Coking Potential and Metallurgical Relevance of the Cretaceous Lafia-Obi Coal Deposit, Nawarawa State, North-Central Nigeria: Insight from Washability and Froth Flotation Tests.

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ABSTRACT

Paralic coal beds are found as interbeds within the Cretaceous system around Lafia/Obi area of Nasarawa State which geologically fall into the Middle Benue Trough of North Central Nigeria. Washability and froth flotation tests using heavy liquids were used to analyze and infer on the coking potential cum usability in the metallurgical industry. Samples of the coal deposit were obtained from seams 30, 13, and 12 after size reduction using hammer and jaw crush, carbon tetrachloride CCl_4, tannile $C_6C_5–NH_2$, nitro benzene $C_6H_5NO_3$, and Bromoform $CHBr_3$. 1.18 to 0.6 micro screened size fractions were adopted for the washability test. 355-600 micro size fractions were used for the initial trial flotation and +180 to 355 micro size fractions were used for the second trial flotation.

From the washability test assuming ash content of 5.7% is acceptable, a separating density of 1.6 and a yield of 80% will be obtained. Froth flotation at pH7 of the coal gave an average ash content of the total float to be 6.64% with the higher ash content reporting in the first float being10.29%. The sulphur, moisture, and volatile matter are same as in the raw coal. Froth flotation at Ph9 of the coal gave an average ash content of6.95% with the fine coal reporting first with less ash content of 3.42%. This difference could be probably due to the presence of pyrite which might have been depressed at Ph9. The Lafia-Obi coal deposit is medium coking in nature and only suitable for blending in the steel and iron industry.

(Keywords: washability, heavy liquids, froth flotation, metallurgical coke, coking coal, upgrading or beneficial blending)

INTRODUCTION

Recently, a shift in trend and interest is noticeable as coal researchers are focusing mainly on other alternative uses of coal. Coal was previously known as combustible energy source. However, with a raising diminishing demand triggered by several technological inventions and applications adopted as power or energy sources today, an alternative use of coal is established in production of coke, combustible in the blast furnace for steel production and potential use as major source of coal-bed methane gas. By and large, an intensive and extensive research drive, channeled towards the afore listed area of technology is highly necessitated by both the vast unharnessed natural and economic endowment of the country.

The Nigerian giant steel plant (Blast furnace type) situated at Ajaokuta in Kogi State was originally meant to produce about 1.3 million tons of steel annually, but shortage of raw material and probably scarcity and or insufficient coking coal, including appreciable amount of local coals Coke is made from coal and the resultant quality is unfortunately incapacitated and handicapped this initial projection and gave slim survival for the whole intended viable project. Today, if production must commence, then, the Nigeria steel plant is expected to import millions of tons of coking coals yearly, but considering the huge sum of foreign exchange required, there is an urgent need to obtain cokeable blends determined to a reasonable extent by the quality of the coal deposit. The current price of about US$300 per ton makes coal blending optimization and co-carbonization with cheaper poorly coking coals more urgent as desirable

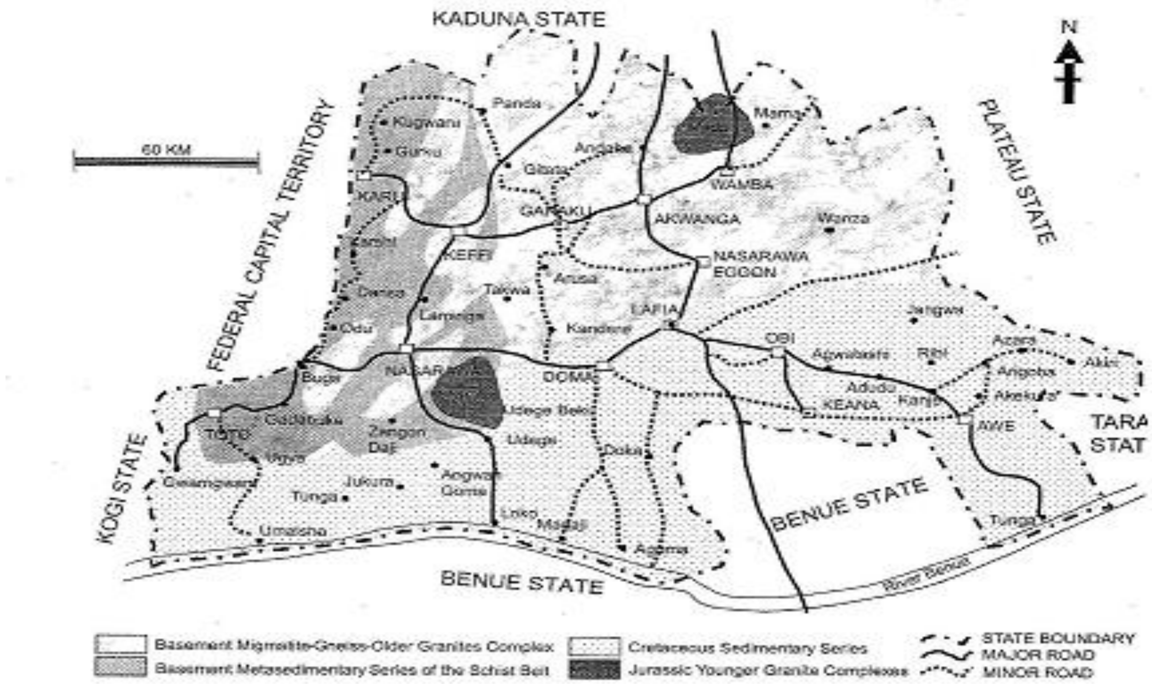

Figure 1: Outline Geological Map of Nasarawa State (Obaje *et al.,* 1999).

LITERATURE REVIEW

The Lafia-Obi coal deposit as it is often referred is situated between Obi and Agwatashi town about 40km south east of Lafia in Nasarawa State Central Nigeria.

The study area falls within the middle belt zone of the country with some relative Plateau features. It is relatively a flat area surrounding the Giza anticline in the North West – South East. It is closely dissected by shallow water courses, the prominent rivers are Bui and Akpaid. The low lands confirm with the synclines, while the high lands with the anticline. The others are Adabu, Aguda and Agyaragu anticlines.

The highest point is about 200m above sea level (Ojulari and Ezenware, 1981). The vegetation is typical of Savannah forest with sparse forest shrubs and bushes. The grasses are fairly tall and relatively thick during raining seasons. Geologically, the study area is predominantly characterized by large sedimentary deposit (rocks) consisting of sandstone. Limestone siltstone, mudstone (coal shale and shaly coal) and shale are present. The formations established are Uomba Formation, Arufu Formation, Keana sandstone and Awgu Formation ranging from late mastrichtian to middle Albian in age (Simpson and Reyment, 1965, Cratchley and Jones, 1968 and Falconer, 1911). Nigeria Local coals deposit is estimated to be about 1.5billion tons unfortunately test conducted on these coal deposits showed that most of them are non-caking. Lafia-Obi coal, the only local coal with good coking properties is however laden with excessive ash and sulphur contents of about 26.3% and 2.3% respectively (Taskforce, 1987).

MATERIAL AND METHODS

Fresh samples of Lafia-Obi coals about 500grammes were initially reduced by hammering and Jaw crushing was used for further reduction. The sieved and screened fraction 1.18mm to 0.6mm was then used for the washability test.

Heavy medium separation of dense medium separation or the sink and float process was used for pre-concentration of the Lafia-Obi coal to produce a commercially graded end product clean coal being separated from the heavier shale a high ash coal. It has ability to make sharp separations at any required density with a high efficiency even in the presence of high percentage of mean density material. The process is applied when the density different occurs at coarse size and the efficiency decreases with size due to the slower setting rate of the particles and best conditions occur with particles larger than 3mm but separation can be achieve with particles of 500mm and below the separation is added by centrifuge separators (Wills, 2007).

Froth flotation is the most important and versatile mineral dressing or processing technique. It permits the mining of low-grade complex ore bodies which would have otherwise termed as uneconomic. This is a selective process used in which specific separation is achieved from complex ore such as lead-zinc and copper-zinc. Initially developed to treat sulphides of copper lead and zinc. Its field has now being expanded to include oxides such as hematite and cassiterate, oxided minerals such as malachite and cerussite and non-metallic ore such as fluorite phosphate, and coal (Wills, 2007). It utilizes the difference in physio-chemical surface properties of particles of various minerals.

After treatment with reagents, such as differences in surface properties become apparent and flotation finally occurs after an air bubbles attaches itself to a particle and lift it to the water surface. It is applicable to relatively fine particles as for the coarse particles the adhesions between the particles and the bubble will be less than the weight and the bubble will drop its load.

Froth flotation is only applicable to very fine coals due to the natural floatability coals which makes it such that, it enable floated by every known reagents. The commonest reagents for coal flotation are the natural oils (kerosene and fuel oil). The aim of this study is to ascertain possibility of cleaning the Lafia-Obi coal by gravity separation process by carrying out a float and sink tests to assess the suitability of heavy medium separation and to determine the economic separating density and the yield of the coal. Direct reduction process of the coal samples were also attempted using the froth flotation process to ascertain reduction or upgrading of the coal deposit for metallurgical purposes.

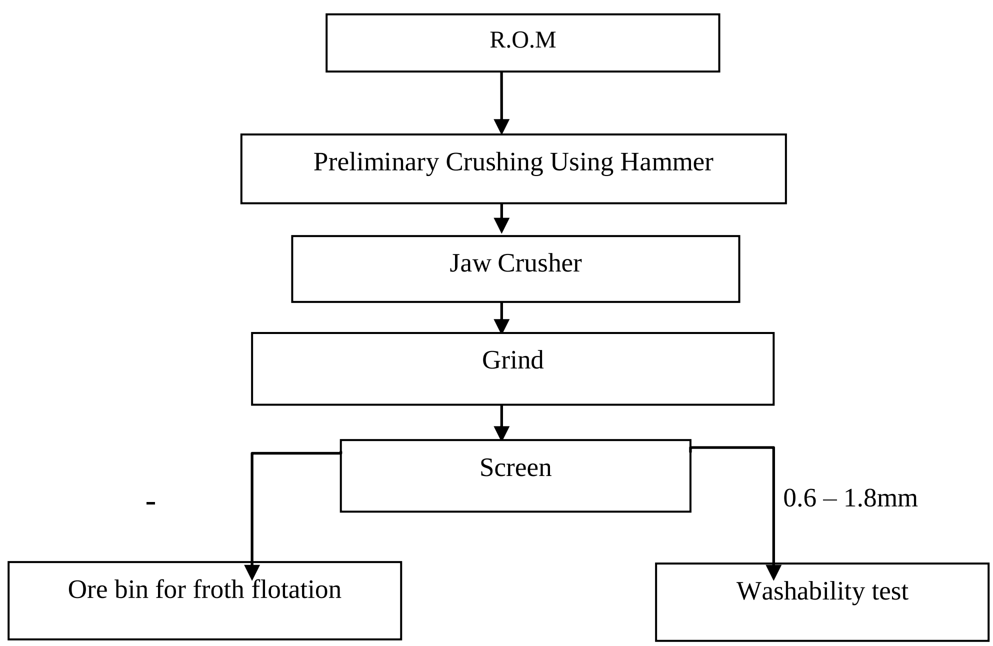

Figure 2: Crushing Circuit for Washability Test.

Carbon tetrachloride (CCl_4), tamide ($C_6C_5 – NH_2$), nitrobenzene ($C_6H_5N0_3$) and Bromoform ($CHBr_3$) were prepared to give specific gravity Liquid from 1.3, 1.4, 1.5, 1.6 to 1.7 using washed and dried beakers for the float and sink processes.

First trial froth flotation was carried out using 400grammes sample of the 180-355mm and 355-600mm size fractions. Flotation cells or machine prepared, washed and cleaned. The flotation cell $^1/_3$ volume was filled with water, samples added and few drops of kerosene added as collector and the pulp conditioned for ten minutes by agitating the pulp at pH 7 and three drops of fine oil added and aerated. Further trial flotation were carried out with +180 to 355mm size fraction, 180 to 355mm and -180mm sizes floated both at pH 7 and pH 9 respectively. The crushing circuits for trial and actual flotation of the different size fractions are shown below.

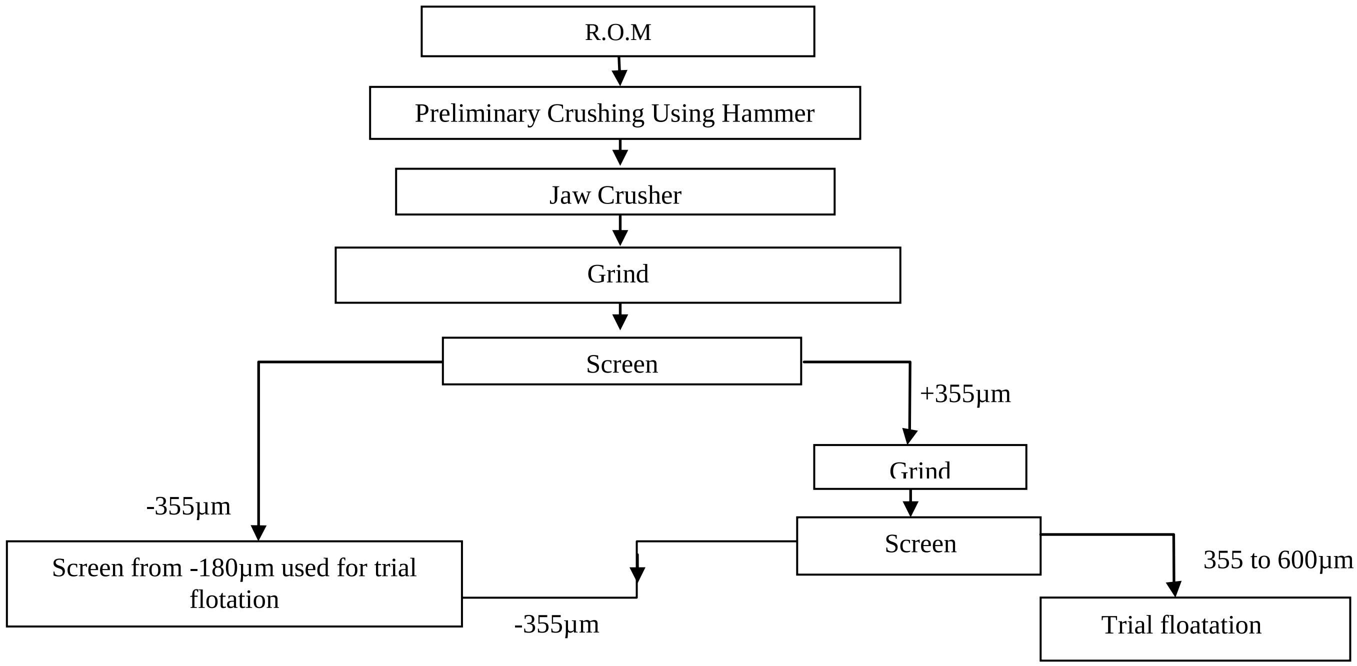

Figure 3: Crushing circuit for trial floatation (180 – 355 to 600µm)

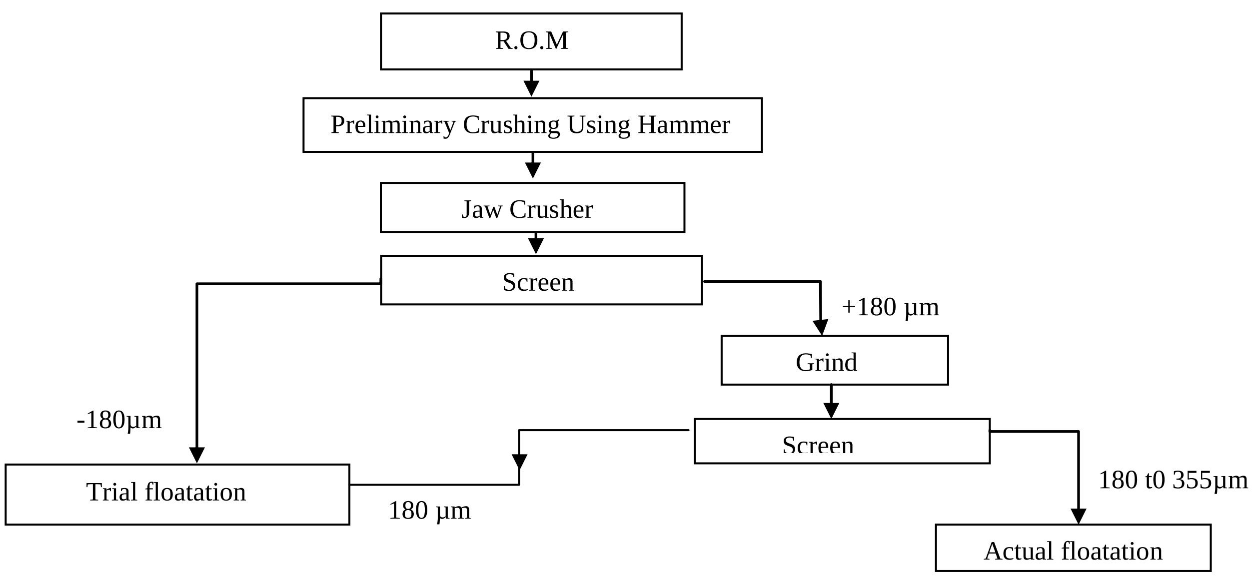

Figure 4: Crushing Circuit for Trial and Actual Floatation.

Table 1: Result of Washability Test for Lafia-Obi Coal Fraction (1.18 to 0.6mm).

Specific Gravity of Liquid	Fractional Float		Ash Content as Product	Ash Product	Cumulative Floats		Fractional Sink % Ash	Cumulative Sizes	
1.3	21.20	3.4	0.72	0.72	21.20	3.4	9.28	78.80	11.78
1.4	20.21	5.0	1.01	1.73	41.41	4.18	8.27	59.59	14.12
1.5	19.74	7.2	1.42	3.15	61.15	5.15	6.85	38.85	17.63
1.6	19.50	8.0	1.56	4.71	80.65	5.84	5.29	19.35	27.34
1.7	19.35	9.0	1.74	6.45	100	6.46	3.55	-	-
Key	F	FA	TA	CA		CFA	FSA	CS	CSA
Method	Direct weighing	Direct determin-ation	FxFA/100	Cumulative of TA	Cumulati ve of F	CA/CF x 100	A-CA	100-CF	FSA/CS x 100

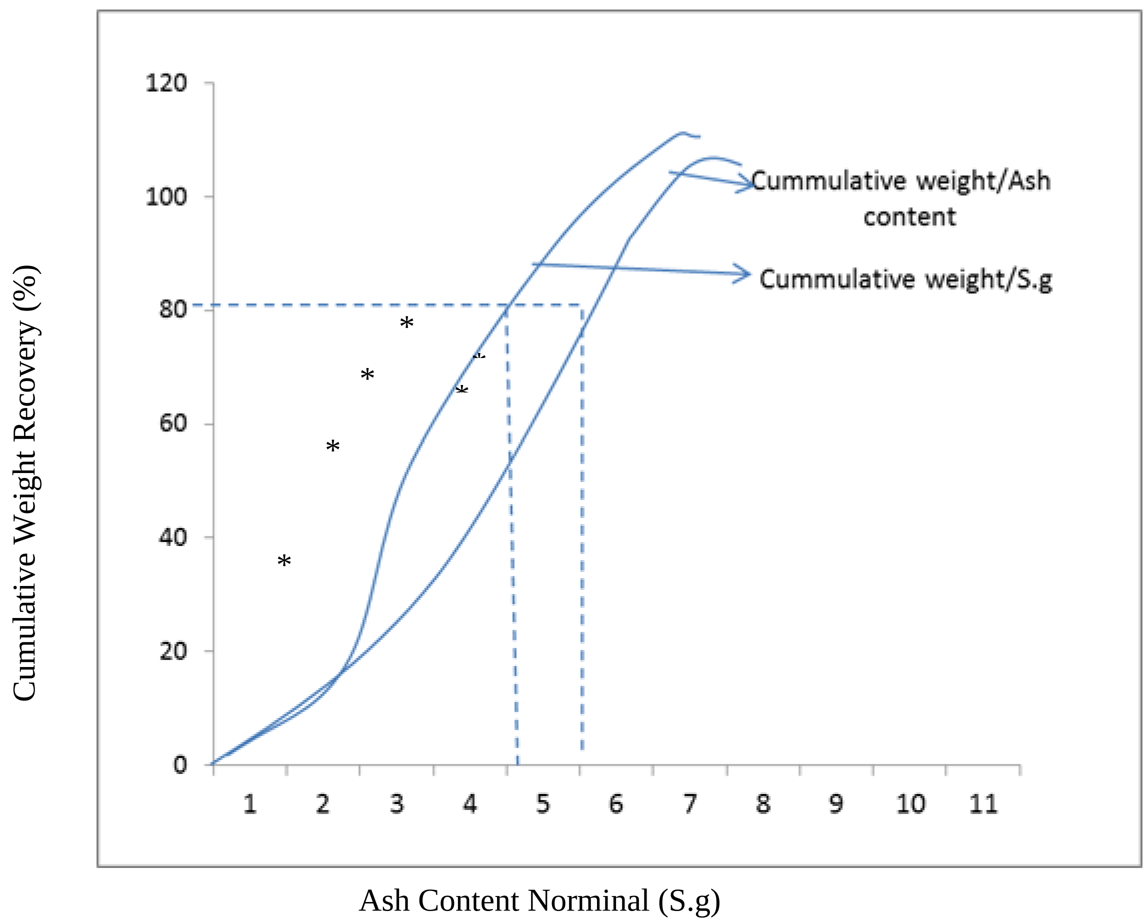

Figure 5: Graph of the Washability Test of the Lafia-Obi Coal Deposit.

Table 2: Result of Flotation pH 7.

S/N	Second	Weight of float	% weight of float	Cumulative weight		Average content	Ash in taking	Ash receive in taking	Ash content float
1	10	8.09	24.63	24.63	100.00	11.00	6.64	100	11
2	20	4.44	13.52	38.15	75.37	10.29	5.21	59.14	9
3	36	4.09	12.45	50.60	61.85	9.48	4.38	40.80	7
4	40	391	11.90	62.50	49.40	8.82	3.72	27.68	6
5	21.5	12.32	37.50	100	37.52	6.64	3	16.94	3
Total		32.85	100						

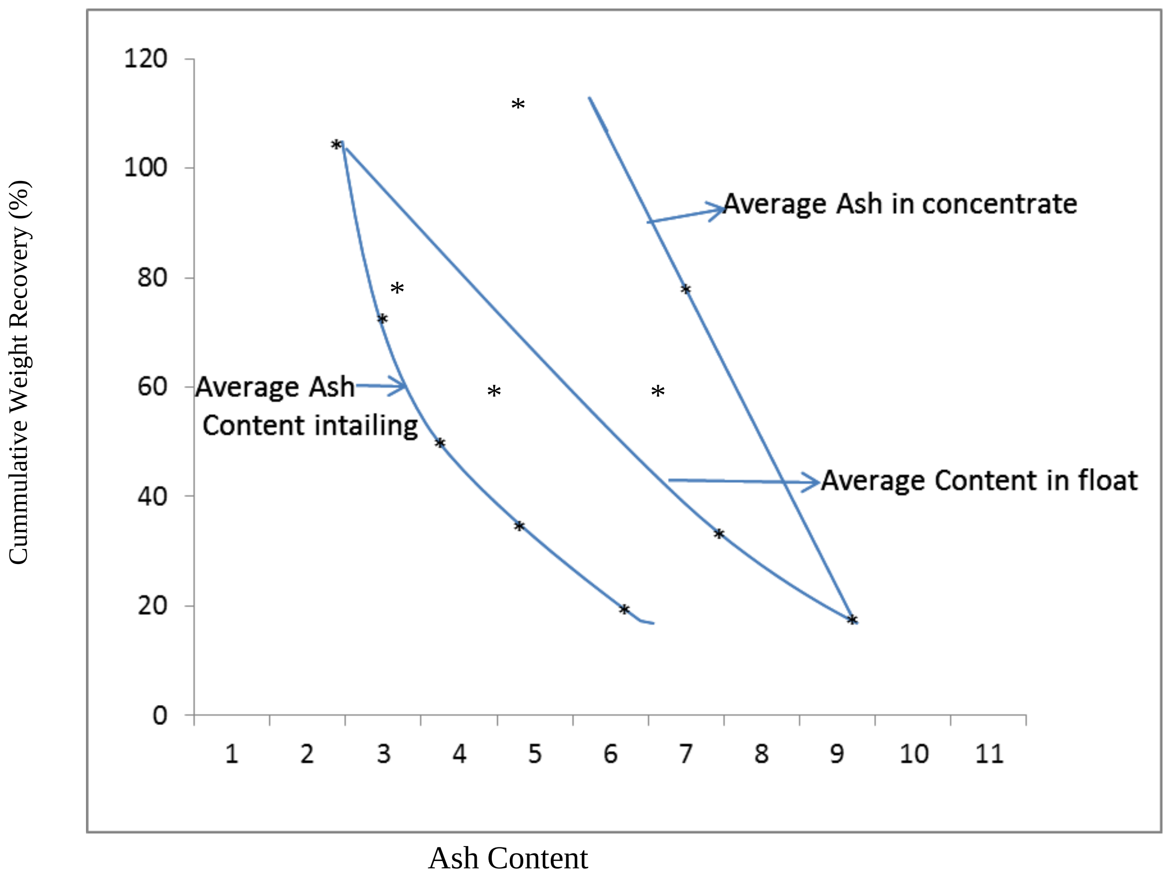

Figure 6: Graph of the Froth Flotation at pH 7.

Table 3: Result of Froth Flotation at pH 9.

S/N	Second	Weight of float	% weight of float	Cumulative weight		Average content	Ash in taking	Ash receive in taking	Ash content float
1	20	8.53	19.23	19.23	100	3	3	6.95	100
2	40	7.62	17.18	36.41	80.77	4	3.47	7.89	91.69
3.	50	6.50	14.66	51.07	63.59	7	4.48	8.94	81.80
4	60	5.18	11.68	62.75	48.92	8	5.14	9.52	67.02
5	230	16.52	37.25	100	37.25	10	6.95	10	53.60
Total		44.35	100						

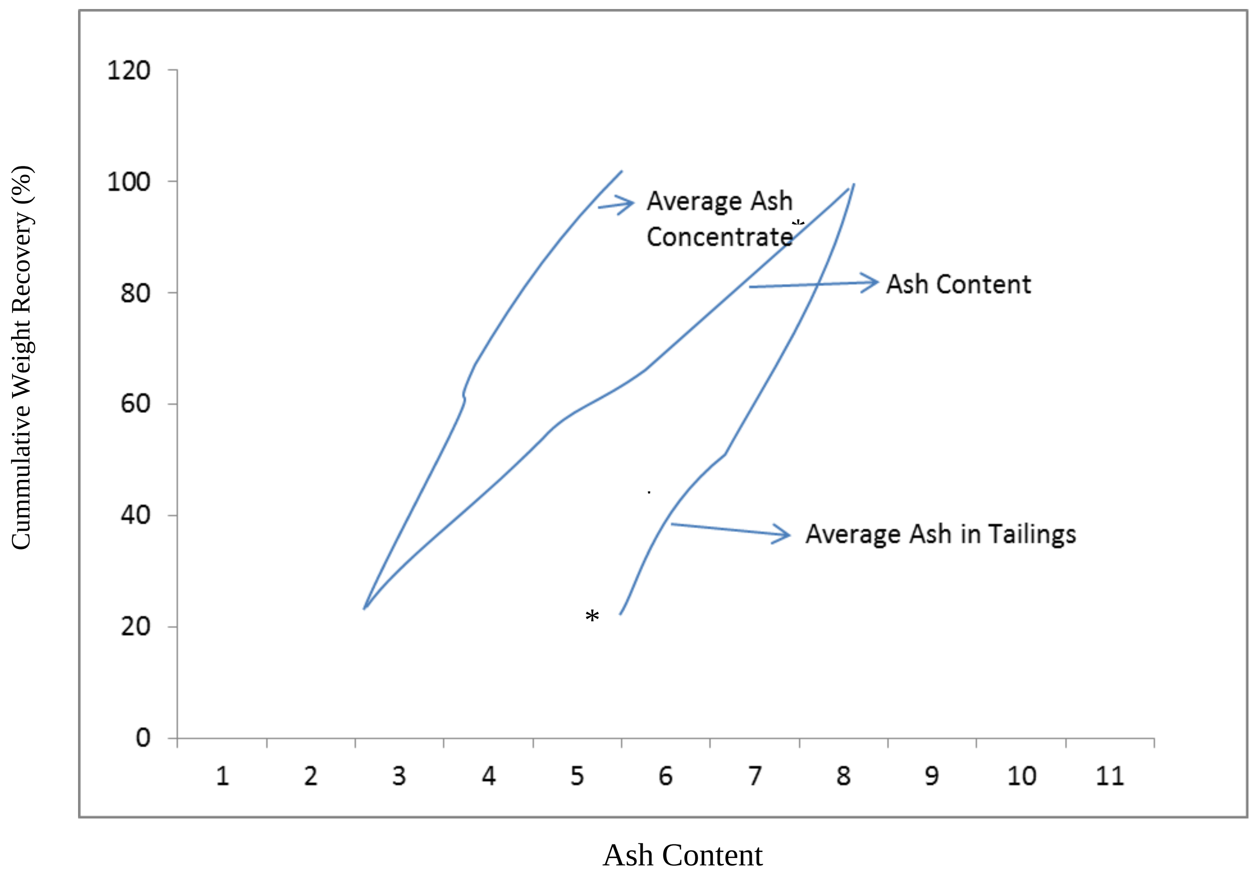

Figure 7: Graph for Flotation at pH 9.

RESEARCH RESULTS AND DISCUSSIONS

The washabilty test result is shown in Table 1, while the graph is illustrated in Figure 4. From the result assuming ash content of 5.70% is acceptable, a separating density of 1.6 and a yield of 80% will then be obtained and be adoptable. However the ash content of the un-concentrated coal which is 9.69% if acceptable for blending for metallurgical purposes ash reduction might not be necessary (Adeleye and Onumayi. 2007; Jatau et al., 2009).

Froth flotation at pH 7 of the coal deposit gave an average ash content of the total float to be 6.64% with the lighter ash content reporting in the first float probably due to the pyrite present. Sulphur test of the float makes no difference with the raw coal, the same is observed with moisture and volatile matter (Jatau, et al., 2009). However froth flotation at pH 9 of the coal samples indicated an average ash content of the total float as 6.95% with the fine coal reporting first, that is with less ash content. This difference could be as a result of pyrite which might have been depressed at pH 9 unlike at pH 7.

DISCUSSION

The Lafia-Obi coal deposit has been found to be geologically faulty and the minimum estimated cost of mining it per ton was at N87.50 as at 1977 (Taskforce, 1987). Considering the present exchange rate of the Nigeria Naira to the US dollar, the current mining price per ton of Lafia-Obi coal can be taken to be US$87.50 (Adeleke and Onumayi, 2007). As of 2013, the cost is expected to be double if not triple.

For coke making, coal blends are required to have specific range of values for volatile matter, ash and sulphur contents (Taskforce, 1987, ASTMS, 2002). Excessive ash increases the volume of slag in the blast furnace and reduces its operating efficiency, sulphur in the coke gets into the iron and reduces the mechanical strength, while very high volatility generally reduce coke output (Banerjee et al, 1972).

Blend formulation by numerical computation on the basis of mathematical model have been employed in the steel industries (Skert, 1988, Adeleke 1997 and Adeleke and Onumanyi, 2007). Petrological and proximate analysis of the Lafia-Obi coal Nasarawa State, Central Nigeria revealed vitrinite, extrinite, fusinite (fossil), and mineral substance mostly pyrite and the proximate analysis indicates probably that the coal is medium coking (Jatau et al., 2009). Determination of optimal conditions for the flotation of Lafia-Obi local using locally dried reagent found that the coal contain 45.54% fixed carbon and 6.7 ash content indicating medium grade and the optimal conditions are five minutes condition time, 3 drops optimal dosage of the reagent palm oil as the best collector which recovers 94% of the sample floated, showing that it can favorably replace the standard collector (Usaini and Ndanusa, 2010).

CONCLUSION

The Lafia-Obi coal deposit is medium coking in nature and only suitable for blending in the steel and iron industry for its metallurgical purposes even though intensify, further and continuous work has to be undertaken as a means of research and development.

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