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Major and trace elements pollution of sediments associated with Abandoned Barite Mines in parts of Oban Massif and Mamfe Embayment, SE Nigeria

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ABSTRACT

The present study was carried out to assess stream sediment quality and pollution level by major and trace elements near six abandoned barite mines in the Oban massif and Mamfe Embayment (SE Nigeria). Results showed that the stream sediments are sandy (>70%) and slightly acidic (pH, 4.1- 6.3) with LOI ≤ 4%, qualitatively indicating low organic matter contents. The concentrations of trace elements varied widely among the dump sites and decreased with depth and distance away from mine dump sites. Comparison of average trace element concentrations in the sediments with background concentrations revealed that most of the sediments were polluted with Fe, As, Cu, Hg, Pb and Zn at all the mine sites. Pollution by Cd was documented at locations underlain by shale rock, while Cr pollution was at area underlain by basement. Pollution by Co was mainly within shale and basement areas. Concentrations of Al, Ni and V across all mine sites and Co at sedimentary area were below background values. Lowest concentrations of elements were recorded with the sandstone area and the highest concentration in the basement area. Moderate values of elements characterized the shale area. The index of geoaccumulation (Igeo) based on average values for the depth range 0-30 cm indicated varying degrees of pollution with Al, Fe, Cd, Co, Cr, Hg, Mn, Ni and V (practically unpolluted, Class 0); As, Ba, Cu and Zn (slightly polluted, Class I) and Pb (moderately to strongly polluted, Class III). However, these levels of pollution are milder compared to when maximum Igeo values were used. The sediments were slightly to strongly polluted with Pb across all the sample sites irrespective to the lithology. The *Itot* defined as the sum of *Igeo* for all trace elements obtained from the different mine sites indicated that the basement areas are most polluted compared to the areas underlain by sedimentary rocks. The spatial distribution of different pollution level by trace elements was irregular and not defined to any geologic terrains.

1. Introduction

Prior to the establishment of the Ministry of Solid Mineral Development (MSMD) in 1995, not much emphasis was placed on exploration of solid minerals in Nigeria. During the pre-1995 period, the exploration of solid minerals had remained the exclusive stock in trade of the artisanal miners. The exact reserve and quantity of barite exploited were difficult to estimate since exploitation was in a haphazard manner. In an attempt to conserve foreign exchange and create employment opportunities in the solid mineral sector, the Federal Government of Nigeria encouraged and emphasized the sourcing and utilization of local raw materials, especially as related to the oil and gas industry (Adamu et al., 2009). This was the beginning of a new era in exploitation for solid mineral, especially barite which was in high demand from the local and oil and gas industries. The mining operations involved removal of vegetation and overburden, drilling, blasting and haulage from the pit to the dump site before for sale. While only the highest grade barites were sold, the low quality ones and associated impurities as well as rock fragments were abandoned as mine spoils, which constitutes sources of contaminants.

The recovery of barite deposits by open-pit surface mining has generated several quarries within the area of study that are several kilometers long and 10-50 m deep. Open cast mining of barite in the study area was carried out without an environmental impact assessment (EIA) study, thereby resulting in poor waste management. Thus the exposed rocks and waste materials could be mobilized to contaminate the soils, waters, sediments and biota (Jung, 2008; Lee et al, 2005). This may therefore pose a potential health risk to residents in the vicinity of the barite mining areas (Cox, 1995). It has been noted that dumping of mine waste, and discharge of mine water as well as the flooding and erosion of mine area into the river systems may have resulted in enhanced concentration of elements and other contaminants in bottom sediments compared to the overlying water (Clark et al, 1998). This is due to the high absorptive and binding force of the

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substrate, particularly in areas with high organic matter content (Siegel, 2002).

Although sediments act as a sink for mine waste, unstable environmental conditions, high flow regimes, bioturbation, human activities among others, can result to changes in the chemical properties of sediments that may result in the large scale remobilization of contaminants along the bottom sediments and in the overlying water leading to the dispersion of contaminants many kilometers from mine dump sites. Some elements are generally considered as serious inorganic pollutants due to their toxic effects, surface enrichment and slow removal rates. Once metal contaminants are released into the environment, they accumulate in soil, water, sediment and biota, thereby polluting the environment (Cox, 1995; Forstner, 1980; Siegel, 2002). Trace elements move through aquatic environments via two mediums; as particulate matter and as dissolved forms such as free metal ions and soluble complexes. Once the transported trace metals are deposited on the sediments, binding by diverse mineral phases (colloids, sulphides, carbonates, etc) immobilize them until change in ambient pH and redox condition occurs. Although there has been numerous studies on trace metal pollution and its effects (Adamu and Nganje, 2010; Bhattacharya et al., 2006; Edet et al, 2003; Hwang et al, 2009; Jung, 2008; Kabata – Pendias and Pendias, 2007; Lee et al, 2005), only a limited number of publications have investigated trace metal contamination around barite mine dump sites (Franciskovic-Bilinski, 2006; Nagaraju et al, 2006). This is worse in Nigeria and other developing nations, where environmental consideration usually takes a second place to economic growth. There is thus, scarcity of information on the impact of barite mining activities on the environment in the study area and, indeed the whole of Nigeria. The main objectives of this study were: (i) To determine the content of some major and trace elements in surface and subsurface sediments in rivers draining abandoned barite mine sites in parts of Oban massif and Mamfe embayment (SE, Nigeria) and (ii) To estimate degree and extent of anthropogenic input and assess the pollution status of the abandoned mine area.

2. Study area

2.1. Geography

The study area lies between the geographic coordinates of latitudes 05°30' - 06° 10'North and longitudes 08° 00' - 08° 50'East (Fig. 1). It is situated within the subequatorial south climatic region of Nigeria with a total annual rainfall of between 200 and > 300 cm in the rainy season months of April to October. In the dry season months of November to March, the annual mean precipitation ranges from 25 to > 50 cm. The mean annual temperature varies between 25 and 27oC (Iloeje, 1999). The mean humidity drops from 80% in the rainy season to as low as 60% in the dry season. The vegetation of the area is characterised by High Forest. The elevation ranges from 100 m in the low lying sedimentary areas in the north to more than 500 m above sea level in the high lying Oban Massif in the south. The area is drained by tributaries of the Cross River including Ukpan, Etuhl, Okwa, Lokpai, Udip and Udom rivers. The landuse patterns in the area include cultivated land, plantations (oil palm, rubber, cocoa and plantain), built up areas and thick forest cover. Majority of the inhabitants make their living from farming, fishing, hunting and recently mining.

2.2. Mine site locations

Nde mine site is located in the extreme northern part of the study area (Figs. 1 and 2a). Geographically, it is situated on latitude 6° 03 53 N and longitude 8° 36 20E at about 140 m above the mean sea level (amsl). Alese mine site is located south of Nde mine near Ukpan River. The mine site is located on approximately on latitude 5° 58 31 N and longitude 8° 28 14E (Fig. 2b) at an elevation of about 180 m amsl. Okumeretet mine is situated at the break of hill slope in a thick forest south of Alese near a tributary of Okwa River. It is located on latitude 5° 59 30 N and longitude 8° 20 59E at an elevation of about 240 m amsl (Fig. 2c).

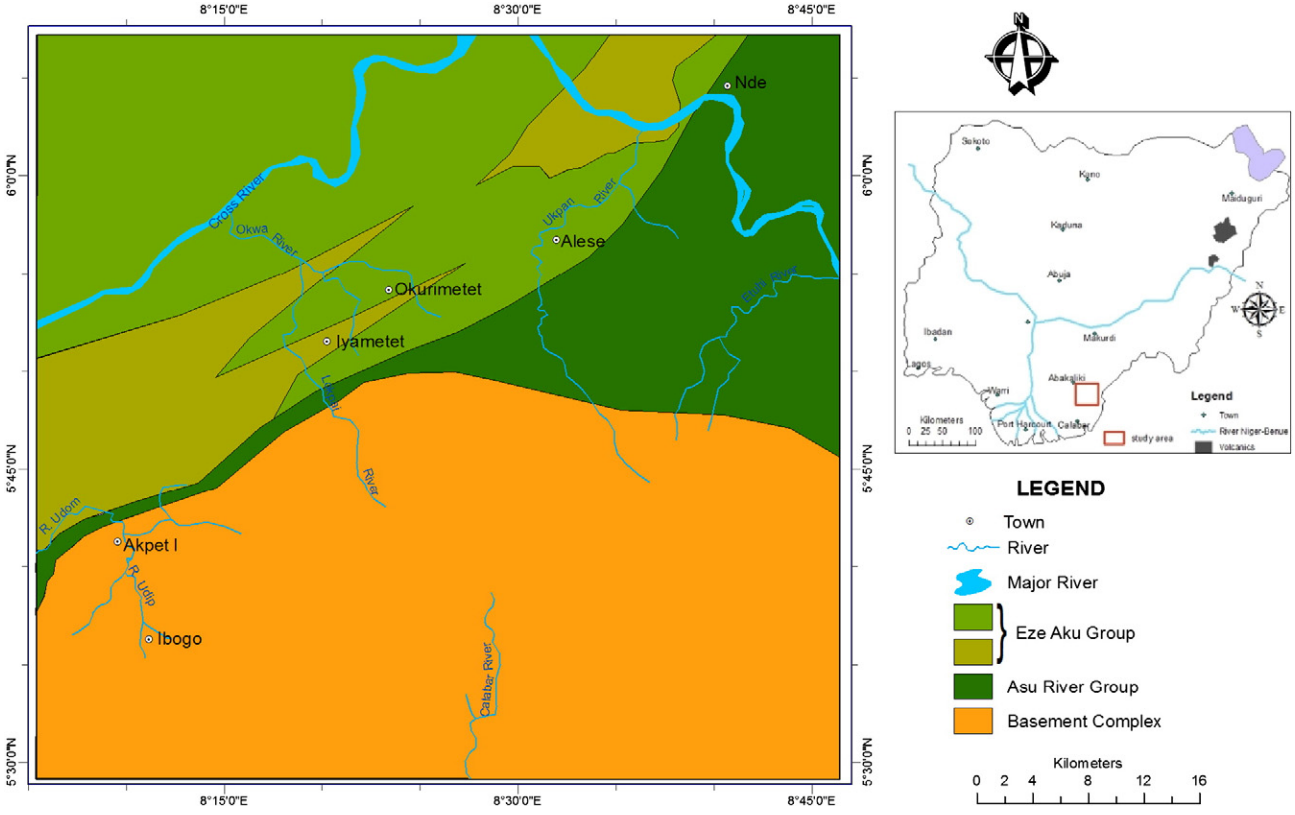

Fig. 1. Simplified geological map of the study area including mine sites.