Harnessing Nigeria's Abundant Lead Ore Deposits for the Development of Lead-Acid Battery Materials

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Abstract: This project work presents the development potentials for the production of lead acid battery materials from selected Nigerian lead ores. This is predicated on the need for a growing awareness to achieve a more sustainable societal use of materials. The selection of the ore was based on economic quantity, economy of refining, and proximity to a refining and development (centre) plant. Chemical compositions of existing lead acid battery terminal materials were determined so that they can be used as controls. The results show that the selected ores naturally contains high percentage of lead with sufficient percentage (although less than 0.01%) of residual elements which are requisite elements (tin and copper) in the control samples inferring that there is large amount of recoverable lead with little quantity of disposable elements in the form of slag when the ore is smelted. Fortunately, Nigeria provides a veritable and safe ground for investors, thus the need to develop the nation's God given resources to meet developmental challenges cannot be overemphasized.

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1. Introduction

The Earth as a resource system has a limited capacity for supporting a growing human population with an intensive exchange of materials and energy with its environment, hence the need for a growing awareness to achieve a more sustainable societal use of materials (Karlsson, 1999). High rates of mobilization combined with often very dissipative use (Ayres and Ayres, 1994) have led to increased concentrations of metals in various ecosystem compartments. Nigeria is one of the tropical countries of the world which lies approximately between 4^o and 13^o with landmass of 9.24 x 105 km^2 (Bala et al., 2000). It is bordered by the Gulf of Guinea, Cameroon, Benin, Niger, and Chad. The topography ranges from mangrove swampland along the coast to tropical rain forest and savannah to the north (NNPC, 2004).

Nigeria's rich human and material resource endowments give it the potential to become Africa's largest economy and a major player in the global economy (NNPC, 2004). As at the last count, the Federal Ministry of Mines have found over five hundred (500) locations of mineral deposits in the country and identified nine (9) that they would want to concentrate on and promote. These include Iron ore, Coal, Tin ore, Bitumen, Gold, Columbite-Tantalite, Lead/Zinc, Wolframite and industrial minerals (Anaekwe, 2010).

The tectonic history of the Benue Trough has been extensively treated (Ofoegbu, 1985; Ofoegbu and Onuoha, 1991; Burke and Dewey, 1973). Accompanying the thick sedimentary pile-up in the trough is Pb-Zn mineralization. Mineralisation is restricted to cretaceous rocks found in about 48,000 sq. km. of the trough. Workers in the Trough agree that mineralisation is epigenetic and fracture controlled (Ezepue, 1984; Olade and Morton, 1980; Akande *et al*, 1990; Orazulike, 1994). A definite source of the mineralizing fluid remains to be established. Olade and Morton (1980) prefer remobilized connate waters. Orazulike (1994) used sulphide textural analysis to conclude that at least two generations of hydrothermal fluid were involved in sulphide mineralisation. Lead is found in commercial deposits in Nigeria in states as Plateau, Gombe, Zamfara, Nasarawa, Cross River, Ebonyi, and along the Benue River in Taraba and Adamawa State (Ababio, 1991). Orazulike (2002) estimated a reserve of 2 – 2.5 million tonnes of combined lead and zinc deposit in Nigeria whose commercial exploitation ceased during the civil war. It must be noted however that the determination of accurate estimation of mineral deposits is a complex exercise as new findings are made thus; any estimate is likely to be out of date when it is published (Eastop and McConkey, 2002).

Compared with other African and Asian countries, which is comparable to Nigeria in many respects, economic development in Nigeria, has however been disappointing (Muhammad-Lawal and Atte, 2006). The dynamic entity of mineral resources identified by Bailly (1982) and powered by five controlling factors, often known as the "Five E's" include the existence of a deposit, extractability of the mineral values, energy and material requirements for extraction, environmental acceptability requirements, and economics of a possible operation.

Solid minerals have capacity to provide the all-important launching pad for the development of other sectors of the economy as well as give sense and meaning to the oneness of the Nigerian state as minerals are located in all states of the Federation (MOMSD, 2012). It is therefore vital that the nation explores this latent potential which has slumbered over the years. In addition, solid minerals will provide local raw materials for industries and bring vital infrastructure and wealth to rural areas.

This study focuses on the development of lead which is a solid mineral resource in Nigeria and assess its adequacy in the production of lead-acid battery terminal material (which makes up the largest percentage of the end uses of lead) and by extension other associated products from Nigeria's lead ore deposits taking into cognizance the nation's increasing bold steps into industrialization and constant call for self-sufficiency.

2. Material and Methods

2.1 Collection of Samples

The lower and upper Benue trough and extend over 600 km stretching from Ishiagu in the South-East to Gombe State, North East of Nigeria (Onyemaobi, 1990). For this study, representative samples of the bulk complex sulphide ore deposit were collected from the northern (Wase, Plateau State) and southern (Ishiagu, Ebonyi State) part of the country. The selection was based on three key factors which are the economic quantity of the deposits, proximity of the deposit to an existing refining (beneficiation) plant or centre, and the economy of refining. Orazulike (2002) has shown that known deposits in Ebonyi and Bauchi State make up about 2-2.5 million tonnes. Also, the location of the National Metallurgical Development Centre in Jos, Plateau State makes the ore from these areas suitable for this study. However, since Olubambi (2008) has carried out extensive work on the characterization of the Ishiagu ore, characterization was done for the Jos ore only and the result presented in figure 1.

2.2 Characterisation Method

2.2.1 X-ray powder diffraction measurements

For this study, representative samples of the bulk complex sulphide ore deposit were collected from two small scale miners in Wase Local Government area of Plateau State, Nigeria. The X-Ray analysis was carried out at the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile Ife, Osun state, Nigeria. The measurements were taken with XRD (MD10) Monochromatic CuK_{α} radiation (wavelength = 1.5406) produced by Radicon limited. The samples were exposed to the X-ray beam from an X-ray generator running at 25kV and 20mA.The scanning regions of the diffraction were 16- 72^{o} on the 2theta angle.

2.3 Determination of Chemical Composition of existing terminal material

It is a well-known fact that successful studies on the various composition of battery terminal material have been carried out. Thus, a wide range consultation of literatures was done to determine the acceptable ranges of chemical composition of lead acid battery materials available in the market. These acceptable ranges of composition were noted so as to determine what constituent elements of the ore are to be removed and what reducing agents to employ during the smelting process. It also helps us to determine what constituent elements are to be added to produce a standard battery material. The acceptable range of composition found in literature is presented in table 1.

3. Results

Table 1: Typical Ranges of Chemical Composition of lead acid battery terminal materials (Klebanov et al, 2001)

Element	Symbol	Percentage Composition
Lead	Pb	96.1-97.02%
Antimony	Sb	2.75-3.25%
Arsenic	As	0.05-0.20%
Tin	Sn	0.15-0.40%
Copper	Cu	400-600 ppm
Sulphur	S	Less than 30 ppm
Selenium	Se	Less than 20 ppm

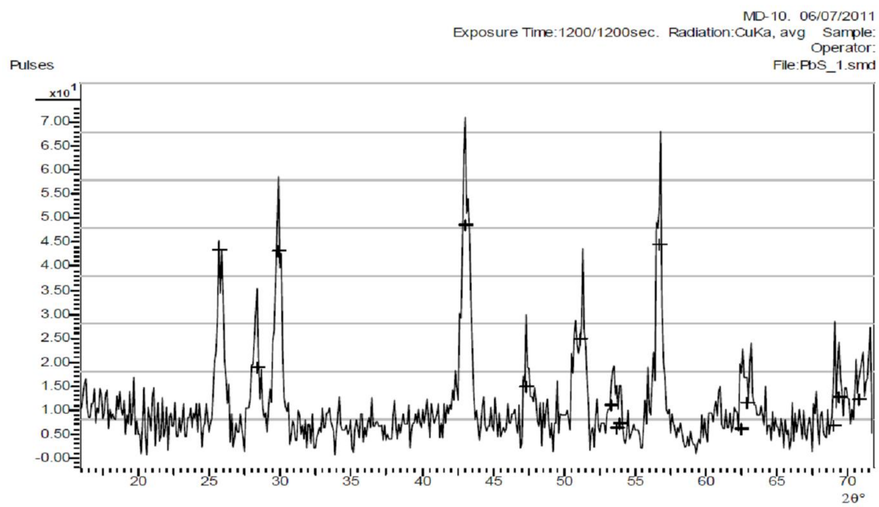

Figure 1: Typical diffraction pattern of the Wase (Plateau State Nigeria) lead ore.

4. Discussions

The diffractogram (Figure 1) shows a typical X-ray diffraction pattern of the Wase ore. First, the background and peak positions were identified and based on the peak positions and intensities a search-match routine was performed. Generally, there are matches of line of mineral phases. The matching of lines of mineral phases could be that some of the minerals must have precipitated from the same fluid. This in conjunction with phase disorientation could result in overlapping effects of the minor minerals with those of the major minerals. The maximum intensity values range from 5.1 to 47.7 pulses obtained at 2θ values of 62.49^{o} and 43.05^{o} respectively. The peaks of the minor mineral phases might occur at the same or in the neighbourhood of locations as the peaks of the major phases, thereby leading to inaccuracy in resolving the peaks (Olubambi et al., 2008).

Despite the fact that there is an abundance of these mineral deposits within the Benue trough, and their existence has been known for a long time (Akande et al., 1989; Maluski et al., 1995), only a few are presently being exploited at different low levels by ineffective small scale private entrepreneurs. This noneffective exploitation and processing technologies of these minerals has made them a burden.

Table (1) shows typical ranges of chemical composition of lead acid battery terminal materials. A cursory look at this values shows that when compared to the chemical composition of the lead ore sample, element such as iron, silver, aluminium, magnesium, silicon, and calcium which occur in trace values must be extracted from the ore as impurities during the smelting process. This can be achieved by the addition of appropriate reducing agents at appropriate temperatures. On the other hand, elements such as antimony, arsenic, sulphur and selenium must be added during the process. Element ranges such as those of copper and sulphur are background concentrations which are typically found in smelted lead (Oji, 2011; Klebanov et al, 2001).

5. Challenges

The following challenges confronting the mining industries in general are particularly applicable in hampering effective harnessing of lead ore to produce lead related products. These are but not limited to;

- Environmental degradation in the mining area.
- Health and safety practices in the mining industry.
- Inadequate financial & fiscal Incentives in the mining Industry.
- Host community discontent.

6. Recommendations

The following recommendations are imperatives for surmounting the challenges highlighted above;

- Provision of incentives to the local community and encouragement of grassroot participation.
- Enhancing public enlightenment & discouraging community agitation.
- Enforcing environmental protection and industrial safety laws.
- Improving the legal, regulatory, financial, institutional, and other conditions necessary to attract investment.

- Making deliberate efforts to increase small scale enterprises in Nigeria. This includes the development of well-equipped shop floor foundries.
- Increase in per-capita productivity of the people through improved technological innovation
- Attract private investment and expand value adding in downstream industries through creating investment friendly environment.

7. Conclusion

It is a fact of modern international trade that developing countries such as Nigeria stand to gain more from processing their metal ore endowments into primary metal or even final products before sales rather than trading the crude ores. In view of this in the case of lead ores there is the need for the establishment of smelting plants to produce lead metals and the development of manufacturing industries that would utilize lead as a raw material to fabricate finished and semi-finished products. Nigeria is generously endowed with abundant natural resources. With its reserves of human and natural resources, Nigeria has the potential to build a prosperous economy and provide for the basic needs of the population. This enormous resource base if well managed could ensure the supply of raw materials for the moribund battery producing companies as well as provide gainful employment for the teeming population. Nigerians support efforts to improve their well-being, thus this is just the time to use this resource to the nation's benefit.

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