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Investigating the Gravity Beneficiation Consequence on Farin-Lamba (Plateau State) Cassiterite towards Tin Oxide Production

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Abstract

This research aims to assess the amenability of Farin-Lamba cassiterite to the gravity concentrations techniques towards tin oxide production. The ore was subjected to fractional sieve size analysis, work index, and the concentration test to gravity method using the Wilfley shaking table and Spiral concentrator processing. Fractional sieve analysis of the crude sample was carried out at a sieve range of 500-63 µm towards liberation size determination. Five hundred (500) g each of Farin-Lamba cassiterite and Igbokoda silica sand was prepared by grinding to 100% passing 500 µm sieve towards work index determination and the gravity separation method was determined using the Wilfley shaking table and spiral concentration method. The fractional sieve size analysis carried out revealed that the Tin oxide-bearing mineral can be liberated at the particle size fraction of -180 + 125 µm. The work index alongside the energy expended in grinding the ore was found to be 9.980 Kwh/ton and 2.435 Kwh respectively. The chemical analysis of the ore concentrates revealed that the optimum yield was obtained at +125 µm assaying 62.74% SnO_2 for Wilfley shaking table and 60.07% SnO_2 for spiral concentration.

Keywords: Farin-Lamba, Cassiterite, Gravity Separation, Spiral Concentrator, Wilfley Shaking Table.

1. INTRODUCTION

Cassiterite is the most important mineral from which tin metal is extracted cost-effectively. The mineral is heavy, hard, extremely brittle in nature, and is generally associated with lighter gangue minerals (Bulatovic, 2010). Ruiz *et al.*, (2004) reported that cassiterite beneficiation plants all around the world have undergone many developments in terms of modifications in the conventional flowsheets, incorporation of newly invented equipment, and revision and adoption of novel chemical reagents, etc., and most of these developments have been market driven.

The cassiterite occurring in hard-rock deposits is associated with granitic host rock that needs comminution, classification, gravity concentration, and flotation techniques to beneficiate.

Farin-Lamba is in Jos North Local Government of Plateau state Nigeria with geological coordinates of 8º 34′ 07″ E longitude and 9º 16′ 25″ E latitude at an elevation of 246 m and land mass of about 1023 meters square of mine site (Alabi *et al.*, 2017). Plateau state (latitudes 9º51′30″N and longitudes 8º48′00″E) is located in Nigeria's middle belt, with an area of 30,913 km^2 (11,936 sqm) (Kwaghe *et al.*, 2012; Itodo *et al.*, 2019). It was noted that plutonic and volcanic rocks predominate in the Jos Plateau, with some alluvium and other unconsolidated deposits. Years of tin mining have also left the area strewn with deep gorges and lakes (Adeniran *et al.*, 2013; Itodo *et al.*, 2019).

There are limited studies on the Farin-Lamba cassiterite nationwide and based on the present economic situation, there is a need for the exploration and exploitation of minerals that will help in increasing the nation's source of revenue. Daily there is demand for tin products and the only source of tin is from its ore. Therefore, to recover valuable minerals from Farin-Lamba cassiterite, gravity separation has been suggested by authors that will invariably add to the standard of living.

Gravity separation is an industrial method of separating two components, either in suspension or in dry condition, from a granular mixture of different specific weights. The process of separating the components is done using gravity as the major criterion. The most outstanding benefits of the gravitational methods are their cost effectiveness and in some cases excellent reduction. The gravity separator separates products of the same size but with differences in specific weight (Balasubramanian, 2017; Alabi and Gbadamosi 2023).

2. METHODS

Sample collection

Farin-Lamba cassiterite samples were sourced from 10 different pits, dug at a dimension of 1.0 m by 1.0 m by 2.0 m. The collected samples were properly mixed to obtain homogenization from which 50 kg was weighed using a random sampling technique. Twenty (20) kg of the as-received alluvial deposit was sampled out for the research.

Particle size analysis of the Farin-Lamba Cassiterite sample

One hundred grams (100 gms) of the prepared cassiterite ore was charged into an array set of sieves arranged in root sieve (√2). The arrangement ranges from 500-63 µm, with a tight-fitted pan placed below the bottom sieve to receive the final undersize and a lid placed on the topmost sieve that houses the coarsest size to prevent escape of samples during operation. This set was sieve shaken on Denver automated sieve shaker model MY-2014 at the Mineral Research Laboratory of the Metallurgical and Materials Engineering Department Federal University of Technology, Akure (Gbadamosi *et al*., 2017).

Bond index determination of the Farin –Lamba Cassiterite

The work index of Farin-Lamba cassiterite was determined using the modified Bond's method of Gaudin Schumann expression. Silica Sand was sourced from Igbokoda, Ilaje local government area of Ondo State, as the reference ore was weighed and charged into the Denver Laboratory Milling Machine. Both the test and reference ore were subjected to the same crushing and grinding processes. One hundred (100) g of each of the samples (test and reference ore) was charged into the set of sieves which was placed on the shaker which vibrated the sieve in a vertical plane for 15 minutes and each sieve fraction retained the test and reference ore were

$$\text{Sieve } 1 = \frac{\%\ \text{passingsieve } 1}{\%\ \text{passingseive } 2} \times \text{Sieve } 2 \ \ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

The results obtained were computed to establish the amount of energy needed to reduce the mineral to its liberation size (Gbadamosi *et al*., 2021).

Gravity separation method of the Farin-Lamba cassiterite using Wilfley shaking table

1 kg each of Farin-Lamba cassiterite of sieve size -355+ 250 µm, -250 + 180 µm, -180 + 125 µm, -125 + 90 µm, and -90 + 63 µm were mixed with 4 liters of water respectively to form a slurry with a constant ratio of 1:4. These slurries were charged through the charging chamber onto the deck of Wilfley shaking table, tilted at an angle of 180º at a feed rate of 50 liters per hour with deck speed set at 1000 revolution per minute (rpm) respectively (Alabi, 2020; Alabi and Gbadamosi 2023). The resulting products were allowed to settle down and were decanted after 24 hours. The pulp product was filtered and the cake from the filtering process was dried in a carbolite oven model OV95C at a temperature of 110ºC for the total removal of moisture. Then, the resulting products (concentrate and tailing) were weighed, sampled, and chemically analyzed.

Gravity separation method of Farin-Lamba cassiterite using spiral concentrator

1 kg each of Farin-Lamba cassiterite of sieve size -355+ 250 µm, -250 + 180 µm, -180 + 125 µm, -125 + 90 µm, and -90 + 63 µm were mixed with 4 liters of water respectively to form slurry with a constant ratio of 1:4. These slurries were charged through the charging chamber onto the spiral concentrator, and then flows on to the spiral surface, as the slurry travels down the spiral, mineral grains settle and sort according to size, shape and specific gravity (Alabi, 2020). The resulting products were allowed to settle down and were decanted after 24 hours. The pulp product was filtered and the cake from the filtering process was dried in a carbolite oven model OV95C at a temperature of 110ºC for the total removal of moisture. Then, the resulting products were weighed, sampled, and chemically analyzed.

3. RESULTS

Table 1: Sieve size analysis of Farin-Lamba Cassiterite showing Assay (%) of Tin Oxide and silica towards liberation size determination

Sieve size	Weight Retained	% Weight retained (g)	% Cumulative weight retained	% Cumulative weight Passing	% SnO_2	% SiO_2
+500	27.78	28.66	28.86	71.14	20.17	45.08
-500+355	16.63	17.28	46.14	53.86	20.14	44.52
-355_250	20.36	21.15	67.29	32.71	20.18	44.38

Sieve size	Weight Retained	% Weight retained (g)	% Cumulative weight retained	% Cumulative weight Passing	% SnO_2	% SiO_2
-250+180	7.71	8.01	75.30	24,70	21.33	43.11
-180+125	14.67	15.24	90.54	9.46	23.23	40.08
-125+90	6.71	6.97	97.51	2.49	21.13	40.11
-90+63	1.71	1.78	99.29	0.71	20.03	40.48
-63	0.68	0.71	100	0	20.21	42.02

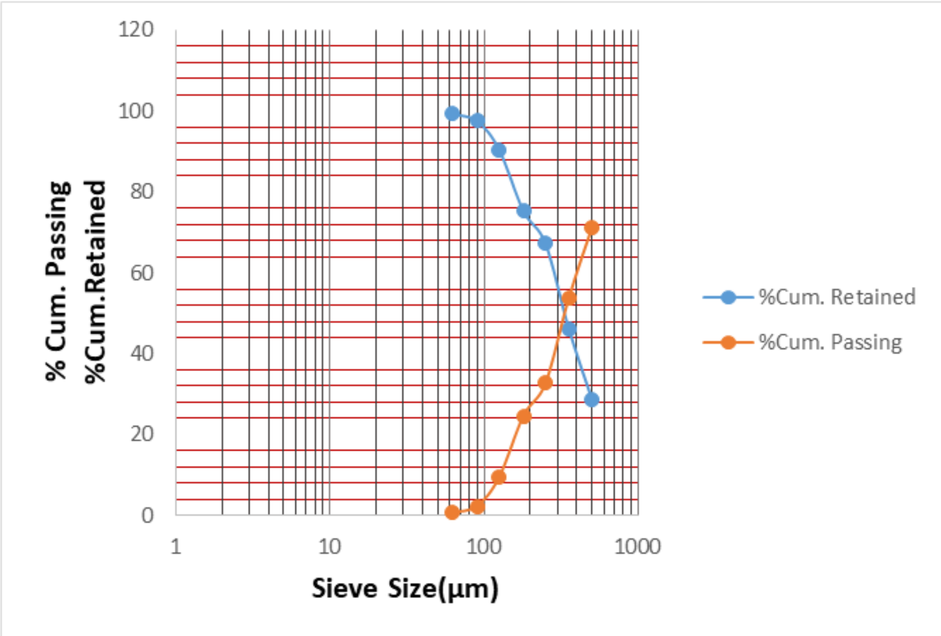

Figure 1: A Plot of log-log of Percentage Cumulative Retained and Passing against Sieve Sizes (µm) of the Fractional Analysis of Farin-Lamba Cassiterite

Table 2: Sieve Analysis of Farin Lamba Cassiterite (Test Ore) Feed to the Ball Mill

Sieve size range (µm)	Weight retained (g)	% Weight retained (g)	Cumulative weight retained (g)	Cumulative weight passing (g)
-600+500	27.78	28.86	28.86	71.14
-500+355	16.63	17.28	46.14	53.86
-355+250	20.36	21.15	67.29	32.71
-250+180	7.71	8.01	75.32	24.7
-180+125	14.67	15.24	90.54	9.46
-125+90	6.71	6.97	97.51	2.49
-90+63	1.71	1.78	99.29	0.71
-63	0.68	0.71	100	0

Table 3: Sieve Analysis of Igbokoda Silica Sand (Reference Ore) Feed to the Ball Mill

Sieve size range (µm)	Weight retained (g)	% Weight retained (g)	Cumulative weight retained (g)	Cumulative Weight Passing (g)
-600+500	2.346	2.43	2.432	97.568
-500+355	6.645	6.88	9.32	90.68
-355+250	18.469	19.2	28.466	71.534
-250+180	28.895	29.9	58.42	41.579
-180+125	20.820	21.6	80.01	19.99
-125+90	12.309	12.7	92.76	7.235
-90+63	4.965	5.14	97.91	2.088
-63	2.011	2.08	100	0

Table 4: Sieve Analysis of Farin-Lamba Cassiterite (Test Ore) Product from the Ball Mill

Sieve size range (µm)	Weight Retained (g)	% Weight retained (g)	Cumulative weigh retained (g)	Cumulative weight passing (g)
-600+500	0.27	0.28	0.28	99.72
-500+355	2.93	3.08	3.36	96.64
-355+250	14.63	15.3	18.75	81.25
-250+180	11.7	12.4	31.06	68.94
-180+125	26.36	27.7	49.29	50.71
-125+90	21.3	22.4	81.19	18.81
-90+63	14.6	15.4	96.57	3.43
-63	3.26	3.43	100	0

Table 5: Sieve Analysis of Igbokoda Silica Sand (Reference Ore) Product from the Ball Mill

Sieve size range (µm)	Weight retained (g)	% Weight retained (g)	Cumulative weight retained (g)	Cumulative weight Passing (g)
-600+500	0.54	0.56	0.559	99.441
-500+355	2.69	2.80	3.362	96.638
-355+250	20.8	21.7	25.018	74.982
-250+180	14.3	14.9	39.87	60.129
-180+125	26.8	27.9	67.835	32.165
-125+90	16.8	17.46	85.295	14.705
-90+63	11.47	11.95	97.248	2.752
-63	2.64	2.75	100	0

Table 6: Sieve mesh size (500 µm and 250 µm) at 80% of Particle Size Passing

Sample	80% Passing of Feed Product (µm)	80% Passing Milled Product (µm)
Test Ore	632.25	242.25
Reference Ore	312.5	284.55

Work Index Determination

The work index was determined using equation 1 by imputing the values of the results obtained in Table 6.

Where; Wir = 12 Kwh/ton

$$Wit = Wr \times \left(\frac{\frac{10}{\sqrt{284.55}}}{\frac{10}{\sqrt{242.25}}} - \frac{\frac{10}{\sqrt{312.5}}}{\frac{10}{\sqrt{632.25}}} \right)$$

= 9.980 Kwh/ton

Energy Expended in Grinding Determination

$$Wt = \left(10Wit \times \frac{1}{\sqrt{242.25}} - \frac{1}{\sqrt{632.25}}\right)$$

$$= 10 \times 9.980 \times \left(\frac{1}{\sqrt{242.25}} - \frac{1}{\sqrt{632.25}}\right)$$

= 2.435 Kwh

Table 7: Chemical Analysis of the Wifley Shaking Table Concentrate of Processed Samples of Farin-Lamba Cassiterite

Sieve size Range (µm)	Al_2O_3 %	SiO_2 %	SnO_2 %	SO_3 %	CaO %	TiO_2 %	Nb_2O_3 %	ZrO_2 %	Fe_2O_3 %	MgO %	K_2O %	MnO %
355	3.57	9.02	54.86	0.07	2.42	1.03	1.18	3.1	8.0	0.58	1.02	0.56
250	3.84	7.71	53.65	0.03	4.26	2.29	2.20	3.41	6.41	0.47	1.90	0.03
180	4.62	7.17	53.58	0.03	3.21	0.64	3.05	5.22	12.18	0.36	2.10	0.72
125	4.74	6.96	62.74	0.05	3.85	0.62	2.50	3.57	13.20	0.28	1.84	0.65
90	4.21	7.06	54.29	0.02	1.57	0.76	2.41	2.39	9.42	0.54	2.91	0.3

Table 8: Chemical Analysis of the Wifley Shaking Table Tailings of Processed Samples of Farin-Lamba Cassiterite

Sieve size Range (µm)	Al_2O_3 %	SiO_2 %	SnO_2 %	SO_3 %	CaO %	TiO_2 %	Nb_2O_3 %	ZrO_2 %	Fe_2O_3 %	MgO %	K_2O %	MnO %
355	9.73	52.2	11.5	0.03	5.72	1.07	0.15	0.11	5.52	1.38	1.12	0.34
250	11.08	54.2	13.45	0.03	5.24	0.49	0.24	0.21	10.75	1.18	1.05	0.05
180	4.06	47.91	3.39	0.11	12.42	0.41	1.54	7.05	7.61	2.29	1.13	1.08
125	3.36	56.26	2.86	0.09	11.63	0.46	2.01	7.21	7.93	2.38	1.93	1.08
90	4.19	50.14	3.74	0.08	7.33	1.57	1.78	11.24	5.93	1.38	1.71	1.42

Table 9: Chemical Analysis of the Spiral Concentrator for Concentrate of Processed Samples of Farin-Lamba Cassiterite

Sieve size Range (µm)	Al_2O_3 %	SiO_2 %	SnO_2 %	SO_3 %	CaO %	TiO_2 %	Nb_2O_3 %	ZrO_2 %	Fe_2O_3 %	MgO %	K_2O %	MnO %
355	9.95	3.08	51.96	0.03	6.98	1.05	1.20	3.13	7.10	0.85	0.96	0.68
250	6.5	3.84	54.75	0.09	8.25	2.41	1.97	3.26	6.55	0.31	1.64	0.38
180	9.02	1.25	55.18	0.09	5.02	0.61	2.03	3.11	10.75	1.01	1.73	1.42
125	8.62	1.05	60.07	0.22	4.98	0.64	4.98	3.18	10.24	0.93	1.61	1.31
90	9.43	2.18	54.07	0.23	3.42	0.72	1.60	4.72	11.03	1.84	1.97	1.20

Table 10: Chemical Analysis of the Spiral Concentrator Tailings of Processed Samples of Farin-Lamba Cassiterite

Sieve size Range (µm)	Al_2O_3 %	SiO_2 %	SnO_2 %	SO_3 %	CaO %	TiO_2 %	Nb_2O_3 %	ZrO_2 %	Fe_2O_3 %	MgO %	K_2O %	MnO %
355	6.79	54.61	9.14	0.12	8.06	0.93	2.74	3.68	5.11	0.62	0.86	0.03
250	6.35	55.32	6.28	0.18	4.31	0.75	2.42	3.90	9.22	0.98	0.75	0.02
180	4.67	57.71	0.93	0.05	5.15	0.36	3.25	10.93	4.33	2.81	1.46	0.34
125	4.67	59.34	0.82	0.06	6.20	0.49	3.03	14.78	5.25	2.62	1.60	0.47
90	4.71	53.1	1.88	0.04	5.22	1.07	2.73	15.13	5.31	2.40	1.62	0.32

4. DISCUSSION

Size/Assay analysis and liberation size determination

Table 1 shows the fractional sieve size analysis of crude Farin-Lamba cassiterite. It can be observed that 27.78 g of 100 g was retained on 500 µm, 16.53 g on 355 µm, 20.36 g on 250µm, 7.71 g on 180 µm 14.67g on 125 µm, 6.71 g on 90 µm, 1.71 g on 63 µm, 0.68 g and on -63 µm. The cumulative percentage passing following the order of sieve arrangement from the coarsest is obtained as 71.14 %, 53.86 %, 32.71 %, 24.7%, 9.46 %, 2.49%, and 0.71%.

The chemical analysis of the ore sample conducted on all the sieve size fractions shows the elemental form of Tin oxide which is as follows; +500 µm (20.17% SnO_2), -500+355 µm (20.14% SnO_2), -355+250 µm (20.18% SnO_2), -250+180 µm (21.33% SnO_2), -180+125 µm (23.23% SnO_2), -125+90 µm (21.13% SnO_2), -90+63 µm (20.03%SnO_2), and -63 µm (20.21% SnO_2).

Significant liberation of mineral of interest (Tin Oxide) was achieved at a sieve size fraction of - 180 +125 µm with a percentage assay of 23.3% SnO_2 being the highest percentage of Tin Oxide when compared to other sieve sizes. This indicates that a reasonable quantity of Sn can be obtained if the ore is ground to -180+125 µm when compared to other sieve fractions. Hence, -180+125 µm is the liberation size of Farin-Lamba Cassiterite.

Figure 1 shows that the two curves which are mirror images of each other intercepted at -180+125 µm which is in agreement with the result of the chemical analysis of sieve fractions. -180+125 µm has the highest assay. Therefore, -180 + 125 µm is the liberation size for Farin-Lamba Cassiterite.

Bond index determination of the Farin-Lamba Cassiterite

Tables 2 – 5 present the result of the grindability test of Farin-Lamba cassiterite (Test ore) and Igbokoda silica sand (Reference ore). The result revealed that 80% passing particle size fractions for feed to the ball mill (Fr, Ft) of both the test ore and reference ore were found to be 632.25 µm and 312.5 µm. The 80% passing particle size fractions for a product from the ball mill (Pr, Pt) of both the test ore and reference ore were found to be 242.25 µm and 284.55 µm respectively. The work index of the Farin-Lamba cassiterite was computed to be 9.980 Kwh/ton. The value obtained indicates the energy required to reduce one ton of the cassiterite ore sample from 80% passing size. The value was also used in calculating the amount of energy expended in grinding the test ore using Bond's equation and was found that 2.435 Kwh/ton was the energy required.

Gravity separation method of the Farin-Lamba Cassiterite using Wilfley shaking table

Table 7 shows the chemical composition of the concentrate and the economical liberation size (125µm) has the highest assay of SnO_2 which is 62.74% when compared to other sieve size fractions. This shows an improvement in the percentage assay of the cassiterite ore present in this mineral.

Table 8 indicates that there is an increase in the assay of SiO_2 for the entire sieve size fraction and there is a decrease in the assay of SnO_2 compared to the assay of the concentrate but for -180+125 µm sieve fraction which is the actual liberation size, there is increase due to over-grinding of the sample (Wills and Napier-Munn, 2006).

Gravity separation method of the Farin-Lamba Cassiterite using spiral concentrator

Table 9 shows the chemical composition of the concentrate and the economical liberation size (125µm) has the highest assay of SnO_2 which is 60.07% when compared to other sieve size fractions. This shows an improvement in the percentage assay of the cassiterite ore present in this mineral.

Table 10 revealed that there is an increase in the assay of SiO_2 for the entire sieve size fraction and there is a decrease in the assay of SnO_2 compared to the assay of the concentrate but for -180+125 µm sieve fraction which is the actual liberation size, there is increase due to over-grinding of the sample (Wills and Napier-Munn, 2006).

5. CONCLUSIONS

The research on Farin-Lamba Cassiterite has helped to provide ample information about the consequence of chemical and mineralogical characterization of the ore on the gravity concentration of Farin-Lamba Cassiterite towards the production of tin metal for metallurgical usage globally. However, from the results obtained the following were therefore concluded:

i. The particle size analysis carried out on the ore revealed that -180 + 125 µm is the liberation size and assaying 40.08% of SnO_2.
ii. The work index of the ore was found to be 9.980 Kwh/ton using the Gaudin Schumann expression and the amount of energy expended in grinding the test ore using Bond's equation was computed to be 2.435 Kwh/ton;
iii. The chemical analysis of the concentration test using Wilfley shaking table revealed that the economic liberation fraction (125 µm) has the highest assay of 62.74% SnO_2; likewise,
iv. The chemical analysis of the concentration test using Spiral Concentrator revealed that the economic liberation fraction (125 µm) has the highest assay of 60.07% SnO_2; and finally
v. Comparing the two concentration test, Wilfley shaking table method was more economically viable compared to spiral concentrator at liberation sieve size of 125 µm assay of 62.74% SnO_2.

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REFERENCES

- Adeniran, M. A., Ekpo, E., Adedayo, O. A., & Ibekwe, V. J (2013), Case study of Jos Metropolis, Plateau State, Nigeria, 1, pp. 1-3.
- 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, pp. 1-4.
- Alabi, O. O. (2020). Upgrading a low-grade Wasagu – Danko (Nigeria) manganese ore using gravity separation methods. *Indian Journal of Engineering*, *17*(48), 357-362.
- Alabi, O. O., & 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), pp. 20-27.
- Balasubramanian, A. (2017). Gravity Separation in Ore Dressing. *ResearchGate*, pp. 1-9.
- Bulatovic, S. M. (2010). Handbook of flotation reagents: chemistry. Theory and Practice, Flotation of Gold, PGM and Oxide Minerals, *Elsevier*, 2, pp. 1-12.
- Gbadamosi, Y. E., Alabi, O. O., 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. *National Metallurgical Society*, NMS 2017-TP004, pp. 29-36.
- Gbadamosi, Y. E., Alabi, O. O., & Borode J. O. (2021). Evaluating the Potentials of Liberation Size Determination in Anka (Zamfara State, Nigeria) Manganese Ore and its Communition Tendency using Bond Index Technique. *Journal of Materials Science Research and Reviews*, *8*(1), 7-18.
- Gbadamosi, Y. E., Alabi, O. O., Ola-Omole, O. O., & Adetula, Y. V. (2021). Petrological, Chemical, and Mineralogical Characterization of Anka (Zamfara State) Manganese Ore, *NanoNEXT*, *2*(1), 7-12.
- 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, pp. 147-164.
- 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). Highly

Pathogenic Avian Influenza Participatory Disease Surveillance in Plateau State, *Nigeria, Archives Des Sciences*, 65, pp. 1-12.

- Oladunni, O. A., Yaro, S. A., Dungka, G. T., Asuke, F., & Hassan, B. (2016). Comparative Beneficiation Study of Gyel Columbite Ore Using Double Stage (Magnetic-to-Magnetic and Magnetic-to-Gravity) Separation Techniques *Journal of Minerals and Materials Characterization and Engineering*, 4, pp. 181-193.
- Ruiz, F. A., Dun, I. G. H., Panuera, J. D., Calero, R. H., & Longley, R. (2004). In: Line pressure jig (Gekkos) Starts the Modernisation Plan at the San Rafael plant, Gravity '04, *Perth*, Australia, pp. 12-32.
- Wills, B. A. (2006). Mineral Processing Technology, 7th ed. Pergamon Press, Oxford, pp. 225-245.
- Wills, B. A., & Napier-Munn, J. T. (2006). Wills' Mineral Processing Technology. *Elsevier Science and Technology*, 7th Edn., pp. 1-29.