INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN APPLIED SCIENCE (IJRIAS)
ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VII July 2026

Beneficiation of Farin-Lamba (Plateau State, Nigeria) Cassiterite on Jig Machine at Varying Sieve Sizes for Tin Oxide Production

Hakeem Adeoye Alapepesile[1], Akeem Damilola Akinwekomi[2], Oladunni Oyelola Alabi[2], Muhammad Halliru Jikamshi[1], Joseph Oluwafemi Aliyu[1]

[1]Department of Materials Science and Engineering, Obafemiv Awolowo University, Ile-Ife, Nigeria.

[2]Department of Metallurgical and Materials Engineering, Federal University of Technology, Akure, Nigeria

DOI: https://doi.org/10.51584/IJRIAS.2026.11070158

Received: 31 July 2026; Accepted: 05 August 2026; Published: 16 August 2026

ABSTRACT

The global drive towards economic diversification emphasizes the exploration and exploitation of solid minerals such as tin oxide from cassiterite as Federal Government focus towards economic reform. This research aims at beneficiating Farin-Lamba cassiterite using jig machine at varying sieve sizes for the production of tin oxide. The crude ore was subjected to chemical analysis and jigging separation processing. The sample was ground to sieve ranges of 90 µm, 125 µm, 180 µm, 250 µm, and 355 µm. 500 g each of Farin-Lamba cassiterite prepared by grinding to 100% passing these sieves were processed using jigging separation method to obtain the underflow and the overflow products which were allowed to settled, filtered, and then dried using sun drying followed by oven drying at 105 ºC, then weighed and analyzed using ED-X-Ray Fluorescence spectrometer. The ED-XRFS result showed that as-received cassiterite assayed 26.120% ZrO_2, 15.397% SiO_2, 13.08% SnO_2, 10.644% TiO_2, 9.860% CuO, and other compounds in trace forms. The chemical analysis of the underflow and overflow samples after the processing using a jig machine revealed that the optimum result was obtained at 125 µm with 42.057% SnO_2, 78.17% recovery, 3.22 enrichment ratio, and 4.11 concentration ratio respectively. It was deduced from the research that the optimum results of 42.057% obtained for SnO_2, at 125 µm is low. However, the tin oxide obtained should be reprocessed either by re-cleaning using Jig at 125 µm sieve size or reprocessed using another processing method to achieve the required metallurgical grade of 65% Tin oxide for metal smelting process in extractive metallurgy outfit.

Keywords: Beneficiates, Farin-Lamba deposits, Jig, Cassiterite, Tin Oxide

INTRODUCTION

The main ore used for tin extraction is the mineral, cassiterite, which consists of tin oxide (SnO_2) (Figure 2). Cassiterite is highly dense and is resistant to weathering and erosion as it has a Moh's hardness of 6 to 7. Its name originates from the Greek word kassíteros, meaning tin. As the most significant source of tin, cassiterite is cost-effective to extract and process. The mineral is heavy, hard, and extremely brittle, often found alongside lighter gangue minerals [10]. Approximately 80% of the world's tin reserves are reported to be in placer or alluvial deposits [19], which are easier to process using gravity separation due to their coarse liberation size [21]. Cassiterite is also found in hard rock deposits associated with granitic host rocks, requiring communition, classification, gravity concentration, and flotation techniques for beneficiation [7]. Minerals from these deposits are more challenging to process due to their fine liberation size. Beneficiation flowsheets for cassiterite typically include gravity separation and flotation to produce market-grade concentrates [20]. The mineral typically forms in hydrothermal veins and granite pegmatites, often found with quartz, feldspar, and mica. It also occurs in alluvial

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VII July 2026

deposits formed by the transport of eroded minerals via rivers and streams. Cassiterite's color ranges from brown to black, and may be red, yellow, or gray. It has a tetragonal crystal structure, often appearing as prismatic or stubby crystals, but it can also be found in huge or granular forms, or as tin oxide-stained quartz.Despite its industrial value, cassiterite mining raises environmental and social concerns. Deforestation, soil erosion, and water pollution may occur as a result of mining activities [15]. Social issues, including labor rights violations and disputes regarding ownership of resources, are also associated with the industry. Efforts to mitigate these challenges are being pursued through responsible mining practices [18].

As a critical source of tin, cassiterite is essential for industrial use, but its extraction highlights the need for sustainable and ethical practices.

The imperative properties of Tin include; Malleability, Ductility, and corrosion resistant, which make it a suitable material for a variety of applications. Tin was alloyed with copper to form bronze metal that found wide applications, such as, making weapons, metal object and sculptures and cutting tools during the Bronze Age. Cassiterite is a vital mineral because of its tin content, a metal with numerous industrial uses. Tin extracted from cassiterite is utilized in producing alloys like bronze, a combination of tin and copper. It is also widely used in soldering materials, electrical components, and as a protective coating for other metals to prevent corrosion [13]. Their deposits in Nigeria are Adamawa, Cross-River, Ekiti, Gombe, Kaduna, Kogi, Nassarawa and Plateau [17]. This study is focused on the cassiterite in Jos,Pateau state. Farin-Lamba is located in Jos North Local Government Area of Plateau State, Nigeria (Figure 1), with geographical coordinates of 8º34′07″E longitude and 9º16′25″E latitude. It lies at an elevation of 246 meters and encompasses a mining site covering approximately 1,023 square meters [4,5]. Plateau State, situated in Nigeria's Middle Belt, spans an area of 30,913 km² (11,936 square miles) and is positioned between latitudes 9º51′30″N and longitudes 8º48′00″E [12,9]. The Jos Plateau is characterized by a predominance of plutonic and volcanic rocks, along with some alluvium and unconsolidated deposits. Prolonged tin mining in the region has left behind deep gorges and lakes [1,9].

The jigging process for the beneficiation of cassiterite involves separating the valuable cassiterite mineral from the gangue minerals and impurities. This process is commonly used in the mining industry to extract tin and other valuable minerals [16]. It is worth noting that the beneficiation process may vary depending on the specific characteristics of the cassiterite ore at the Farin-Lamba deposit and the equipment available for processing. Therefore, a detailed mineralogical and metallurgical analysis of the ore is typically conducted to optimize the beneficiation process. However, we will provide an overview of the cassiterite ore in Farin-Lamba, discuss the importance of tin oxide, and outline the methodology employed in this study. Additionally, the results and implications of our research will be thoroughly examined, with a focus on its potential impact on the local mining industry, environmental considerations, and the broader economic landscape.

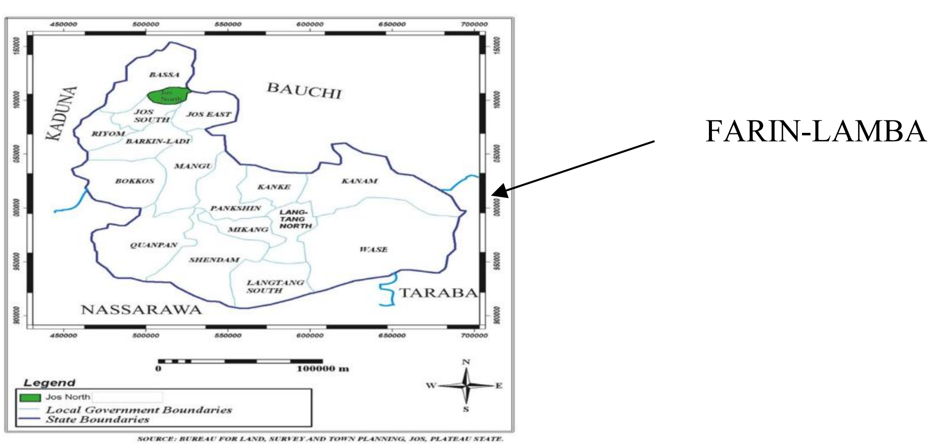

Figure 1: Topographical map of the study area. [17].

Cassiterite

Minerals are typically found in association with the parent rocks from which they originate. The content of the ore mineral is determined by the composition of the parent rock (Figure 2), and when these minerals are present in sufficient concentrations, they can be mined and processed into valuable products for human use and economic purposes [11]. For instance, [14], described the overall geology of the Jos Plateau and established the existence of tin ore and columbite-tantalite, both of which hold economic significance. These minerals are derived from pegmatites associated with the older granites. However, the pegmatites are considered less significant compared to the richer alluvial deposits of tin and columbite, which are associated with younger granites. Despite this, cassiterite mining in the study area has been largely unprofitable due to the low tin content found in the ore. Cassiterite remains the primary mineral ore for tin production. It has a chemical composition of tin dioxide (SnO_2) and typically appears as brown to black crystals or grains. The beneficiation of cassiterite involves various processes to extract tin oxide (SnO_2), which is used in the production of tin metal. Cassiterite typically forms in hydrothermal veins and pegmatite [6]. These veins are created when hot fluids carrying tin and other minerals infiltrate fractures in the surrounding rocks. Cassiterite deposits in Farin-Lamba and the surrounding areas are found in veins within the granitic rocks [2]. These veins contain cassiterite along with other minerals like wolframite and tantalite.

Beneficiation of Cassiterite ore has been research of interest in the mining industry for its potential to increase productivity and efficiency in tin oxide production. One common method used in the beneficiation process is the jig machine, which helps in separating valuable minerals from gangue materials based on their density differences [2]. However, this paper stands to address the beneficiation of Farin-Lamba Cassiterite using machine at different sieve sizes for tin oxide production and this will be addressed by randomly collecting samples from the various pits in the mine site and then an X-ray fluorescence analysis (ED-XRFS) was conducted.

Figure 2: Pictorial view of tin oxide mineral (SnO_2) in lode form [8].

METHODOLOGY

Materials

The raw materials used for this work was sourced from Farin-Lamba town located in Jos North Local Government Area, Plateau State Nigeria. The mining site lies on the geographical coordinatesof 8º34'07"E longitude and 9° 16' 25"E latitude at an elevation of 246 meter and land mass of about 1023-meter square of mine site [4,5]. Plateau State (latitudes 9°51'130"N and longitudes 8°48'00"E). An estimate dimension from artisanal mines out areas. 250 kg of the sample was sourced from five different pits tagged pit Fa-1, Fa-2, Fa-3, Fa-4, and Fa-5. These five sourced samples were combined and mixing together thoroughly to obtain homogeneity and from which a final sample of 50 kg was randomly picked; from this mix, sample was sieved to 90, 125, 180, 250 and 355 µm at ore's

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VII July 2026

liberation size at a determined energy needed to be applied to give a well ground ore through which Tin oxide (mineral) will be liberated, from the cassiterite.

Methods

The material used for this research work was sourced from Farin-Lamba deposits. The samples were combined and mixed together thoroughly to obtain homogeneity and from which a final sample of 50 Kg was randomly picked. The sieves, ranging from 90 to 355 µm, were properly cleaned and arranged with the coarsest sieve on the top and the finest at the bottom, i.e in order of decreasing aperture size. A receiver was placed below the bottom sieve to collect the under sized material, The cassiterite sample ground to liberation size of 90 µm out of which 500 g was weighed and fed into the ore box of the jig machine where seven hundred and seventy-seven (777) steel short of diameter (2 mm) has initially been charged as base. The water in the jig was moving rhymically and creating a column that rises and falls. As the water rises and falls, it lifts the lighter particles and allows heavier particles to settle to concentrate outfit. The sample was collected in different compartment based on their density. This was repeated for 125 µm, 180 µm, 250 µm, and 355 µm respectively. The jig was operated under a fixed laboratory setting for all particle-size fractions. No values of pulsation frequency, stroke length, or flow rate of the water were measured in the experimental records provided. These parameters were maintained as constants. However, the pulp products (concentrate and tailing) were allowed to settled followed by filtering through the filter and was sun dried, followed by oven dried at 105 ºC for the total removal of moisture. Then, the resulting products (concentrate and tailing) were weighed, sampled, and chemically analyzed. Finally, the results obtained and analyzed using percentage recovery, enrichment ratio, concentration ratio and grade (grade) of the tin oxide obtained, through metallurgical accounting parameters.

RESULTS AND DISCUSSION

Results

The chemical composition of the as-received alluvial cassiterite from Farin-Lamba deposit using XRF analysis is presented in Table 1 respectively. Figure 1 is the graphical representation of Chemical Characterization of crude Farin-Lamba Cassiterite using X-Ray Fluorescence Spectrometer (ED-XRFS) (element against composition).

The present study does not offer definitive mineralogical characterization of the Farin Lamba ore but rather offers chemical characterization. A detailed mineralogical investigation would be necessary to identify the mineral phases, mineral associations and ore liberation characteristics.This constitutes the limitation of the present study.

Table 1: ED-XRF Determined composition of crude Farin-Lamba cassiterite

Compositions	SiO_2	Fe_2O_3	NiO	CuO	Nb_2O_5	P_2O_5	SO_3	Ta_2O_5	TiO_2	ZrO_2	SnO_2
Content (%)	15.397	10.118	0.023	0.0247	9.860	1.932	0.460	1.788	10.644	26.120	13.076

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VII July 2026

Table 2: Weight of charged (crude cassiterite) and product of tin-oxide from Jig machine using Farin-Lamba cassiterite

Sieve size (µm)	Wt of charge (g)	Wt of sink (g)	Wt of float (g)
-500+355	500.0	122.38	377.62
-533+250	500.0	135.24	367.76
-250+180	500.0	126.34	373.66
-180+125	500.0	121.56	378.44
-125+90	500.0	114.43	385.57

Table 3: Chemical characterization of sink products using Jig machine to process Farin-Lamba cassiterite

Sieve sizes (µm)	SiO_2 (%)	Fe_2O_3 (%)	NiO (%)	CuO (%)	Nb_2O_5 (%)	P_2O_5 (%)	SO_3 (%)	Ta_2O_5 (%)	TiO_2 (%)	ZrO_2 (%)	SnO_2 (%)
355	13.699	8.653	0.038	0.072	8.744	0.995	0.546	1.199	6.542	29.539	27.989
250	13.698	9.413	0.038	0.044	8.544	0.900	0.220	1.280	7.579	27.908	29.963
180	13.904	8.991	0.035	0.021	8.257	1.207	0.544	1.145	7.090	27.051	30.701
125	15.564	8.690	0.038	0.050	8.136	1.177	0.498	1.142	6.220	25.795	42.057
90	13.640	8.880	0.038	0.064	9.258	1.047	0.408	1.226	6.962	27.524	39.955

Table 4: Assay of Tin oxide in charge products (sink and float) obtained from Farin-Lamba Cassiterite using Jig machine

Sieve size (µm)	Assay of charge (%)	Assay of sink (%)	Assay of float (%)
-500+355	13.08	27.989	20.888

-533+250	13.08	29.693	10.849
-250+180	13.08	30.701	17.706
-180+125	13.08	32.057	21.834
-125+90	13.08	39.955	17.955

Table 5: Chemical characterization of concentrate product using Jig machine to process Farin-Lamba Cassiterite

Sieve sizes (µm)	SiO_2 (%)	Fe_2O_3 (%)	NiO (%)	CuO (%)	Nb_2O_5 (%)	P_2O_5 (%)	SO_3 (%)	Ta_2O_5 (%)	TiO_2 (%)	ZrO_2 (%)	SnO_2 (%)
355	13.133	8.884	0.036	0.039	7.964	0.606	0.311	1.150	7.556	28.848	20.888
250	21.433	8.338	0.039	0.040	7.512	0.816	0.372	0.978	6.977	31.387	10.849
180	14.369	11.080	0.043	0.069	8.094	1.467	0.542	1.057	6.633	27.076	17.706
125	13.826	8.323	0.038	0.034	9.059	0.495	1.054	1.164	6.898	26.757	21.834
90	13.778	12.101	0.044	0.051	9.631	1.124	0.556	1.234	5.493	26.902	17.955

Table 6: Metallurgical Accounting Parameters of Jigging separation process carried out on Farin-Lamba Cassiterite at varying sieve size for concentrate

Sieve size (µm)	**Feed wt (g) F**	**Feed grade (%) f**	**Concentrate wt (g) C**	**Concentrate Grade (%) c**	**Recovery (%)** $\frac{Cc}{Ff}x100$	**Enrichment Ratio** $\frac{C}{F}$	**Concentration Ratio** $\frac{F}{C}$
355	500.0	13.08	227.62	27.989	52.37	2.14	4.09
250	500.0	13.08	235.24	29.693	61.40	2.27	3.69
180	500.0	13.08	308.34	30.701	59.31	2.35	3.96
125	500.0	13.08	209.56	42.057	78.17	3.22	4.11
90	500.0	13.08	307.43	39.955	69.91	3.05	4.37

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VII July 2026

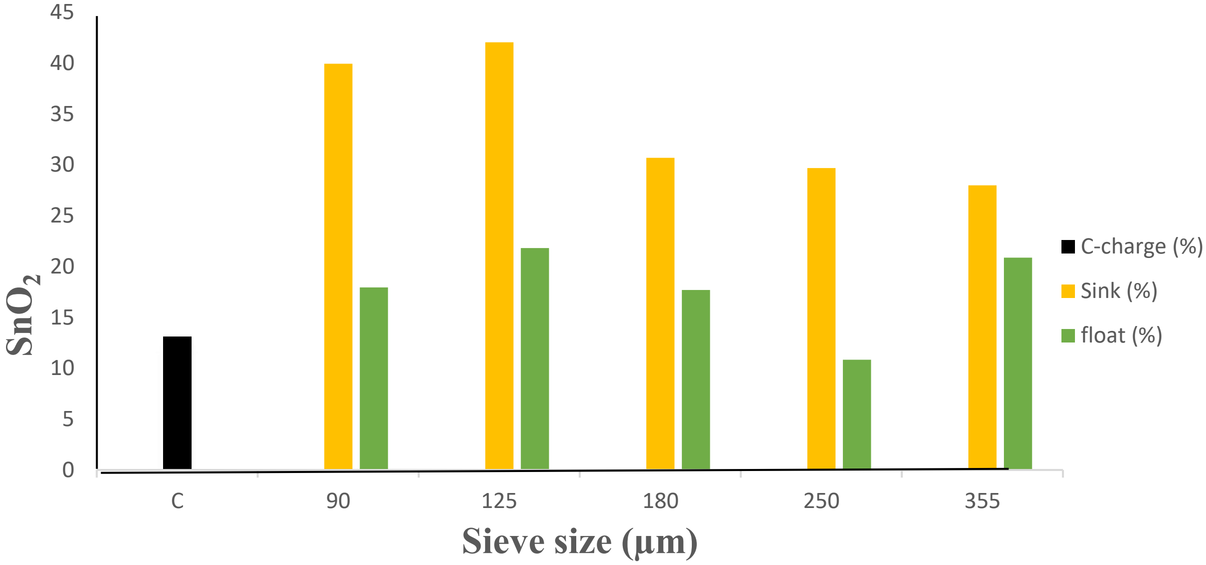

Figure 3: Assay of SnO_2 (sink and float) against Sieve Size (µm) of beneficiated Farin-Lamba Cassiterite using Jig machine

DISCUSSION

Table 1 present the chemical composition of the as-received alluvial cassiterite from Farin-Lamba deposit. The result shows that zircrium oxide (ZrO_2) is the most abundant associated mineral component having 26.120% followed by Silica oxide with 15.397% SiO_2, tin oxide-13.076% SnO_2, titanium oxide-10.644% TiO_2, iron oxide-10.118% Fe_2O_3, and niobrium oxide-9.860% Nb_2O_5. These findings indicate that the mine has the potential to be a significant source of Tin oxide, which can be mined and beneficiated to meet the metallurgical grade of 65% meant to produce tin metal required for use as an alloying element in steel production. The characterization confirms that the cassiterite reserve is in commercial quality, and this research demonstrates that Farin-Lamba cassiterite can be beneficiated to metallurgical grade of 65% SnO_2potentially eliminating the need for Tin import in the country.

Figure 3 presents the results of weight of both the charged crude of cassiterite and the product (sink & float) obtained after the process using Jig machine at varying sieve sizes. This shows that as the product received as sink is increasing the product at the float appears to be decreasing along the sieve sizes this shows an inverse relationship between the wt of sink and wt of float; indicating the effectiveness of the Jig processing in separating the materials [3]. However, to confirm the grades of the products, reference should be made to Table 3 and Figure 3, which provide further details on the separation efficiency.

However, Figure 3 shows that the grade (Assay) of the charge remains constant as 13.08% SnO_2, while that at sieve size at sink gave 27.989%, 29.693%, 30.701%, 42.057%, and 39.955% at respective sieve sizes of -500+355 to -125+90 µm. In contrast, the float product shows fluctuating grades (Assay) of SnO_2: 20.888%, 10.849%, 17.706%, 21.834% and 17.955%at the respective sieve sizes of -500+355 to -125+90 µm. notably, as the SnO_2assay in the sink increases, the SnO_2assay in the float decreases or fluctuates. The highest grade obtained were 42.057% SnO_2 in the sink and 21.843% SnO_2 in the float. These results suggest that the Jig machine process alone is insufficient to achieve the required grade for tin oxide needed for tin metal production in pyrometallurgical outfit; highlighting the need for further re-cleaning of the product using the same method or combining it with another method to enhance the grade attainment.

The result obtained from Table 4 build up to give data needed for metallurgical accounting parameters when Jig machine was used in the ore processing as shown in Table 6. This table presents the grade of the ore, recovery, enrichment ratio and concentration ratio at varying sieve sizes. The data shows that as the grade increases with decreasing sieve sizes, the recovery and enrichment ratio also increase, while concentration ratio shows a fluctuating behavior with an optimum value at 125 µm. Notably, the 125 µm sieve size exhibits the highest values in all metallurgical accounting parameters, making it more promising size for obtaining metallurgical-grade tin oxide from Farin-Lamba cassiterite. These findings suggest that the jigging separation process at a sieve size of 125 µm yielded the optimal conditions for producing tin oxide (SnO_2) suitable for use as a charge in extractive metallurgical processes to produce tin (Sn) metal. [3].

CONCLUSION

1. Beneficiation of Farin-Lamba cassiterite using Jig machine at varying sieve sizes was successfully carried out towards production of tin oxide for industrial application. The following conclusions were therefore drawn;

2. Farin-Lamba cassiterite consist of tin oxide to the tune of 13.08% SnO_2 and some other impurities as constituents like iron (Fe_2O) and silica (SiO_2) which are the ore's major impurities.

3. The sourced crude cassiterite yielded positively to Jig machine operation at different sieves by improving the grade of tin oxide in cassiterite from 13.08% SnO_2 to 42.057% SnO_2.

4. Metallurgical accounting parameter were effectively utilized to determine the most effective sieve size for tin oxide production from Farin-Lamba cassiterite, revealing that a sieve size of 125 µm yield the highest efficiency.

ACKNOWLEDGEMENT

The authors wish to thank the Mineral Processing Laboratory of the Department of Metallurgical and Materials Engineering, Federal University of Technology, Akure, Ondo State, Nigeria, for allowing the use of their laboratory equipment's during the course of the research.

Conflict of Interest

The author declare that they have no competing interest that could have appeared to influence the work reported in this paper.

REFERENCES

1. Adeniran, M., A., Ekpo, E., Adedayo, O. A., Ibekwe, V. J., (2013). Case study of Jos Metropolis, Plateau State, Nigeria, 1, 1-3.
2. Alabi O., O., Borode J.O., Ajaka O., E., Gbadamosi Y.E. (2024). Investigating the Gravity Beneficiation Consequence on Farin-Lamba (Plateau State) Cassiterite towards Tin Oxide Production. Saudi Journal Engineering Technology, 9(2), 121-127.
3. Alabi, O., O., and Gbadamosi, Y., E., (2023). Investigating the Production of Ultrafine Engineering Material from Low-Grade Gariti Barite Ore Using Gravity Concentration Methods, Journal of Materials and Engineering, 2 (1), 20-27.

4. Alabi, O. O., Gbadamosi, Y. E., Olatunji, T. A., Ola-Omole, O. O. (2017). Froth Flotation of Itakpe Iron Ore Dumped Tailings at Varied Agitation Time: Research and Development for Economic Sustainability, Nigerian Metallurgical Society, NMS 2017-TP004, 29-36.
5. Alabi, O. O., Borode, J. O., Oloruntoba, D. T., Abere, V. (2017). Influence of Local Paddock Processing Operation on Farin-Lamba Cassiterite to Conventional Wilfley Gravity Processing Method, National Metallurgical Society. NMS 2017-TP001, 1-4
6. Angadi, S. I., Sreenivas, T., Jeon, H. S., Baek, S. H., Mishra, B. K. (2015). A review of cassiterite beneficiation fundamentals and plant practices. Minerals Engineering, 70 (1), 178-200.
7. Bustillo R. M., (2018). Mineral deposits: types and geology. Mineral Resources: From Exploration to Sustainability Assessment, 49-119.
8. Cheng, Y., Spandler, C., Kemp, A., Mao, J., Rusk, B., Hu, Y., Blake, K. (2019). Controls on cassiterite (SnO_2) crystallization: Evidence from cathodoluminescence, trace-element chemistry, and geochronology at the Gejiu Tin District. American Mineralogist, 104(1), 118-129.
9. Itodo, A. U., Wuana, R. A., Duwongs, B. E., Bwede, D. D. (2019). Mineralogy and Pollution Status of Columbite-Tin Ore Contaminated Soil.Adv J. Chem. A, 2, 147-164.
10. Jun, W. S., Yun P. S., Lee, E. C., (2004). Leaching behavior of tin from Sn–Fe alloys in sodium hydroxide solutions Hydrometallurgy, 73 (1), 71–80.
11. Kesler, S. E., Simon, A. C., and Simon, A. F. (2015). Mineral resources, economics and the environment. Cambridge University Press.
12. Kwaghe, A. V., Ndahi, M. D., Usman, J. G., Sambo, E., Waziri, I., El-oji, A. A., Pam, E. G., Jost, C. C., Acho, I. O., Tchangai, C. P., (2012). HighlyPathogenic Avian Influenza Participatory Disease Surveillance in Plateau State, Nigeria, Archives Des Sciences, 65, 1-12.
13. Lllés, B., Horváth, B., Géczy, A., Krammer, O., Dušek, K. (2017). Corrosion-induced tin whisker growth in electronic devices, A review. Soldering & Surface Mount Technology, 29 (1), 59-68.
14. Mallo, S., J., (2000). Scientific Approach to Sub-Surface (Loto) Mining Technique. Journal of Engineering Technology and Industrial Applications, 1 (2), 17-22.
15. Mensah, A. K., Mahiri, I. O., Owusu, O., Mireku, O. D., Wireko, I., Kissi, E. A. (2015). Environmental impacts of mining: a study of mining communities in Ghana. Applied Ecology and Environmental Sciences, 3 (3), 81-94.
16. Nie, S., Guo, Z., Tian, M., Sun, W. (2023). Selective flotation separation of cassiterite and calcite through using cinnamon hydroxamic acid as the collector and Pb_2+ as the activator. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 66, 131-262.
17. Olade, M. A. (2019). Solid mineral deposits and mining in Nigeria: a sector in transitional change. Achievers Journal of Scientific Research, 2(1), 1-16.
18. Wang, W., Lu, J., Wang, C., Yuan, J., Hou, X., Pan, M., Zhao, Y. (2022). Study on screening probability model and particle-size effect of flip-flow screen. Advanced Powder Technology, 33 (8), 103-668.
19. Wills, B. A., and Napier-Munn, J. T., (2006). Mineral Processing Technology. Elsevier Science and Technology, 7, 1-29.
20. Yang, J., Zhang, D., Mei, X., Zhao, L., Ma, C., Shi, H., (2015). Thermal error simulation and compensation in a jig-boring machine equipped with a dual-drive servo feed system. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 229(1), 43-63.
21. Yuce, A. E. (2017). Grinding size estimation and beneficiation studies based on simple properties of ore components. Physicochemical Problems of Mineral Processing, 53(1), 541-552.