

Full Length Research Paper

## Environmental and health hazards associated with exploration of barite from Bukkuyum (Zamfara State), Nigeria

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Received 7 May, 2015; Accepted 4 June, 2015

Barite is barium sulfate with the chemical formula of  $\text{BaSO}_4$ . Unlike barite witherite ( $\text{BaCO}_3$ ) it is not chemically inert, it can dissolve in water and, when dissolved, can cause an environmental hazard. Barite forms in many geologic environments with both metallic and nonmetallic minerals. Minerals associated with the ore are a main concern when mining and processing barite. In many barite deposits, silica is present, if the level of  $\text{SiO}_2$  is high enough with prolong exposure to particle size of less  $10 \mu\text{m}$  pose a health hazard, and the ore must be handled so as to reduce the respirable silica level. If unoxidized minerals such as pyrite are present with the barite, acidic runoff could result from groundwater or storm water content. The runoff may also leach additional minerals from the ore, resulting in high minerals concentration. Both the runoff of this water as well as the accumulation of this water in mining pits is of possible environmental concern. These issues must be addressed within the context of the environmental requirements in place in the jurisdiction within which the mining occurs. This paper is aimed at characterizing Barite from Bukkuyum local government area of Zamfara state of Nigeria, using Empyrean diffractometer DY 674 (2010) for XRD phase analysis of the powdered sample. The peaks generated match those of a  $\text{BaSO}_4$  in ICDD PDF 2 (2010) database. Minipal 4 energy dispersive X-ray Fluorescence (XRF) provided the elemental analysis in their oxides, with  $\text{SiO}_2$  of 4.55% content and 19.5% of  $\text{SO}_3$  that could be the source of silicosis and acidic runoff, respectively, that are of health and environmental concern. The SEM provided the photomicrograph picture with the fiber histogram giving the statistics of particle size of 2.19, 8.73 and  $20.70 \mu\text{m}$ , all with the objective of giving adequate information of the environmental hazards associated with its exploration base on the findings of these characteristics.

**Key words:** Characteristics, barite, exploration, environmental, health, hazard.

### INTRODUCTION

Barite is barium sulfate with the chemical formula of  $\text{BaSO}_4$ , unlike barite the carbonate of barium mineral is witherite ( $\text{BaCO}_3$ ) it is not chemically inert. Witherite can dissolve in water and, when dissolved, can cause an

environmental hazard. Barite by far the predominant barium mineral used by industry because of its high density and chemical inertness, it is ideal for use in the petroleum, automotive, and paint industries, and in other

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applications (Paul, 2006; Brobst, 1994). Barite forms in many geologic environments and can be found with both metallic and nonmetallic minerals. The barite can either be the major component of the mineral or minor fraction. In most cases, the barite must be a major component of the mineral and must be substantial thickness for the ore to be economic. Mineral associated with the ore are a main concern when mining and processing barite. In many barite deposits, quartz is present with the barite. If the level of quartz is high enough, the ore must be handled so as to reduce the respirable silica level (Gianella, 1940; Ketner, 1963; Papke, 1984). Exposure to silica can be deadly, and limiting that exposure is essential. For the particle size the Occupational Safety and Health Administration (OSHA) proposes a new permissible exposure limit, calculated as an 8h time-weighted average, of 50 micrograms of respirable crystalline silica per cubic meter of air ( $50\mu\text{g}/\text{m}^3$ ).

OSHA also proposes other ancillary provisions for employee protection such as preferred methods for controlling exposure, respiratory protection, medical surveillance, hazard communication, and recordkeeping (Harben and Bates, 1990; Duhamand Hanor, 1967; Suresh et al., 2007). If unoxidized minerals such as pyrite are present with the barite, acid mine drainage or low-pH runoff could result from ground-water or storm water content with the pyrite. The acidic runoff may also leach additional minerals from the ore, resulting in runoff with a low pH and high minerals concentration. Both the runoff of this water as well as the accumulation of this water in mining pits is of possible environmental concern. These issues must be addressed within the context of the environmental requirements in place in the jurisdiction within which the mining occurs (Siegel, 2002; Nordstrom, 2008; Oden, 2012).

This paper is aimed at characterizing Barite from Bukkuyum local government area of Zamfara state of Nigeria, with the objective of giving adequate information of the environmental and health hazards associated with its exploration base on the findings of these characteristics which is a function of its geological origin. The characterization includes chemical analysis, mineralogical examination, and particle-size distribution of the crushed ore, depending on the nature of the deposit. Chemical analysis and mineralogical data allow identification of the minerals present. The size distribution gives an idea to grind ability and examining the size fractions will indicate liberation size.

## MATERIALS AND METHODS

### Experimental procedure

The sample of Barite was collected from Bukkuyum local government area, Zamfara state of Nigeria (Figure 1). Using, Empyrean diffractometer DY 674 (2010) for (XRD) phase composition analysis, Minipal 4 energy dispersive X-ray Fluorescence (XRF) for elemental analysis and Scanning Electron

microscope (SEM) for micrograph morphological picture of the kaolin sample.

### XRD Analysis of the sample

The sample of Barite was analyzed using the reflection-transmission spinner stage using the Theta-Theta settings. Two-Theta starting position is 0.00483 and ends at 75,000 with a two-theta step of 0.026 at 3.57 s per step. Tube current was 40mA and the tension was 45kV. Fixed Divergent Slit size of  $1^\circ$  is used and the goniometer radius is 240mm. The intensity of diffracted X-rays is continuously recorded as the sample and detector rotate through their respective angles. A peak in intensity occurs when the mineral contains lattice planes with d-spacings appropriate to diffract X-rays at that value of  $\theta$ , although each peak consists of two separate reflections ( $K_{\alpha 1}$  and  $K_{\alpha 2}$ ), at small values of  $2\theta$  the peak locations overlap with  $K_{\alpha 2}$  appearing as a hump on the side of  $K_{\alpha 1}$ . Greater separation occurs at higher values of  $\theta$ . Typically these combined peaks are treated as one. The  $2\theta$  position of the diffraction peak is typically measured as the center of the peak at 80% peak height.

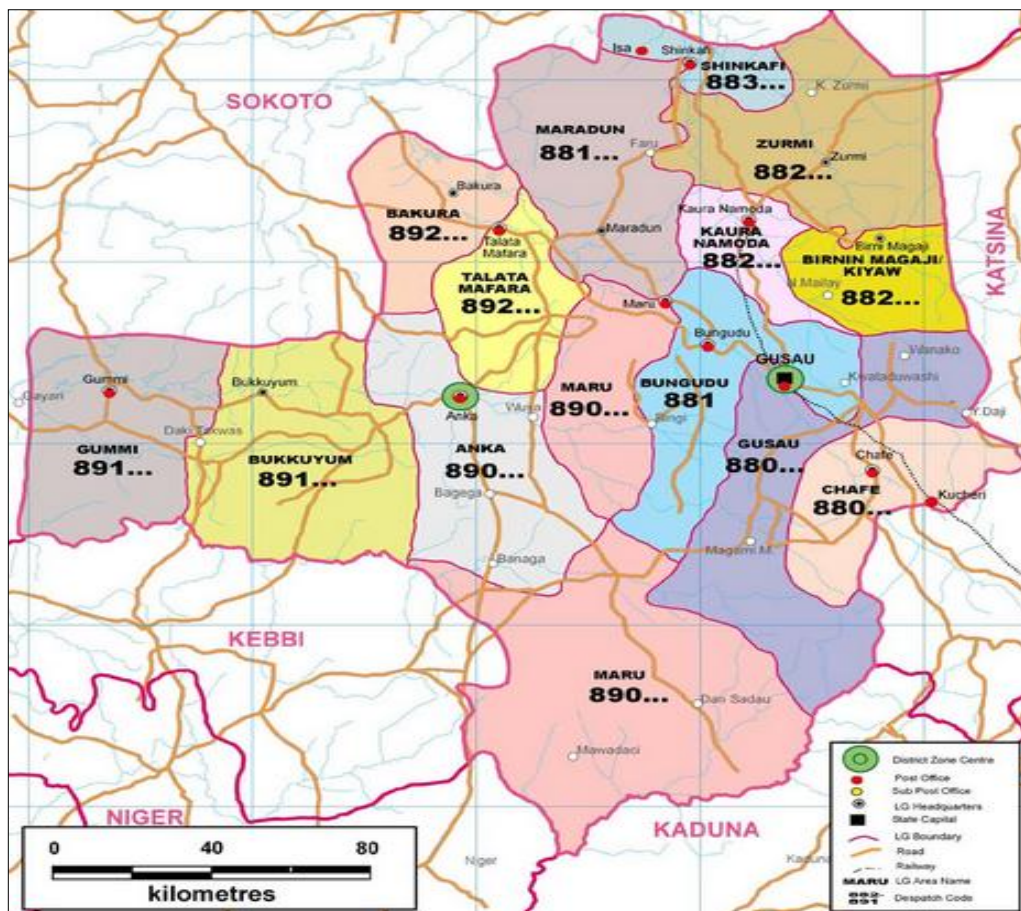
Results are presented as peak positions at  $2\theta$  and X-ray counts (intensity) in the form of a table, and x-y plot. Intensity ( $I$ ) is reported as peak height intensity. That is intensity above background, or as integrated intensity, the area under the peak. The relative intensity is recorded as the ratio of the peak intensity to that of the most intense peak ( $\text{relative intensity} = I/I_1 \times 100$ ). The d-spacing of each peak is then obtained by solution of the Bragg equation for the appropriate value of  $\lambda$ . Once all d-spacings have been determined, automated search/match routines compared the unknown to those of known materials. Because each mineral has a unique set of d-spacing, matching these d-spacings provides an identification of the unknown sample. A systematic procedure was used by ordering the d-spacings in terms of their intensity beginning with the most intense peak. Files of d-spacings for hundreds of thousands of inorganic compounds are liable from the International Centre for Diffraction Data as the Powder Diffraction File (PDF). The peaks obtained from the analyses were matched with the minerals from ICDD database which is attached to the software of the machine.

### XRF Analysis of the sample

Solid pellet sample of 10g was placed in the special "dekat" plastic cup sample holders. The sample was then loaded on the sample changer and the position label was noted. Beads used for the major oxide analysis were  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{TiO}$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{K}_2\text{O}$  and  $\text{P}_2\text{O}_5$  expressed in weight percent were prepared. 10g of pulverized sample was weighed and mixed exactly with 5 times of X-Ray flux (66.0% lithium Tetraborate, 34.0% Lithium Metaborate). This weighed mixture was mixed properly in a Platinum crucible and ignited in a pre-set furnace at  $1150^\circ\text{C}$  for 10 min, immediately, the weighed mixture in the crucible was placed on the crucible holder, and the preparation process commenced as the start button was pressed on. It was heated, mixed and automatically cast into a dish (mold). During this process a releasing agent was added (ammonium iodide tablet). Upon completion of cooling the cold glass bead was unload ready for analysis. The glass bead was labeled and slotted into the Minipal 4 energy dispersive XRF for major oxide analysis. For XRF Trace elemental Analysis, the pellets were prepared by weighing 10g of oven dried pulverized sample and 5.0g flux (cellulose powder) added as a binder. This is mixed thoroughly with glass rod in a bowl. The well mixed was then compressed by applying a pressure of 1500kg using manual compressor. The steps carried out for measurements were; Loading the sample, and opening the measure window for the required application.

### SEM of the sample

The Solid Barite sample pellet was prepared for scanning electron



**Figure 1.** Map of Zamfara state showing fourteen local government areas, with Bukkkuyum local government area where the barite was collected second from left shaded in black.

microscopy by crushing and grinding. The SEM has an electron optical column in which a finely focused electron beam can be scanned over a specified area of the specimen, small particles mounted on a stub. Resolution in the SEM ranges from about 50 to 25Å (5 to 2.5 nm). In the electron column of the SEM, a high intensity electron beam is scanned across the specimens. The impact of an electron beam on the surface of a solid sample causes various types of radiation signals that were recorded by detector above the specimen.

## RESULTS AND DISCUSSION

### XRD Phase analysis

From the Figure 2, it show the XRD peaks of the crude Barite powder, which indicates peaks corresponding to Barite with chemical formula  $BaSO_4$  on ICPDS card number 00-024-0020.

### XRF Elemental analysis

From the Table 1, it has substantiate the XRD results by providing the elemental composition in their oxides,

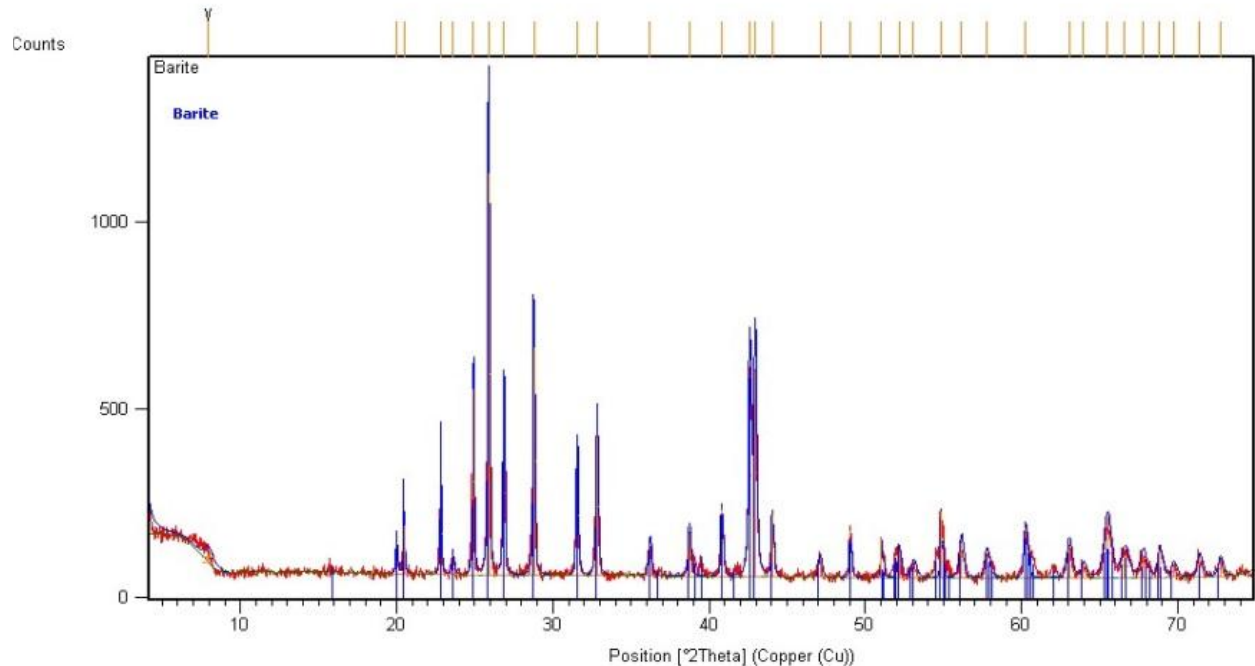
oxides of particular interest are BaO of 71.46%,  $Al_2O_3$  of 14.98%,  $Fe_2O_3$  of 0.58%,  $SO_3$  of 19.5%, CaO of 0.71%, MgO of 0.03%, and LOI of 0.04%. The  $SiO_2$  of 4.55% can cause silicosis especially with prolong exposure to the mineral mining and processing with particle size less than  $10\mu m$ . The high percentages of  $SO_3$  and  $Fe_2O_3$  indicates possible acid run-off from ground water with pyrite content.

### SEM Morphological analysis

From the Figure 3 and 4, it shows the fracture surface and the grind ability of the mineral with particle size distribution of 2.19, 8.73, 20.70 $\mu m$  of the crude barite. From the fiber histogram statistics, about 62 to 65% are less than  $10\mu m$ . Depending on application the specification of particle size are provided.

### Conclusion

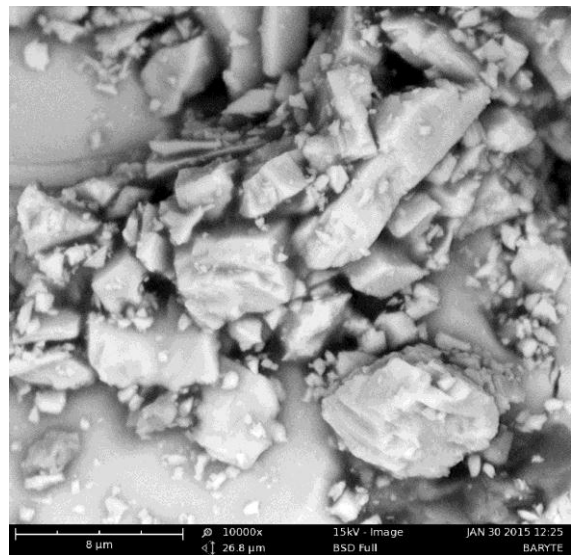
Based on the experimental results analysis, the following conclusions have been presented.



**Figure 2.** X-ray diffraction of crude Barite from Bukkuyum local government, Zamfara State, Nigeria.

**Table 2.** X-Ray fluorescence (XRF) elemental analysis result of crude barite From Bukkuyum local government area, of Zamfara State, Nigeria.

Oxides	Percentage (%) presence
SiO <sub>2</sub>	4.55
Al <sub>2</sub> O <sub>3</sub>	1.31
K <sub>2</sub> O	0.06
Na <sub>2</sub> O	0.07
SO <sub>3</sub>	19.5
CaO	0.09
MgO	0.03
TiO <sub>2</sub>	1.6
Fe <sub>2</sub> O <sub>3</sub>	0.27
MnO	0.01
BaO	71.46
LOI	1.050

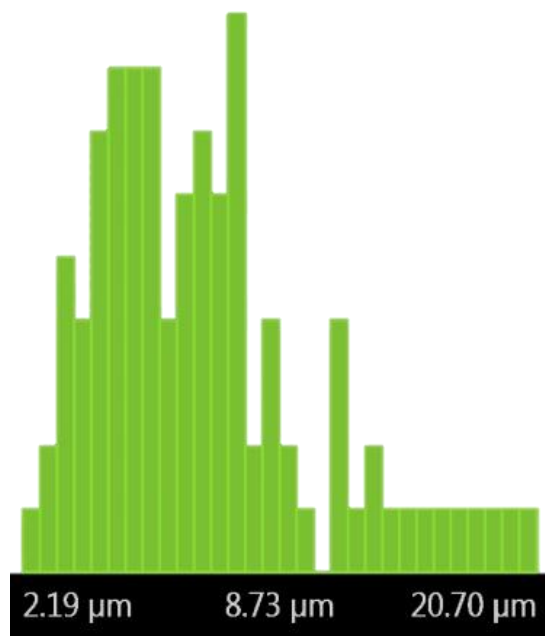


**Figure 3.** Scan Electron photomicrograph showing the fracture surface of fine barite crude that is representative of the barite deposit in Bukkuyum local government area of Zamfara State, Nigeria.

1. XRD analysis confirms the Barite BaSO<sub>4</sub> phase.
2. The XRF presented the elements in their oxides SiO<sub>2</sub> of 4.55%, Al<sub>2</sub>O<sub>3</sub> of 1.31%, K<sub>2</sub>O of 0.06%, Na<sub>2</sub>O of 0.07%, SO<sub>3</sub> of 19.5%, CaO of 0.09%, MgO of 0.03%, TiO<sub>2</sub> of 1.6%, Fe<sub>2</sub>O<sub>3</sub> of 0.27%, MnO of 0.01%, BaO of 71.46% and LOI of 1.05%.
3. The SEM shows the morphology along with statistics of particle size of 2.19, 8.73 and 20.70 μm.
4. Finally, it can be concluded that barite from Bukkuyum

local government area of Zamfara state has SiO<sub>2</sub> of 4.55% content as such the primary health risk is the inhalation of "respirable" particles smaller than 10 μm. Generally, the smaller the particles are the greater hazard and potential injury to the lungs. Dust particles larger than these are not





**Figure 4.** The fiber histogram showing the particle size distribution of the crude crushed barite that is representative of the barite deposit in Bukkuyum local government area of Zamfara State, Nigeria.

capable of penetrating the defense mechanisms of the lung. Prolonged exposure may cause delayed chronic silicosis. Chronic silicosis may take many years of exposure to develop, but with acute exposure rapid development can occur. In latter stages of silicosis, known as complicated or conglomerate silicosis, lung function may be reduced, resulting in symptoms of shortness of breath. The content of  $\text{SO}_3$  of 19.5% can possibly lead to acidic low-pH runoff from ground-water that may also leach additional minerals from the ore, resulting in high minerals concentration of environmental concern (NIOSH, 1992; NLMC, 1991).

### Conflict of interests

The author(s) did not declare any conflict of interest.

### ACKNOWLEDGEMENTS

Authors would like to thank (NGRL), Kaduna for their kind help of XRD and XRF analysis, and also Department of Chemical Engineering, ABU, Zaria for the SEM morphology analysis.

**Abbreviations:** OSHA, Occupational safety and health administration; PDF, powder diffraction file; XRF, X-ray fluorescence; SEM, scanning electron microscope.

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