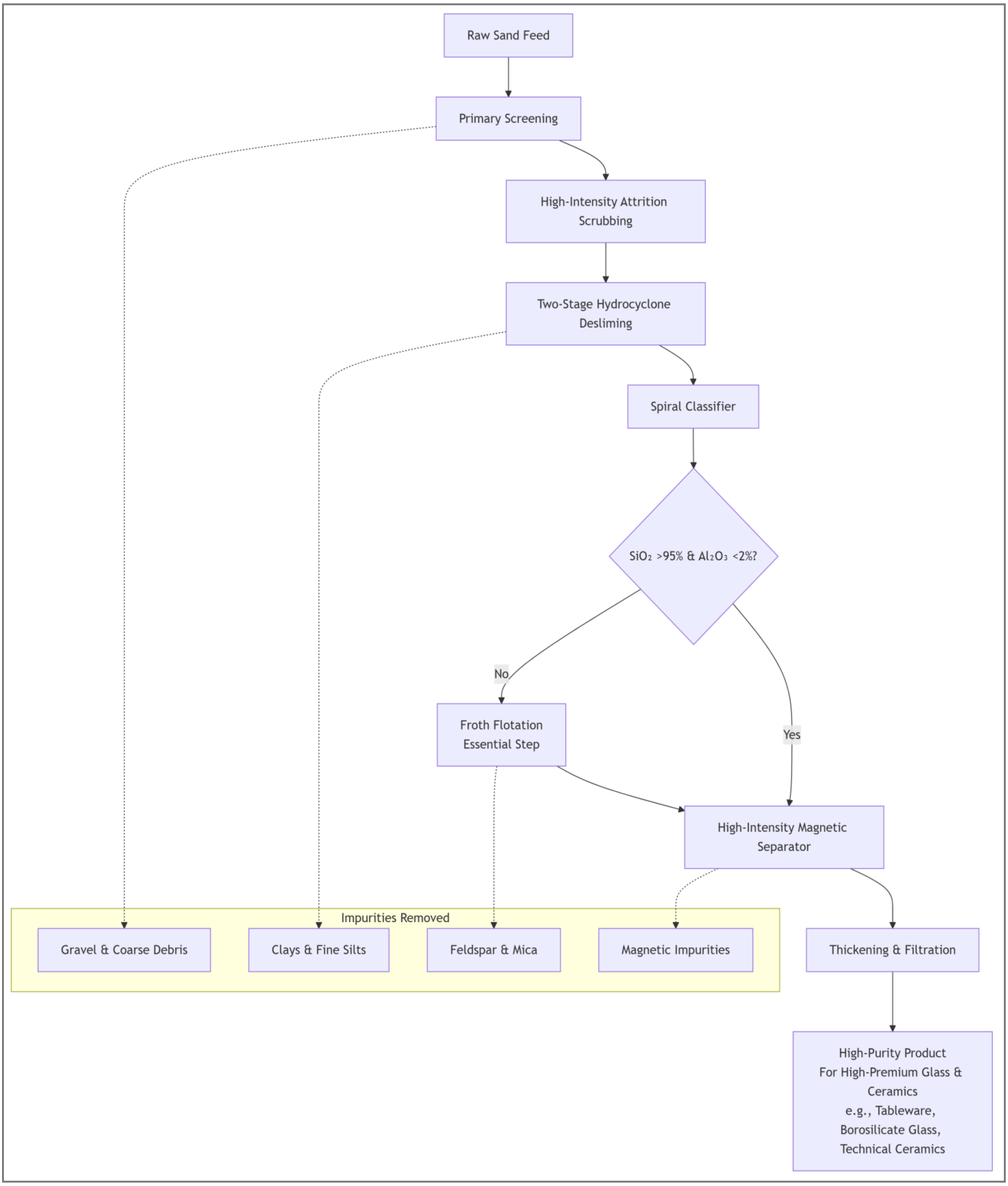

Figure 4. Beneficiation flow sheet for theDire Dewa-Belewa low gradesilica sand deposit.

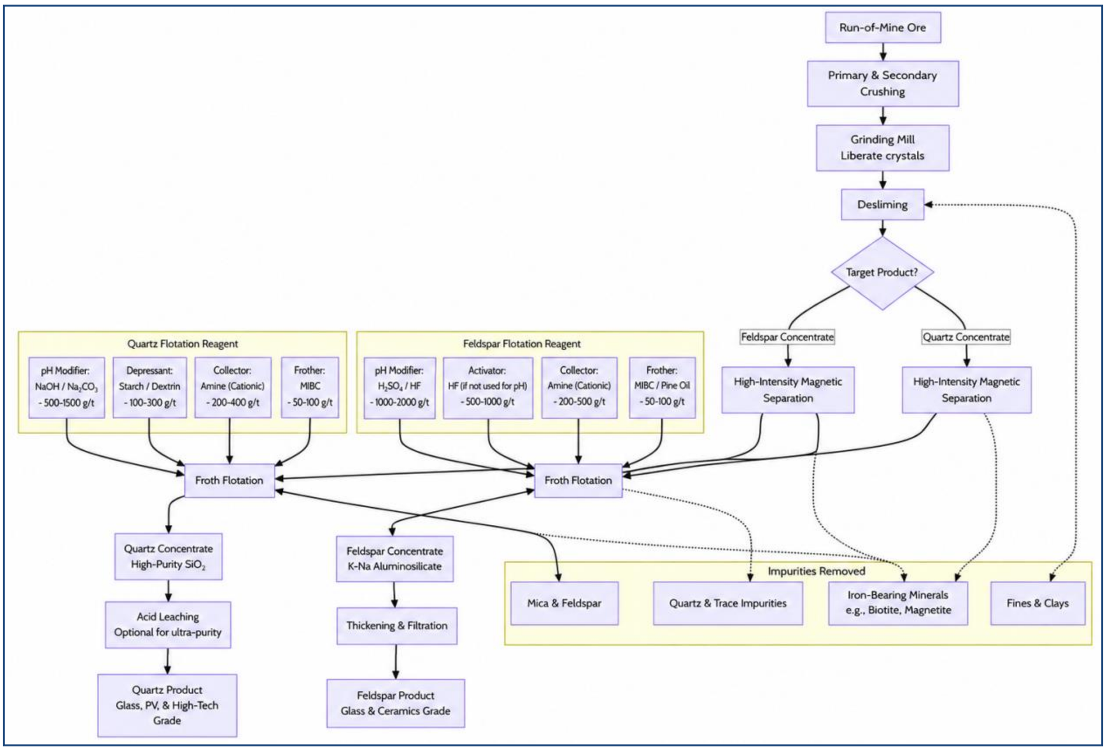

Figure 5. *Beneficiation flowsheet for the Kenticha feldspar deposit.*

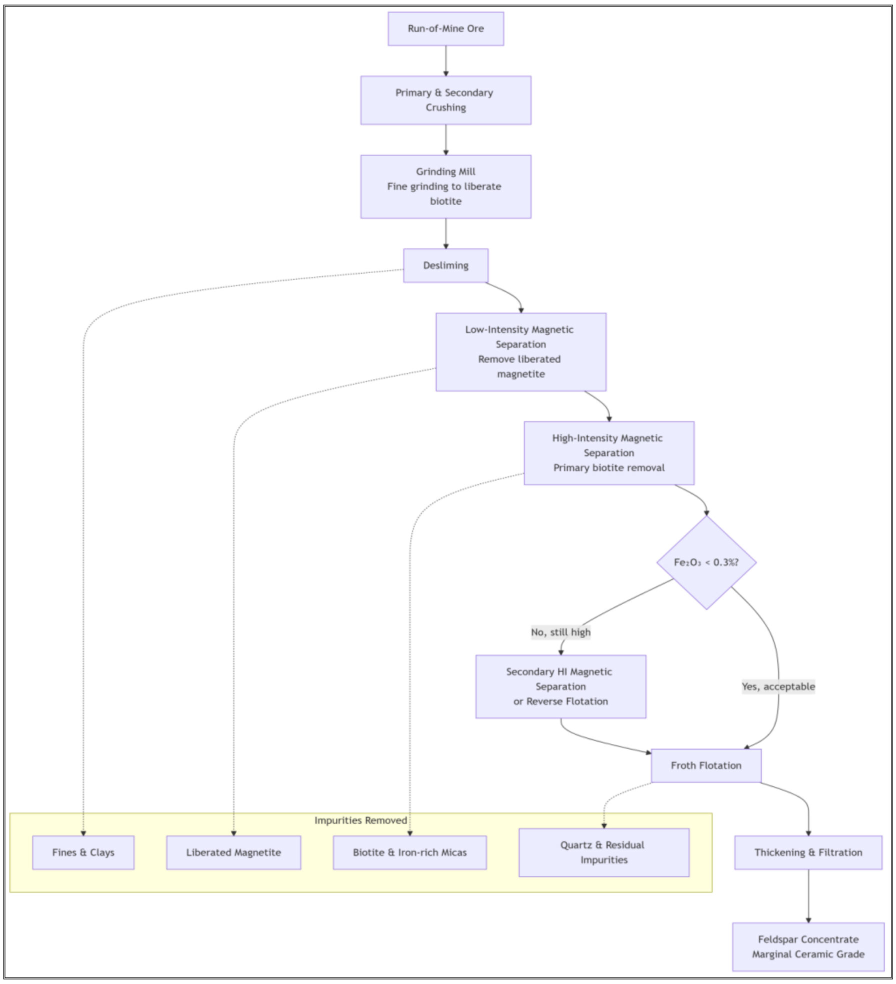

Figure 6. *Beneficiation flow sheet for theNegelle -Borena feldspar deposit.*

6. Conclusion and Recommendation

This review highlights that Ethiopia hosts substantial and geologically diverse silica sand, quartz, and feldspar resources with strong potential to support domestic industrial development and reduce reliance on imported raw materials. Silica sand deposits associated with Mesozoic sandstones and Quaternary alluvial environments, particularly at Mugher, Fetra, and Lemi, are characterized by high SiO_2 contents, favorable grain size distributions, and generally acceptable impurity levels. These characteristics make them suitable for foundry molding sands, water filtration media, construction materials, and amber and green glass production. In contrast, deposits at Atsbi and Dire Dawa (Belewa) are constrained by elevated loss on ignition, alumina, and weathering-related impurities, limiting their direct industrial use without intensive beneficiation.

Feldspar deposits in Ethiopia occur predominantly within pegmatite bodies and granitic intrusions emplaced in Precambrian basement complexes, notably within the Adola-Kenticha Belt and eastern to southeastern Ethiopia. Major occurrences at Kenticha, Shebelle, Negelle Borena, and Hamariesa are hosted by coarse-grained pegmatites dominated by K-feldspar, quartz, and muscovite, with iron impurities primarily derived from biotite and accessory minerals. These deposits contain adequate alkali and alumina contents for ceramic and glass flux applications; however, iron oxide remains the principal limiting factor, requiring beneficiation to meet premium industrial standards. Shebelle and Kenticha show the most favorable combination of geological setting and chemical quality, whereas Negelle Borena exhibits comparatively lower and more variable quality.

Abbreviations

API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BIS	Bureau of Indian Standards
BS EN	British Standard European Norm
Cc	Coefficient of Curvature
Cu	Coefficient of Uniformity
D10	Effective Grain Size
DLS	Debre Libanos Sandstone
GSE	Geological Survey of Ethiopia
ISO	International Organization for Standardization
LOI	Loss on Ignition
TAPPI	Technical Association of the Pulp and Paper Industry

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Author Contributions

Yohanes Belachew: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing

Getnet Belachew: Data curation, Formal Analysis, Investigation, Validation, Visualization, Writing – review & editing

Data Availability Statement

The data supporting the findings of this research have been compiled from published and unpublished reports of the Geological Survey of Ethiopia, Ministry of Mines, and academic literature. The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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