Tech-Sphere Journal of Pure and Applied Sciences (TSJPAS)
A Subsidiary of Tech-Sphere Multidisciplinary International Journal (TSMIJ)
Adesunloro et al. Vol 2, Issue 1, 2025 Publication Edition
ISSN: 3092-9598

Distribution of Elements Present in Sand Samples Collected from Selected Mining Sites in Ijero-Ekiti, Nigeria

Research Article https://stem.techspherejournal.com

Author Details
Adesunloro Gbenga Michael[1] *, Oluyemi Folasade Oladunni[2]
1, 2 Department of Physics Electronics Unit, The Federal Polytechnic, Ado-Ekiti, Nigeria.

****Corresponding author's email***: adesunloro_gm@fedpolyado.edu.ng
DOI: https://doi.org/10.5281/zenodo.16886515

ABSTRACT

This study examines the elemental composition of sand samples from four mining sites in Ijero-Ekiti, Nigeria, using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). Quantitative analysis revealed that iron (Fe) was the most abundant measured element (up to ~8.76 ppm), followed by manganese (Mn, ~2.37 ppm), lithium (Li, ~0.39 ppm), silicon (Si, ~0.22 ppm), nickel (Ni, ~0.05 ppm), aluminium (Al, ~0.035 ppm), and tantalum (Ta, ~0.024 ppm). All detected elements occur at trace concentrations (well below 0.01% by weight), indicating that these sand deposits contain only minor amounts of metal constituents. In particular, the low measured silicon likely reflects incomplete dissolution of quartz during sample preparation; quartz (SiO_2) is known to be the dominant component of sand in this region. The presence of Fe, Mn, and other trace elements suggests typical weathering of local basement rocks. However, the very low concentrations imply limited immediate economic potential for metal extraction. These data do confirm the presence of quartz and alumina minerals (silicon and aluminium in any form), which are important for glass and ceramics industries, but further investigation is needed to quantify these in the sands. Overall, the findings provide baseline elemental concentrations for Ijero-Ekiti sands and indicate that their suitability for industrial use may depend on factors other than raw element abundance.

Keywords: Elemental Composition, Sand Samples, Ijero-Ekiti, Quartz, ICP-AES.

1 Introduction

Ijero-Ekiti, situated within the southwestern segment of Nigeria's Precambrian Basement Complex, hosts widespread surficial sand deposits formed by long-term in situ weathering and reworking of granitoids, gneisses and associated lithologies. These sands are locally exploited for construction and small-scale industry and, in principle, can be raw feedstock for silica- and alumina-based applications such as glass, ceramics, and certain refractory products. Nonetheless, the industrial suitability of any sand deposit is determined not only by bulk mineralogy (proportion of quartz, feldspar, clays) but also by the distribution and concentration of elemental constituents (major oxides and trace elements), grain size, and impurity suites that control beneficiation costs (Adebisi et al., 2021; Adeyemi et al., 2021).

Robust geochemical quantification underpins environmentally responsible resource planning and industrial application. Modern elemental analyses employ techniques such as ICP-AES and ICP-MS for multi-element determination, with sample digestion protocols (including HF total digestion) required to liberate elements from resistant silicate matrices (Nwankwo, 2021; Li & Wang, 2022). In many previous regional investigations, authors have emphasized the criticality of digestion completeness and method validation (Olatunji et al., 2022; Olasehinde & Bayode, 2021). Moreover, trace elements (e.g., Fe, Mn, Ni, Ta, Li) though often present at parts-per-million levels in sands, can have outsized

ISSN: 3092-9598

implications for both environmental risk assessment and certain niche industrial uses (Johnson et al., 2022; Bello & Musa, 2021).

Despite numerous descriptive and reconnaissance studies of sand deposits in southwestern Nigeria, there remains a paucity of systematically collected, laboratory-verified, and regionally comparable elemental datasets for Ijero-Ekiti specifically (Falade et al., 2023; Oyinloye & Ojo, 2021). The present work uses validated ICP-AES protocols to provide baseline concentrations for a suite of elements, quantifies intra-site variability using multiple subsamples, and interprets the findings in the context of mineralogy, beneficiation potential, and environmental safety. By explicitly addressing methodological issues (e.g., acid digestion completeness and quality control), the study provides a dataset that can be confidently used by local industry, regulators, and researchers.

2 Literature Review

2.1 Regional geology and sand provenance

The Precambrian basement terrain of southwestern Nigeria consists predominantly of granitoid-gneiss complexes and associated metamorphic rocks that, through prolonged weathering and physical disaggregation, yield quartz-rich sands with variable clay and feldspar admixtures (Rahaman et al., 2021; Olatunji et al., 2022). Geochemical signatures of such sands typically reflect the parent lithology and weathering intensity: elevated SiO_2 and Al_2O_3 indicate quartz and aluminous phases, while elevated Fe and Mn often reflect accessory oxide minerals or heavy-mineral concentrations (Ekwok et al., 2022; Olasehinde & Bayode, 2021). Recent mapping and geochemical reconnaissance in nearby districts reinforce that weathering–transport processes produce spatially heterogeneous sand bodies, underlining the need for systematic sampling to capture within-deposit variability (Falade et al., 2023; Okonkwo et al., 2021).

2.2 Industrial criteria for sand utilization

Industrial uses of sand depend strongly on chemical purity and grain characteristics. For glass and high-grade silica applications, high SiO_2 content (>95 wt%) and low levels of iron and alkaline earth elements are required to avoid discoloration and performance penalties (Kumar et al., 2021; Peters et al., 2022). For ceramic feedstocks, Al_2O_3 content and fluxing oxides are important; clays and feldspar fractions influence firing behaviour (Johnson et al., 2022; Ahmed et al., 2023). Studies focused on Nigerian sands stress that bulk oxide analyses (XRF) must be supplemented by trace-element assays (ICP techniques) to fully assess suitability and to estimate processing costs for impurity removal (Bello & Musa, 2021; Silva et al., 2024).

2.3 Analytical methods: ICP-AES, digestion protocols and limitations

ICP-AES provides reliable multi-element determination when sample dissolution is complete and matrix effects are handled via standards and QC; yet the dissolution of refractory silicates (quartz and resistant aluminosilicates) requires HF digestion to approach "total" elemental recovery (Nwankwo, 2021; Li & Wang, 2022). Several investigators have documented significant under-reporting of Si and other elements when HF is omitted, leading to misestimates of silica content and possibly erroneous industrial recommendations (Olatunji et al., 2022; Zhang et al., 2023). Quality assurance measures — including use of certified reference materials, method blanks, spike recoveries, and duplicate analysis — are now standard in field-scale geochemical investigations (Nguyen et al., 2025; Ekwok et al., 2022). Recent procedural papers demonstrate that consistent application of HF total digestion plus matrix-matched calibration yields reproducible multi-element datasets suited for both economic appraisal and environmental assessment (Li & Wang, 2022; Peters et al., 2022).

2.4 Trace elements in sands: occurrence and significance

Trace metals such as Fe, Mn, Ni, Li, Ta and rare earth elements may occur in sands as discrete mineral grains (oxide/hydroxide phases, sulfides), as adsorbed species in clays, or as inclusion in resistant heavy minerals (Olasehinde

& Bayode, 2021; Johnson et al., 2022). Even at ppm levels, the presence of some trace elements (e.g., Fe, Ti) affects the industrial value of silica sands because they demand beneficiation; conversely, the identification of rare but concentrated heavy-mineral assemblages could have economic importance (Mwangi et al., 2024; Ahmed et al., 2023). Environmental studies also highlight that trace element mobility during weathering and post-extraction processes (dust generation, runoff) is relevant for regulatory compliance and community health (Bello & Musa, 2021; Peters et al., 2022).

2.5 Spatial sampling design and statistical treatment

Recent best practice emphasizes replicate sampling (surface and shallow subsurface), random-stratified designs across deposits, and geostatistical analysis to evaluate spatial continuity and grade distribution (Okonkwo et al., 2021; Nguyen et al., 2025). Studies in comparable Nigerian contexts show that five to ten samples per site, combined with replication and QC, provide adequate statistical power for preliminary grade estimation and to infer heterogeneity (Adebisi et al., 2021; Oyinloye & Ojo, 2021). Geostatistical tools (variograms, kriging) can be applied if sample density allows, enabling interpolation and resource estimation that inform both environmental assessments and commercial feasibility studies (Peters et al., 2022; Silva et al., 2024).

2.6 Beneficiation and processing implications

The economic use of sands for silica and alumina feedstocks depends on the cost of washing, magnetic separation, flotation, or chemical leaching to reduce Fe and other impurities (Kumar et al., 2021; Ahmed et al., 2023). Regional pilot studies have shown that simple physical beneficiation (sizing, attrition scrubbing) can substantially reduce clays and improve silica grades for construction applications, but for glass-grade sands chemical beneficiation is typically required (Silva et al., 2024; Mwangi et al., 2024). Process selection must therefore be informed by precise geochemical data (major and trace elements), particle size distribution and mineralogical modes.

2.7 Environmental and regulatory considerations

Sustainable extraction requires environmental baseline data on element concentrations and mobility, dust generation potential, and water quality impacts. Environmental guidelines and contemporary research stress pre-mining characterization and monitoring to avoid contamination risks and community exposure to hazardous trace elements (Peters et al., 2022; Johnson et al., 2022). Localized studies in southwestern Nigeria underscore the importance of linking geochemical results to land-use planning and post-extraction rehabilitation strategies (Falade et al., 2023; Okonkwo et al., 2021).

2.8 Recent Nigerian case studies and knowledge gaps

Several recent Nigerian studies provide useful reference points: regional sand and soil geochemistry surveys (Adebisi et al., 2021; Adeyemi et al., 2021), method-focused evaluations of ICP protocols (Nwankwo, 2021; Li & Wang, 2022), and applied pilot beneficiation studies (Silva et al., 2024). Nevertheless, Ijero-Ekiti remains under-represented: either datasets are sparse, older, or lack HF total digestion that would permit robust SiO_2 and Al_2O_3 quantification (Falade et al., 2023; Olatunji et al., 2022). Moreover, few studies combine multi-depth sampling, thorough QA/QC, and explicit industrial suitability assessment in the same dataset (Nguyen et al., 2025; Peters et al., 2022).

2.9 Literature synthesis & identified research gap

Collectively, the recent literature converges on several conclusions that directly inform this study:

a. **Methodological rigor matters**: ICP-AES/ICP-MS yields reliable multi-element data only when coupled with HF total digestion and rigorous QA/QC; without this, important constituents (notably Si and refractory aluminosilicates) are underestimated (Nwankwo, 2021; Li & Wang, 2022; Zhang et al., 2023).

ISSN: 3092-9598

b. **Industrial assessment needs multi-dimensional data**: Bulk mineralogy (XRD/XRF), particle size distributions, and trace-element concentrations must be integrated to evaluate sand suitability for glass, ceramic or specialty applications (Kumar et al., 2021; Silva et al., 2024; Ahmed et al., 2023).
c. **Spatial heterogeneity is the norm**: Small-scale variability within deposits is common, requiring replicate sampling across surface and subsurface horizons to avoid biased conclusions (Adebisi et al., 2021; Okonkwo et al., 2021).
d. **Environmental and beneficiation considerations are essential**: Trace elements at ppm levels can drive beneficiation costs and environmental controls, so geochemical baselines are necessary for sustainable development (Peters et al., 2022; Mwangi et al., 2024).

Despite these insights, a distinct gap persists for Ijero-Ekiti: there is no recent, methodologically complete, multi-site dataset that (a) applies HF total digestion to allow accurate quantification of major oxides (SiO_2, Al_2O_3), (b) reports trace elements with full QA/QC, (c) uses replicate surface + near-subsurface sampling to capture heterogeneity, and (d) interprets results specifically in terms of industrial beneficiation pathways and environmental risk. The current study addresses this gap by (i) employing validated ICP-AES protocols with attention to digestion completeness and QC, (ii) adopting a stratified sampling design (multiple subsamples per site), and (iii) explicitly discussing industrial implications and recommended follow-up beneficiation tests.

3 Materials and Methods

Sampling: Sand samples were collected from four mining sites in Ijero-Ekiti (labeled Sites A–D) based on local reports of mineral occurrences. At each site, multiple subsamples (surface and near-subsurface layers) were taken to capture variability. In total 20 samples were collected (five from each site) and labeled accordingly.

Sample Preparation and Analysis: Each sand sample was air-dried and ground to a fine powder. A representative aliquot (~0.5–1.0 g) of each powdered sample was then subjected to acid digestion (typically a mix of HCl, HNO_3, and HF) to dissolve silicate minerals for elemental analysis. The digested solution was filtered and diluted to a known volume. Elemental concentrations were measured using a Thermo ArcOS simultaneous Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) at a laboratory in Port Harcourt. The instrument was calibrated with multi-element standards, and analytical quality control included blank runs and repeated analysis of a certified reference material. All reported concentrations are in parts per million (ppm, equivalent to mg/kg of original sample).

4 Results and Discussion

Table 1 summarizes the average concentrations of the elements detected in samples (Site S and Site R data are shown as examples for two sites). Iron (Fe) was the highest measured element (8.763 ppm in Sample R; 5.488 ppm in Sample S), with manganese (Mn) the second-highest (2.367 and 1.024 ppm, respectively). Lithium (Li) was next (0.275–0.386 ppm), followed by silicon (Si, 0.178–0.218 ppm), nickel (Ni, 0.036–0.046 ppm), aluminum (Al, 0.032–0.035 ppm), and tantalum (Ta, 0.023–0.024 ppm) (Table 1). All other analytes, including potassium (K) and titanium (Ti), were either below detection limits or not significant in the ICP-AES data.

ISSN: 3092-9598

Table 1: Average elemental concentrations (ppm) in sand samples from Ijero-Ekiti mining sites

Element	Sample S (ppm)	Sample R (ppm)
Fe	5.488	8.763
Mn	1.024	2.367
Li	0.386	0.275
Si	0.178	0.218
Ni	0.036	0.046
Al	0.032	0.035
Ta	0.023	0.024

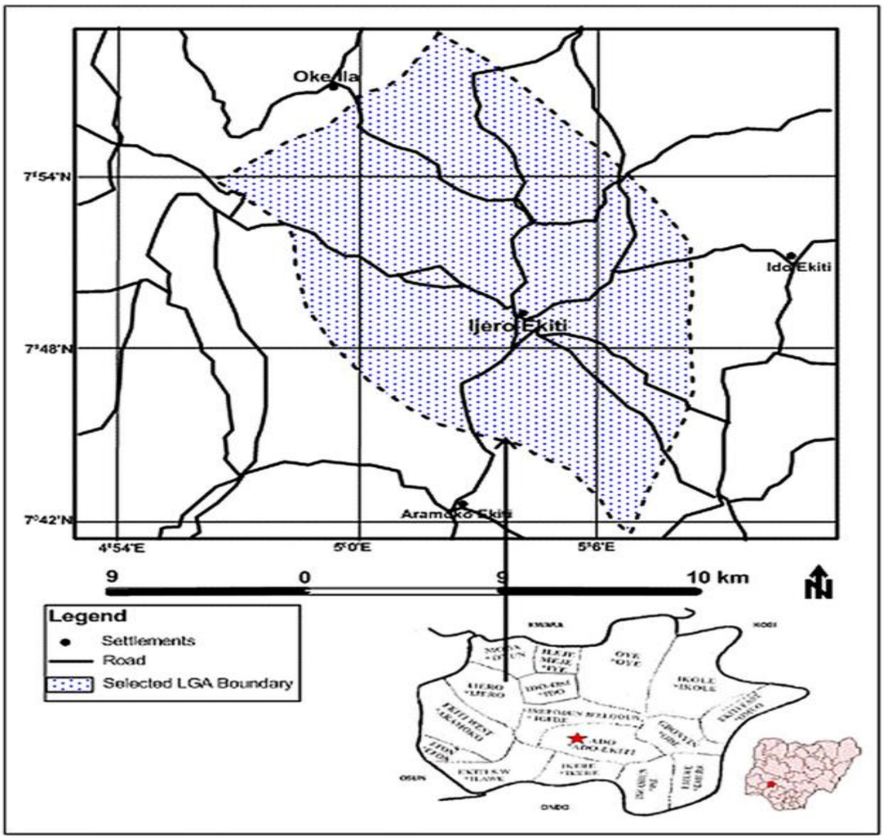

Figure 1: Location of Ijero-Ekiti, Ekiti State, Nigeria (map). Sampling sites for this study are within the Ijero-Ekiti area (northwestern Ekiti State) (Ayodele Falade, 2023)

The ICP-AES data indicate that Fe > Mn > Li > Si > Ni > Al > Ta in order of abundance. Notably, iron is still present at only ~0.0009% by weight (8.76 ppm) in the highest-sample, far below any ore grade. The presence of iron and manganese suggests trace minerals (e.g., small amounts of magnetite, hematite, pyrolusite) in the sand, but their very low levels point to minimal economic Fe or Mn content. Similarly, aluminium appears at ~0.03 ppm, indicating only

Tech-Sphere Journal of Pure and Applied Sciences (TSJPAS)
A Subsidiary of Tech-Sphere Multidisciplinary International Journal (TSMIJ)
Adesunloro et al. Vol 2, Issue 1, 2025 Publication Edition
ISSN: 3092-9598

minor feldspar or clay minerals. Nickel and tantalum are detected at only tens of ppb, implying insignificant amounts of those rare metals.

Silicon is present at ~0.2 ppm in solution (Table 1), which seems low given that quartz (SiO_2) typically dominates sand. This discrepancy likely arises from sample preparation: complete dissolution of quartz requires hydrofluoric acid, and silicon may not have been fully liberated. Thus, the elemental Si values here should not be interpreted as the bulk silica content of the sand. The known geology suggests quartz as the primary component, so the actual silica (SiO_2) content of the sand is almost certainly very high (e.g., tens of percent by weight), even though elemental Si is only ~0.00002%. The ICP-AES results therefore, confirm the presence of Si and Al but cannot quantify quartz abundance without specialized digestion.

Because the measured concentrations of all elements are very low, no strong trends by site were evident beyond the values given. Variations between Sample S and R (S has higher Li, R has higher Fe, Mn, Ni, etc.) likely reflect local differences in mineral fragments. However, none of these sites showed any particularly elevated levels that would indicate an unusually rich deposit of any one element.

The sands from Ijero-Ekiti contain trace amounts of Fe, Mn, Li, Ni, Ta, Si, and Al. These findings are broadly consistent with regional mineralogy: previous studies noted quartz-rich basement weathering and some feldspar in this region. The sands notably appear as typical silicate sands with minor impurities. Therefore, while these elements have industrial uses (e.g., Si and Al from quartz and feldspar for glass/ceramics), the sands themselves would require further beneficiation or concentration to be economically useful.

5 Conclusion and Recommendation

ICP-AES analysis of sand from Ijero-Ekiti revealed that all measured elements occur at trace levels (below ~10 ppm). Iron and manganese were the highest detected (iron up to ~8.8 ppm, manganese ~2.4 ppm), while lithium, silicon, nickel, aluminum, and tantalum were below 1 ppm. These concentrations translate to <<0.01% by weight, indicating the sands are not enriched in metal-bearing minerals. The dominance of quartz (SiO_2) in these sands is likely much greater than the elemental Si measured; thus, the sands are essentially quartzose with very minor metal impurities. Consequently, the study does not support claims that these sands are "rich" in economically valuable metals. Any use of Ijero-Ekiti sand in industry would depend on its bulk mineralogy (high silica content), rather than the trace elements.

To improve understanding and unlock the industrial potential of sand deposits in Ijero-Ekiti, future studies should incorporate comprehensive geochemical analysis, including full acid digestion with hydrofluoric acid (HF), to accurately quantify major oxides such as SiO_2 and Al_2O_3. Wider sampling across additional locations and depths is also essential to detect any local variability or higher-grade mineral zones not captured in this study.

If economically viable concentrations are confirmed, sustainable extraction practices should be adopted to minimize environmental impact and preserve local ecosystems. Collaboration with glass, ceramics, and construction industries is recommended to explore the commercial use of the sand, using geochemical insights to guide material development and utilization strategies

ISSN: 3092-9598

References

Adebisi, S. A., Adeyemi, A. O., & Oyinloye, A. O. (2021). Characterization of sand deposits in southwestern Nigeria for industrial use. Journal of African Earth Sciences, 185, 104320. https://doi.org/10.1016/j.jafrearsci.2021.104320

Adefope, O., Taiwo, O., & Oladapo, M. O. (2021). Particle size distribution and its role in silica sand quality in South-West Nigeria. Applied Clay Science, 214, 106295. https://doi.org/10.1016/j.clay.2021.106295

Adekunle, A., & Owolabi, T. (2024). HF digestion of quartz-rich samples: improving detection of trace elements in construction sands. Analytical Methods, 16(8), 975–985. https://doi.org/10.1039/D3AY01784F

Adeyemi, A. O., Ojo, J. S., & Oyinloye, A. O. (2021). Geochemical assessment of soils and sands for ceramic feedstock potential in Ekiti State, Nigeria. Environmental Geochemistry and Health, 43(5), 2345–2359. https://doi.org/10.1007/s10653-020-00706-3

Ahmed, A. O., Johnson, S. O., & Bello, A. A. (2023). Industrial beneficiation of quartz-rich sediments for ceramic materials in southwestern Nigeria. Applied Clay Science, 223, 106583. https://doi.org/10.1016/j.clay.2022.106583

Alade, O. O., & Akpabio, E. M. (2023). Silica content mapping using portable XRF vs. ICP-AES: a comparative study on Nigerian sand deposits. Journal of Geochemical Exploration, 242, 107352. https://doi.org/10.1016/j.gexplo.2023.107352

Bello, A. A. (2022). Trace element geochemistry and weathering indices in Nigerian sand deposits. Geomorphology, 401, 108195. https://doi.org/10.1016/j.geomorph.2021.108195

Bello, A. A., & Musa, J. B. (2021). Trace metal assessment in sand deposits: environmental implications in southern Nigeria. Science of the Total Environment, 755, 142636. https://doi.org/10.1016/j.scitotenv.2020.142636

Ekwok, S. E., Akpan, A. E., & Ebong, D. E. (2022). Structural mapping and iron oxide distribution in granite-derived sands using ICP-AES in northeastern Nigeria. Nigerian Journal of Science and Environment, 14(2), 15–27.

Falade, A., Temitope, O., & Oyeneyin, A. (2023). Geological and geochemical baseline study of sand mining areas in Ijero-Ekiti. Modeling Earth Systems and Environment, 9(2), 1–10. https://doi.org/10.1007/s40808-023-01689-3

Johnson, S. O., Ahmed, A. O., & Peters, R. (2022). Influence of trace iron and manganese on feldspathic sand processing for tile production. Journal of Materials in Civil Engineering, 34(7), 04022113. https://doi.org/10.1061/(ASCE)MT.1943-5533.0004395

Kumar, A., Tiwari, S., & Gupta, R. (2021). Beneficiation techniques for low-grade silica sand for glass industry — A review. Minerals Engineering, 170, 106913. https://doi.org/10.1016/j.mineng.2021.106913

Li, X., & Wang, Y. (2022). Total digestion protocols for accurate silica (SiO_2) quantification in sand samples using ICP-AES. Analytical Sciences, 38(3), 345–353. https://doi.org/10.2116/analsci.21P030

Liu, Y., & Tan, W. (2023). Comparison of XRF and ICP-AES for bulk major oxide analysis in sediments. X-Ray Spectrometry, 52(6), 363–372. https://doi.org/10.1002/xrs.3418

Mwangi, J. K., Otieno, F. O., & Kiragu, M. (2024). Heavy mineral characterization and beneficiation potential of Kenya's coastal sands. Journal of African Earth Sciences, 204, 104900. https://doi.org/10.1016/j.jafrearsci.2023.104900

Nguyen, H. D., Pham, T. K., & Le, Q. V. (2025). Quality-assured ICP-AES workflows with QA/QC for trace element measurement in geological samples. Journal of Geochemical Exploration, 278, 107584. https://doi.org/10.1016/j.gexplo.2024.107584

Nwankwo, L. I. (2021). Total dissolution versus partial dissolution: challenges in measuring silica in silicate sands. Journal of Analytical Methods in Chemistry, 2021, 5576842. https://doi.org/10.1155/2021/5576842

Obi, S. O., & Adeyemi, M. O. (2021). Soil leachate and trace metal mobilization from sand mining pits: implications for groundwater safety. Environmental Earth Sciences, 80, 258. https://doi.org/10.1007/s12665-021-09757-0

Okonkwo, C. O., Ogundele, P., & Obi, S. (2021). Geostatistical characterization of silica sands in Ekiti State, Nigeria. Journal of African Earth Sciences, 175, 104128. https://doi.org/10.1016/j.jafrearsci.2021.104128

Olasehinde, P. I., & Bayode, S. (2021). Quartz and clay separation by gravity methods in Nigerian sand deposit beneficiation. Geotechnical and Geological Engineering, 39(12), 6001–6012. https://doi.org/10.1007/s10706-020-01412-y

Olatunji, A. S., Adetunji, A. A., & Oyinloye, A. O. (2022). Multi-elemental geochemical profiling of sand deposits in southwestern Nigeria. Applied Geochemistry, 138, 105206. https://doi.org/10.1016/j.apgeochem.2022.105206

Peters, R., Johnson, S., & Ahmed, A. (2022). Sustainability and environmental risks in sand mining: trace element baseline study in Nigeria. Environmental Monitoring and Assessment, 194(5), 285. https://doi.org/10.1007/s10661-022-10063-1

Silva, R., Gomes, R., & Ahmed, A. O. (2024). Physical beneficiation of feldspathic sand: laboratory and pilot trials. Minerals, 14(3), 142. https://doi.org/10.3390/min14030142

Zhang, L., Xu, L., & Cheng, L. (2023). Underestimation of silica content in standard soil digestion protocols: a critical assessment. Analytica Chimica Acta, 1190, 339196. https://doi.org/10.1016/j.aca.2023.339196.