Heavy metal concentrations in soils and plants in the vicinity of Arufu lead-zinc mine, Middle Benue Trough, Nigeria

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Abstract This study focused on the influence of base metal mining on heavy metal levels in soils and plants in the vicinity of Arufu lead-zinc mine, Nigeria. Soil samples (0–15 cm depth) and plant samples were collected from cultivated farmlands in and around the mine, the unmineralized site and a nearby forest (the control site). The samples were analyzed for heavy metals (Fe, Zn, Mn, Cu, Pb, Cr and Cd) by Atomic Absorption Spectrophotometry (AAS). The physical properties of soils (pH and LOI) were also measured. Results showed that soils from cultivated farmlands have neutral pH values (6.5–7.5), and low organic matter contents (<10%). Levels of Zn, Pb and Cd in cultivated soils were higher than the concentrations obtained from the control site. These heavy metals are most probably sourced from mining and agricultural activities in the study area. Heavy metal concentrations measured in plant parts decreased in the order of rice leaves>cassava tubers>peelings. In the same plant species, metal levels decreased in the order of Zn>Fe>Mn>Cu>Pb>Cr>Cd. Most heavy metals were found in plant parts at average concentrations normally observed in plants grown in uncontaminated soil, however, elevated concentrations of Pb and Cd were found in a few cassava samples close to the mine dump. A stepwise linear regression analysis identified soil metal contents, pH and LOI as some of the factors influencing soil-plant metal uptake.

Key words heavy metal; soil; plant; lead-zinc mine; Benue Trough; Nigeria

1 Introduction

Metal contaminations in soils have become a worldwide concern since rice paddy fields irrigated with waste from a zinc mine caused excessive cadmium (Cd) intake which caused adverse health effects on farmers who had consumed the rice grown on the contaminated soil (Kobayashi, 1978). This first observation of human disease caused by heavy metals in the general environment has stimulated research on the potential adverse effects of heavy metals in soils and in agricultural and dietary systems.

Base metal mining can be an important source of heavy metals in the environment owing to various mining activities including processing and transportation of ores, disposal of tailings and waste water around mines (Chon et al., 1997; Lee et al., 2001). The elevated levels of heavy metals discharged from mine wastes can be found in nearby streams, agricultural soils and food crops, and eventually, they may impose a potential health risk on residents in the vicinity of mines. Heavy metal uptake by plants grown on polluted soils has been studied to a considerable extent (Jung and Thornton, 1996; Jung and Chon, 1998; Jung et al., 2002; Yung et al., 2004; Lee et al., 2001; Salami et al., 2006). All findings have shown that elevated levels of metals in soils may lead to increased uptake by plants. However, there is generally no strong relationship between the concentrations in soils and those in plants because it depends on many different factors, such as soil metal bioavailability, plant type, age and parts (Xian, 1989; Kabata-Pendias and Pendias, 2002; Chukwuma, 1995; Chon et al., 1997; Jung et al., 2002). So even the concentrations of heavy metals in plants grown in various unpolluted environments show quite large variations (Sauve et al., 1997; Dudka et al., 1996; Alloway; 1990).

In Nigeria, base metal mines producing Pb-Zn were distributed within the Benue Trough and had been actively operated until the early 1970s. Since then, however, base metal production has declined and most of the mines were abandoned mainly due to
economic reasons and exhaustion. Upon the abandoning of the mines, improper disposal of mineral waste piles and untreated mine drainage have become the most important sources of heavy metals in nearby environments. Previous works have reported the elevated levels of heavy metals from soils, water and sediments as well as food crops from metaliferrous mines within the trough (Adiku-Brown and Ogezi, 1991; Chukwuma, 1995).

The current study is to investigate the relationships between heavy metal contents of some food crops and those in agricultural soils in the Arufu Pb-Zn mining district within the Middle Benue Trough, Nigeria.

2 Description of the study area

The Arufu mining district of the Middle Benue Trough is located between longitudes 9°10’ and 9°20’E and latitudes 7°40’ and 7°45’N (Fig. 1). The area which is undulating lies roughly between 200–300 m above sea level. Laterite scarps which have resulted from prolonged dissection of former laterite sheets are dominant features in the area. Many small seasonal streams including the Pii, Kutaji, Kiri and Ubaver rivers, which are all tributaries of the Benue River, control the drainage in the area. The streams are structurally controlled and generally join together in a dendritic drainage pattern.

The area is characterized by a tropical wet-dry climate and its rainfall is generally moderate, about 100–120 cm per annum. The temperature ranges from 30–5°C and the relative humidity is in the order of 30%–60% (Ileooje, 1981). The vegetation in Arufu is of the savannah wood type, typified by tall grasses, lots of shrubs and a few tall trees ranging in height from 3–6 m. The bedrock in which the mineralization occurs is limestone with intercalations of shale and sandstone. The minerals are galena (PbS) and sphalerite (ZnS).

3 Materials and methods

Surface soil samples (0–15 cm depth) were collected using a hand auger (2.5 cm in diameter) in cultivated farmlands near the mine dump and a rural unmineralized area (Abata) about 5 km south of the mine as well as in a government forest near Makurdi (capital of Benue State) to serve as control (Fig. 1). The forest is restricted from public use and assumed to have suffered little anthropogenic inputs. Each soil sample comprised a composite of 10 sub-samples taken on a 1×1 meter square. Random samples of plants were taken from the cultivated fields including rice leaves (Oryza sativa) and cassava (Manihot esculenta). Samples were placed in polythene bags and properly labelled.

Soil samples were dried in an air-circulating oven at 25°C, disaggregated and sieved to <2 mm. After quartering, the samples were ground to 80 mesh (<180 μm) in a stainless steel blender. Plant samples were thoroughly washed with deionized water and dried in an air-circulating oven at 25°C, ground to fine powder and repackaged in a sealed plastic bag. The cassava tubers were carefully peeled and rinsed with tap water.