Journal of Applied Sciences

ISSN 1812-5654

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 15 (7): 1020-1025, 2015
ISSN 1812-5654

RESEARCH ARTICLE | OPEN ACCESS

DOI: 10.3923/jas.2015.1020.1025

Physiochemical Analysis of Chanchaga Ore, North Central Nigeria

M.L. Yerima and A.S. Abdulrahman
Department of Mechanical Engineering, Federal University of Technology, Minna, Nigeria

ARTICLE INFO

Article History:
Received: May 07, 2015
Accepted: July 07, 2015

Corresponding Author:
M.L. Yerima
Department of Mechanical Engineering,
Federal University of Technology,
Minna, Nigeria

ABSTRACT

Physiochemical analysis of Chanchaga ore, was investigated in this research work. The techniques involved in the study were sample collection and preparation, density determination, sieve analysis/work index and chemical analysis of the head sample using X-ray Fluorescence (XRF) method. The result showed that the most valuable metal in the ore is Cu, however other important metals such as Pt, Ag, Pb and Cr are present in very low concentrations. The liberation size was established as 125 µm, 2.88 g cm^{-3} was obtained as the average density of the ore while, the mesh of grind was 210 µm and the median size was 50%. The value of work index was calculated as 10.4 kWh t^{-1}.

Key words: Physiochemical, sieve size, work index, ore, Nigeria

INTRODUCTION

Prior to the appearance of petroleum as a major foreign exchange earner in the mid nineteen seventies, the solid mineral sector was placed next to the agricultural sector as a source of foreign exchange earnings according to Taylor and Steven (1985). During the period, Nigeria was famous for the production of coal as an energy source for power supply, railway and for export. Nigeria was a major producer of tin and columbite, accounting for 94% of world production at a certain point. The subsector also contributed substantially to the national output, accounting for about 10% of Gross Domestic Product (GDP) in 1970 (Kogbe and Obialo, 1976). However, with the exit of foreign multinational mining companies, the performance of the subsector began to dwindle. Annual production declined considerably, particularly in metallic minerals. The metallic minerals found in Nigeria include Iron ore, Ferro-alloy minerals, Tin ore, Lead–Zinc, Niobium, Uranium ores and precious metals. Previous studies identified numbers of mineral deposit that are yet to be evaluated (Bamalli *et al*., 2011).

The tempo of mining activities shifted to industrial non-metallic minerals needed for construction, building and industrial applications in domestic industries (Mallo, 2005). The decline of the solid mineral industries started with the discovery of oil which has made Nigeria a mono product economy. Mineral processing is referred as the first step in the solid mineral extractive process. The goal is to produce granular material which meets a specific set of requirements in terms of material composition and physical characteristics. The minerals are either used directly or passed through additional processing stages.

The technology of extraction is expensive primarily because the process always requires the manipulation of large physical quantities of ore for small results. The energy required to mine and process ore is itself valuable and places a lower limit on the quality of ore which can be profitably worked. Rising energy costs always impact the viability of exploitable mines (Yoshiki-Gravelsins *et al*., 1993).

Beneficiation involves processes of mineral separation of valuable material of an ore from the waste material for further processing or direct use. It may be conducted through the combination of various technique including, crushing, grinding, gravity, magnetic, electrostatic, flotation and sorting after proper liberation of the various grains of minerals in the ore.

Characterization, when used in materials science, refers to the broad and general process by which a material's structure and properties are probed and measured. Modern characterization techniques include such as Atomic Absorption Spectroscopy (AAS) which carry out the analysis in solution or methods such as X-ray fluorescence (XRF), which analyze solid samples more or less directly.

This study, which aim at characterizing ore from Chanchaga locality could encourage indigenous processing and transforming of the ore into finished or manufactured products. The study may bring about exposure of indigenous materials in terms of meeting the requirements for attracting foreign direct investment which is being encouraged by the Federal Government to set off the much needed industrial development in the mining and solid mineral sector of the economy as a result, help in saving foreign exchange.

MATERIALS AND METHODS

Location of project area: Nigeria lies approximately between latitude 4 and 14°N and longitude 3 and 15°E. (Fig. 1) Chanchaga, as shown in Fig. 2 lies on latitude 9°3'N and longitude 6°33'E on geological base of undifferentiated basement complex of mainly gneiss and magmatite. The North Eastern part of the city is a more or less continuous step of granite (Paida Hill), which occurs and limits any urban development. The people living in the area are mostly migrants; the working age group and male constitute a higher percentage of the population (NPC., 2006). Though, it is a Gwari town but oher tribes in the country are also present thus making the city heterogeneous.

MATERIALS AND METHODS

In order to determine the physical characteristic and chemical composition of the ore the following methods were adopted:

Sample collection and preparation: Twelve kilogram sample of ore was obtained from Chanchaga area in Niger State from existing mining site dug by artisan miners. Two kilogram sample was collected from each pit from different points and depth using the random sampling. After taking the sample to the laboratory, 290 g of the sample was pulverized and a homogenous portion was obtained for chemical analysis. The equipments used were laboratory Jaw crusher and Pulverizer.

Determination of specific gravity: The following procedures were followed to obtain the specific gravity of the sample:

- Ore sample was first washed thoroughly to remove dust or other coatings from the surface and weighed
- Specific gravity bottle was half filled with, the volume noted and recorded
- Ore sample was dropped into the cylinder and the new level of water in the bottle was recorded
- Volume of sample was calculated by subtracting the initial water volume from the final volume after the sample was introduced

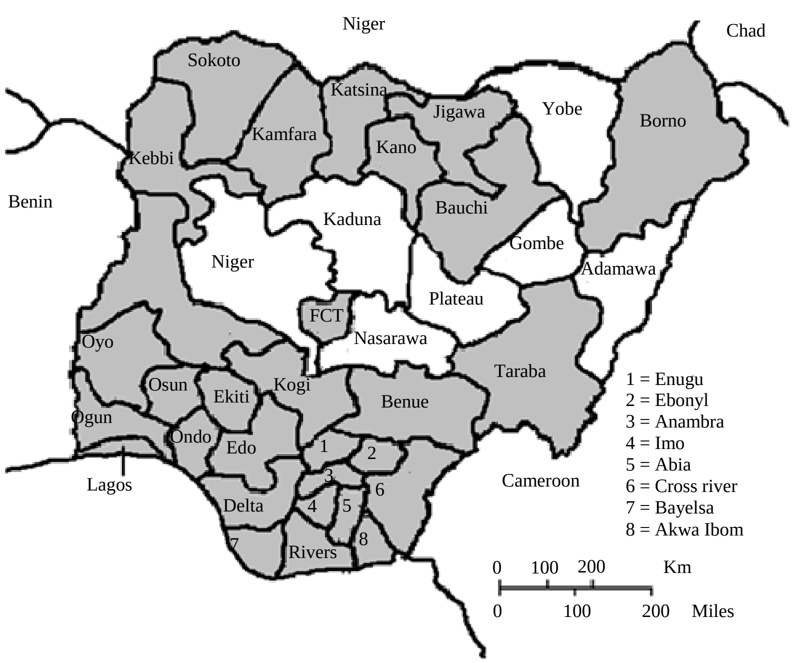

Fig. 1: Map of Nigeria showing Niger State

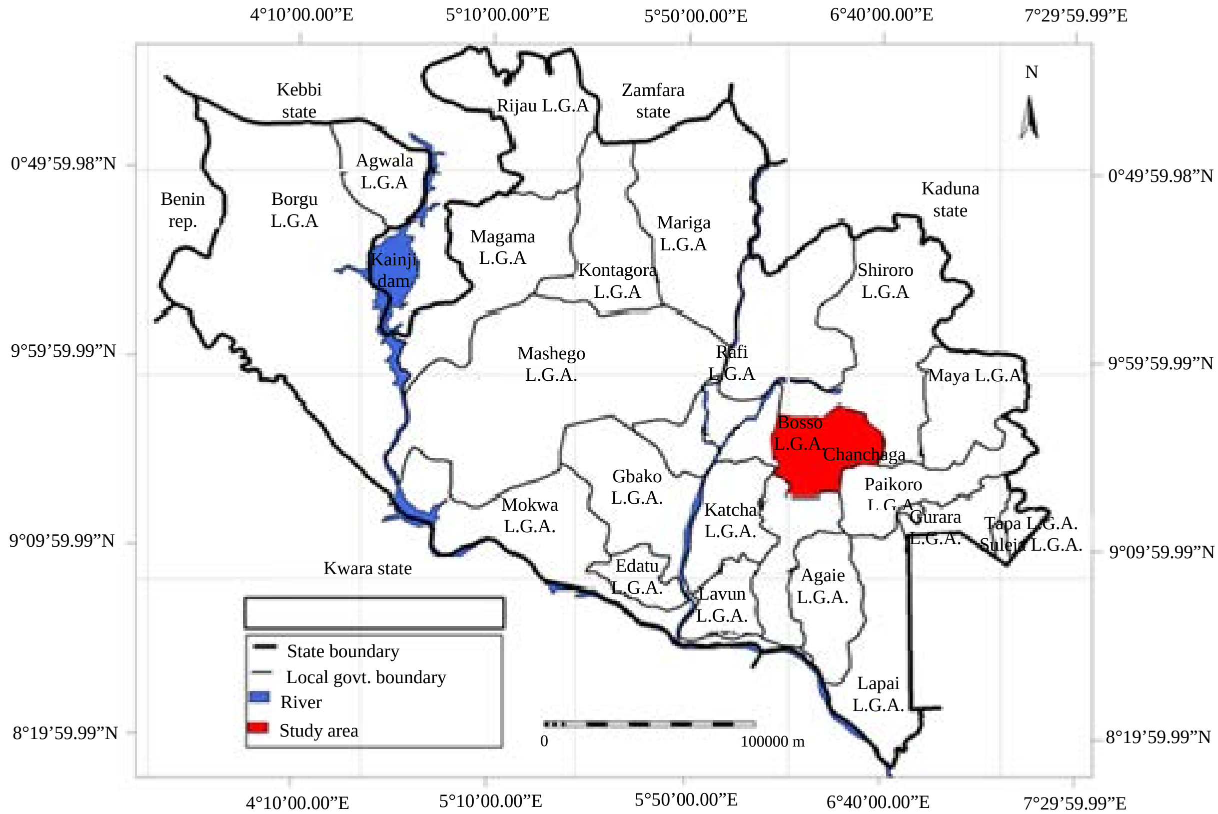

Fig. 2: Map of Niger State Showing Chanchaga area, (Abd'Razack and Muhamad Ludin, 2013)

- Mass of the sample was divided by its volume to get the density of mineral. The density was obtained by dividing the weight of the sample by the volume of water displaced while the specific gravity is determined by dividing the density by equal volume of water

Sieve analysis and work index determination: Comminuted sample of the ore and granite which was used as reference ore was weighed and subjected to size analysis using the laboratory sieve shaker. This was carried out using a nest of sieves with the coarsest on top and the finest sieve at the bottom. The nominal apertures of the sieve were 355, 250, 180, 90 and 50 µm. Milled sample was placed on the topmost sieve and covered with a lid and pan placed under the finest sieve to collect the undersize. The stacks of sieves were then placed on a ro-tap sieve shaker and the timer was set. The stack was then unloaded after 5 min and the sample retained on each sieve were weighed and data were recorded on a sheet.

Chemical analysis: The chemical analysis was conducted using Mini pal 4 version (PW 4030) X-ray spectrometer, which is an energy dispersive microprocessor controlled analytical instrument designed for the detection and measurement of elements in a sample. The pellet is loaded in the sample chamber of the spectrometer and voltage (30 kV maximum) and a current (1 mA maximum) is applied to produce the X-rays to excite the sample for a preset time (10 min in this case). The spectrum from the sample is now analyzed to determine the concentration of the elements in the sample.

RESULTS AND DISCUSSION

Densities of different sieve fractions as listed on Table 1 are found to lie between 2.78 and 2.94 g cm^{-3}. The observed values were close to the values obtained by theoretical calculations as reported by Dana (1965). The density for quartz being 2.65 g cm^{-3} while observed value 2.88 g cm^{-3} indicated that the sample consists of 88% quartz and 12% of other minerals.

It was observed from the sieve result of the test ore presented on Table 2 that 63.29 g of the total weight (200 g) was retained on the 355 µm sieve size, 28.59 g on 250 µm, 25.59 g on 180 µm, 21.69 g on 125 µm, 14.1 g on 90 µm and 11.41 g on 50 µm. Table 2-5 shows parameters used to calculate the energy requirements of the ore. The work index of the ore was calculated as 10.4 kwh t^{-1} tonnes, The work index obtained with granite as reference ore is within the limit of work index of some metallic ores in Nigeria (Olatunji and Durojaiye, 2010).

A graph of cumulative weight, percentage undersize and cumulative weight percentage oversize was plotted against the particle size. From the graph, on Fig. 3, the mesh of grind was 210 µm and the median size was 50%. Similar results were obtained by Usaini *et al*. (2014).

From Table 2, When the nominal aperture size is (90 µm), the cumulative oversize is 27.67%. therefore, X (µm) aperture size at cumulative oversize of 80% is given by:

$$X\ (\mu m) = (80\times 90)/27.67$$
$$X\ (\mu m) = 260\ \mu m \text{ at } 80\%$$

From Table 3, when the nominal aperture size is (90 µm, the cumulative oversize is 50.98%. Therefore, X (µm) aperture size at cumulative oversize of 80% is given by:

Table 1: Sieve size effect on density

Sieve sizes (µm)	Density (g cm^{-3})
+355	2.880
-355+250	2.880
-250+180	2.870
-180+250	2.780
-125+90	2.880
-90+50	2.940
PAN	2.880

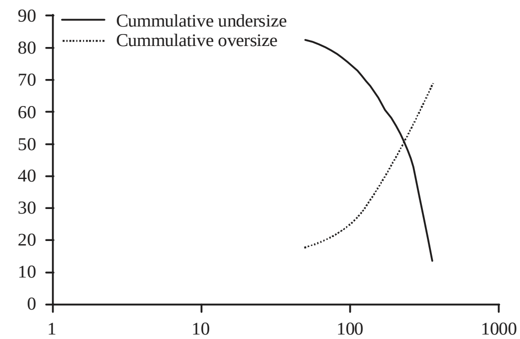

Fig. 3: Particle size distribution graph

Table 2: Sieve analysis of Reference ore for ball mill feed

Sieves ranges	Weight (µm)	Weight (g)	Nominal aperture size (µm)	Cumulative under size (%)	Cumulative over size (%)
+355	37.48	20.15	355	25.15	100.00
-355+250	28.15	18.87	250	44.02	74.85
-250+180	20.11	13.50	180	57.57	55.98
-180+250	22.10	14.81	125	72.33	42.43
-125+90	14.17	9.50	90	81.83	27.67
-90+50	6.84	4.50	50	86.41	18.17
PAN	20.34	13.63	-	100.00	13.59

Table 3: Sieve analysis of reference ore for ball mill discharge

Sieves ranges	Weight (µm)	Weight (g)	Nominal aperture size (µm)	Cumulative under size (%)	Cumulative over size (%)
+355	11.45	7.71	355	7.71	100.00
-355+250	33.43	22.51	250	30.22	92.29
-250+180	14.82	9.98	180	40.20	69.78
-180+250	13.11	8.82	125	49.02	59.80
-125+90	18.24	12.27	90	61.29	50.98
-90+50	27.30	18.37	50	79.66	38.71
PAN	30.22	20.34	-	100.00	20.34

Table 4: Sieve analysis of test ore for ball mill feed

Sieves ranges	Weight (µm)	Weight (g)	Nominal aperture size (µm)	Cumulative under size (%)	Cumulative over size (%)
355	63.29	31.65	355	13.65	68.35
-355+250	28.51	14.26	250	45.91	54.09
-250+180	25.59	12.80	180	58.71	41.29
-180+250	21.69	10.85	125	69.56	30.44
-125+90	14.10	7.03	90	76.59	23.41
-90+50	11.41	5.70	50	82.29	17.71
PAN	35.43	17.71	-	100.00	0.00

Table 5: Sieve analysis of test ore for ball mill discharge

Sieves ranges	Weight (µm)	Weight (g)	Nominal aperture size (µm)	Cumulative under size (%)	Cumulative over size (%)
+355	21.42	10.71	355	10.71	89.29
-355+250	29.28	14.60	250	25.31	74.69
-250+180	23.80	11.90	180	37.21	62.79
-180+250	11.41	5.71	125	42.92	26.77
-125+90	60.19	30.10	90	73.02	57.29
-90+50	23.69	11.84	50	84.86	15.14
PAN	30.21	15.11	-	100.00	0.00

Table 6: Result of chemical analysis of head sample

	Sieves sizes (µm)					
Elements	-90 +50 (%)	-125 +90 (%)	-180 +125 (%)	-250 +180(%)	-355 +250 (%)	+355 (%)
Fe	0.8191	0.841	0.3751	0.3806	0.3783	0.3106
Ti	ND	ND	ND	ND	0.0518	ND
Ca	0.1133	0.1231	ND	ND	ND	0.1330
Nb	0.0653	0.0530	0.0399	0.0652	0.0202	0.0021
Ag	ND	ND	0.0225	ND	ND	ND
Pb	ND	ND	ND	ND	ND	0.0085
Mn	0.0370	0.0530	0.0106	0.0237	0.0127	0.0074
Cr	ND	0.0234	ND	ND	ND	ND
Sb	0.0150	ND	ND	ND	ND	0.0147
Sn	0.0126	0.0142	ND	ND	0.0118	ND
Cd	ND	0.0090	ND	ND	0.0093	ND
Ta	0.0036	ND	ND	0.0070	ND	ND
Pt	ND	ND	ND	0.0029	ND	ND
Cu	0.553	1.182	1.392	0.191	0.319	0.381
Mo	0.0026	0.0026	0.0021	0.0026	0.0026	0.0030
Ni	ND	0.0022	ND	ND	ND	ND
Sr	0.0020	0.0017	ND	ND	0.0015	0.0018
Zr	0.0020	0.0016	ND	ND	ND	ND

NO: Not detected

$$X(\mu m)=(80\times 90)/50.98$$
$$X\ (\mu m) = 141.23\ \mu m \text{ at } 80\%$$

From Table 4, when the nominal aperture size is 90 (µm), the cumulative oversize is 23.41%. Therefore, X (µm) aperture size at cumulative oversize of 80% is given by

$$X\ (\mu m) = (80\times 90)/23.41$$
$$X\ (\mu m) = 307.56\ \mu m \text{ at } 80\%$$

From Table 5, when the nominal aperture size is 90 (µm), the cumulative oversize is 56.29%. Therefore, X (µm) aperture size at cumulative oversize of 80% is given by the following Bond (1952).

$$x(\mu m)=(80\times 90)/56.29$$
$$X\ (\mu m) = 125.66\ \mu m \text{ at } 80\%$$

Applying bond equation:

$$W_{it} = W_{ir}\frac{\left(\frac{10}{\sqrt{P_r}}-\frac{10}{\sqrt{F_r}}\right)}{\frac{10}{\sqrt{P_t}}-\frac{10}{\sqrt{F_t}}}$$

Substituting values in the equation above gives:

$$W_{it} = 15.14\times\frac{\frac{10}{\sqrt{141.23}}-\frac{10}{\sqrt{260}}}{\frac{10}{\sqrt{125.66}}-\frac{10}{\sqrt{307.56}}}$$

$$10.4\ \text{kWh t}^{-1}$$

The results of analysis showed that Iron metal varied between 0.31-0.82% indicating fairly low content of the metal in the ore from this mining site for economic exploitation however, mined ores containing 10% of the metal upward are considered prospective mines depending on the associated minerals (Obaje *et al*., 2006).

Titanium concentration in the sample occurred only at 250 µm particle size. The result indicated poor content of the metal, that is, not in economic quantities for exploitation from the mine. Distinct values of concentration of this metal has being reported (Daspan and Ogezi, 2006) in other geological areas of the country, this may be attributed to the difference in geological formations in the zone of mineralization.

Similarly, the sample showed very low concentrations of Ca metal, Table 6, the result showed average concentration grade of 0.13% indicating that the metal deposit is not quantities for economic extraction. Tin analysis result ranged between 0.11-0.14%. The values are very low indicating that the metal cannot be concentrated from the ore.

Copper (Cu) metal result as presented on Table 6 and Fig. 2 ranged between 0.192-1.392%, indicating a significant quantity of the metal in the sample. The minimum exploitable quantity of Cu ranges between 0.2-2% upwards for underground mines depending on the level of associated metals such as gold. Copper mines as low as 0.5% of the metal with average Cu content not more than 2% has been concentrated (Wills, 1985).

Values for manganese (Table 6) can be compared with those obtained by Idzi *et al.* (2013), in which analysis of sample in Nassarawa, Eggon indicated a concentration range of 0.01-0.02%. The present study recorded a range of 0.007-0.03%, therefore, the metal can be classified as not feasible for further exploitation or economic consideration.

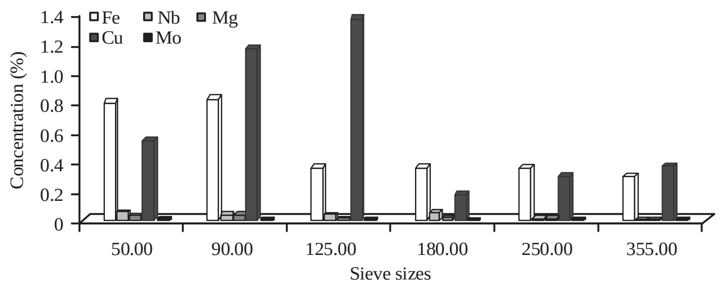

Fig. 4: Concentration versus sieve sizes for various element

From the result shown on Fig. 4 and Table 6, there is a poor presence of Molybdenum in the ore, the result indicate a range of 0.0021-0.003%. Its minimum exploitable grade is 0.1 MoS_2, however very large deposits can be mined at even lower grades. For instance, in the year 2007 Mo was mined at 0.053% in Endako Canada, so also the Ruby Creek project also in British Columbia, Canada was based on an average grade of 0.063% Mo (Antonneio and Edgar, 1988).

CONCLUSION

The chemical analysis detected low concentration of high value metals including Chromium, Platinum, Silver and Copper. However, Copper among these metals appeared to be most significant in terms of suitability for exploitation, the analysis indicated copper assaying between 0.192 and 1.392%. The liberation size was established as 125 μm, 2.88 g cm^{-3} was obtained as the average density of the ore while the mesh of grind was 210 μm and the median size was 50%. The value of work index obtained which was calculated as 10.4 kWh t^{-1}. The research area could as well serve as potential local raw material base in the state for industrial, social and economic advancement in terms of local sourcing of raw materials, most especially Copper and Silver, to the mineral based and allied industries.

REFERENCES

Abd'Razack, N.T.A. and A.N.B. Muhamad Ludin, 2013. Comparative analysis of ecological footprint of two different neighbourhoods in Minna, Nigeria. Int. J. Sci. Eng. Res., 4: 178-183.

Antonneio, V. and B. Edgar, 1988. Exergetic evaluation of natural mineral capital. Applic. Methodol. Curr. World Reserves, 21: 145-173.

Bamalli, U.S., A. Moumouni and M.S. Chaanda, 2011. A review of Nigerian metallic minerals for technological development. Nat. Resour., 2: 87-91.

Bond, F.C., 1952. The third law of communition. Transiton Am. Inst. Mater. Eng., 193: 484-494.

Daspan, R.I. and A.E.O. Ogezi, 2006. Geochemistry of mafic and felsc rocks of the kofayi younger granite ling complex, North Central Nigeria. Afr. J. Nat. Sci., 9: 109-120.

Idzi, A.A., A.M. Olaleke, I. Shekwonyadu and E.A. Christian, 2013. Geochemical studies of mineral bearing ores from Nasarawa Eggon and Udege Beki areas of Nasarawa State, Nigeria. Int. J. Basic Applied Chem. Sci., 3: 93-108.

Kogbe, C.A. and A.U. Obialo, 1976. Statistics of Mineral Production in Nigeria (1946-1974) and the Contribution of the Mineral Industry to the Nigerian Economy. Elizabethan Publishers, Lagos, Nigeria, pp: 391-400.

Mallo, S.J., 2005. Mineral and Mining on the Jos, Plateau. Acon Publishers, Jos Plateau State, pp: 89-91.

NPC., 2006. Population data in Nigeria. National Population Commission, Nigeria.

Obaje, N.G., U.A. Lar, A.I. Nzegbuna, A. Moumouni, M.S. Chaanda and N.G. Goki, 2006. Geology and Mineral Resources of Nasarawa State: An investosrs Guide. Elizabethan Publishers, Lagos.

Olatunji, K.J. and A.G. Durojaiye, 2010. Determination of bond index of birnin-gwari iron ore in Nigeria. J. Mater. Miner. Charact. Eng., 9: 635-642.

Taylor, S.R. and D.A. Steven, 1985. Abundance of chemical elements in the continental crust. J. Geochem. Cosmochim. Acta, 28: 1280-1281.

Usaini, M.N.S., M. Ali and H.A. Usman, 2014. Determination of liberation size of akiri copper ore, Nasarawa State, North-Central Nigeria. Int. J. Eng. Dev. Res., 2: 1444-1452.

Wills, B.A., 1985. Mineral Processing Technology. 4th Edn., Pergamum Press, Oxford, England, pp: 61-69.

Yoshiki-Gravelsins, K.S., J.M. Toguri and T.C. Choo, 1993. Metals production, energy and the environment, part I: Energy consumption. JOM, 45: 15-20.