



Determination of Selected Metal Concentrations in Arable Soil Samples of Lapai Using Thermal Neutron Activation Analysis Technique

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ABSTRACT

Soil is an important and abundant natural resource; it is also an important aspect of the environment as it serves as a sink for by-products of natural and anthropogenic processes. Plants obtain essential nutrients for growth from soil, other chemically similar elements that exist in soil compete for uptake by plant. Thus, these toxic substances accumulate in plants and transfer along food chain. Analysis of soil from selected locations of arable soil of Lapai was carried out using thermal neutrons activation analysis technique (TNAA) produced from Nigeria Research Reactor -1 (NIRR-1) operated at a power of 31kW and a neutron flux of $2.50 \times 10^{11} \text{ cm}^{-2}\text{s}^{-1}$. Seven soil samples were collected from three sites, four elements were determined in all the samples collected. The elements determined were chromium, iron, cobalt and arsenic. The concentrations of all elements found were within permissible limit for agricultural activities.

Keywords: Arable soils, thermal neutron, TNAA Technique, MNSR.

INTRODUCTION

Soil is an important part of the earth crust as it serves as a medium for plant growth as it contains essential nutrients for proper growth. It also serves as habitat for microorganisms and as an ultimate sink for by-products of natural and anthropogenic processes (Chatchai *et al.* 2019). These has made soil a complex system. Activities of man such as fossil fuel combustion, mining and indiscriminate refuse and sewage disposal has continue to alter the balance of nutrients present in soil that are required for proper plant growth (Lago-Vila *et al.* 2015). these processes have led to lingering cases of environmental deterioration by increasing toxic substances above permissible level. Use of pesticides, fungicides and fertilizers have been reported as the primary anthropogenic source of trace metals in agricultural soil (Kelepertzis, 2014). The effects of these metals on plants range from mild to severe toxicity.

Trace elements concentrations such as Co, Fe, As and Cr have increased slightly in areas where varying pollution have been reported (Khan *et al.*, 2008). Increase in abundance of these elements interferes with availability of essential nutrient required for proper plant growth (Gopal

et al. 2003). More so, bioaccumulation of these chemicals along food chain pose a serious concern to human (Zhuang *et al.* 2008). Some of the effects of these substances to man include damage to skin and mucous membrane, pulmonary and perforation of nasal septum. It has also been suggested that these substances are carcinogenic (Costa & Klein, 2006). A number of soil analysis have been carried out to determine concentration of these metals such as atomic absorption spectroscopy and recently inductive coupled plasma spectroscopy (Butler *et al.* 2015). These methods are destructive methods because samples will require digestion prior to analysis. More so, ICP is not readily available for use. Neutron activation analysis is a non-destructive method that is used for analysis elements of interest without matrices interference (Jonah *et al.* 2006 & Oladipo *et al.* 2012). This work was aimed at determining some selected metals in agricultural soil collected from some locations of Lapai in Savannah vegetation belt of Nigeria.

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METHODOLOGY

Sample Collection

A comprehensive representative soils samples were collected from three locations of Lapai, Niger State. The sample locations with ordinance grid reference are Cece Village 09⁰ 04'53N and 006⁰33' 42E Gulu 09⁰ 02'44N and 006⁰36' 16E and IBB university farm 09⁰ 04'42N and 006⁰34' 33E. The soil samples were collected at certain specified depths base on observable soil layer. An auger was used for digging to obtain loose soil samples. The samples were screened and stored in plastic bags. Table 2.1 shows the sample with corresponding horizon height and locations.

Table 2.1: Sampling Sites with their Locations and their Horizons

Sample	Horizon depth (cm)	Location
Cece 1	0 – 20	Cece village
Cece 2	21 – 33	Cece village
Gulu 1	0 – 20	Off Gulu junction
Gulu 2	21 – 40	Off Gulu junction
IBBUL 1	0 – 14	University farm
IBBUL 2	14 – 29	University farm
IBBUL 3	29 downward	University farm

Sample Preparation

Samples were prepared based on the procedure described by Oladipo *et al* (2012) After sampling on the field.

Experimental Analysis

Measurement of pH

pH meter was calibrated with NIST Agros Organics buffer solutions of pH 4, 7 and 11. pH of samples were then measured by weighing 30 g of soil in 60 ml of water. The electrode was

immersed in flask and reading was taken after 5 minutes. The pH and the temperature of the solution were measured simultaneously and the results shown in Table 2.

Neutron Activation Analysis

A four-digit Melter model weighing balance was used for weighing samples. About 150 mg of soil was weighed, encapsulated and sealed in a polyethylene material. The capsules were packed into a cylindrical polyethylene vials and labelled accordingly. The samples were then injected into nuclear reactor.

Sample Irradiation

Miniature Neutron Source Reactor (MNSR) was used for irradiation of samples according to scheme described by Oladipo *et al.*, (2012). The reactor was operated at full power of 30 kW and thermal neutron flux of $2.50 \times 10^{11} \text{ ncm}^{-2}\text{s}^{-1}$.

Gamma ray counting

High purity germanium (HPGe) detector was used for counting and acquisition of gamma ray. The HPGe detector was calibrated using standard radioactive sources of ¹³⁷Cs (661.6 keV) and ⁶⁰Co (1173 keV and 1332.5 keV). Gamma ray spectra obtained were processed using WINSPAN 2004 spectrum analysis software. The scheme for counting was followed as described by Oladipo *et al.*, (2012).

RESULTS AND DISCUSSION

The pH of soils affects the availability of nutrients for plant uptake; therefore, pH is an important parameter to be determined in a soil analysis. The results of the pH readings of the savannah and rainforest regions of Nigeria are shown in Table 3.1.

Table 3.1: Results of pH and elements concentrations of samples found with TNAA using NIRR-1

Sample	pH	Element			
		Cr	Fe (%)	Co	As
Cece 1	6.98	16.2 ± 0.1	0.698 ± 0.006	5.69 ± 0.05	0.527 ± 0.009
Cece 2	7.15	17.2 ± 0.4	0.420 ± 0.013	1.87 ± 0.03	0.351 ± 0.008
Gulu 1	7.01	26.4 ± 0.3	0.612 ± 0.012	6.88 ± 0.09	0.734 ± 0.009
Gulu 2	7.11	35.6 ± 0.7	0.702 ± 0.010	7.43 ± 0.06	0.715 ± 0.007
IBBUL 1	6.91	40.6 ± 0.5	1.380 ± 0.014	3.00 ± 0.07	0.938 ± 0.005
IBBUL 2	7.02	28.9 ± 0.4	0.996 ± 0.008	3.76 ± 0.04	0.942 ± 0.006
IBBUL 3	7.6	24.4 ± 0.6	0.663 ± 0.007	3.45 ± 0.03	0.670 ± 0.012

Concentrations are in ppm except otherwise stated

The results of pH of samples are generally neutral and increase slightly with increasing depth height at sampled location. The range of pH found fall within 5.5 to 7.0 required for optimal availability of nutrients for plant growth as reported by Doerr (2007).

Assessment of results obtained in this study were carried out by analysing Coal fly ash standard reference material under same conditions used for determination of elements of interest in the samples. The concentrations of analytes of interest in reference material obtained using NIRR-1 (this work) were compared with values quoted on the reference certificate as given Table 3.2. A p value of 0.21 at α of 0.05 was obtained when t-Test was conducted. This suggests that the values obtained using NIRR-1 were not different from the true values of analytes.

Table 3.2: Results of elements concentrations in standard

Elements	Coal fly ash	
	This work	Reference value
Cr	192.0 \pm 2.3	198.2 \pm 0.05
Fe (%)	8.48 \pm 0.42	7.78 \pm 0.04
Co	50.8 \pm 0.09	50.1 \pm 0.01
As	135 \pm 1.90	136.2 \pm 0.8

Concentrations are in ppm except otherwise stated

Cr concentration range from 16.2 \pm 0.1 (Cece 1) to 40.6 \pm 0.5 ppm (IBBU farm). These falls within the range of 10 to 150 ppm reported in worlds soil (Zayed and Terry, 200). A general trend of chromium concentration observed was a decrease with increasing depth height in all the sampled locations except at Cece where only slight difference in concentrations was observed. The values of chromium of found in the sampled falls within the natural range of 10 to 50 ppm reported for natural occurrence in soil. Jain *et al.* reported decrease in germination of sugarbud in Cr concentration of 20 to 80 ppm (Shanker *et al.*, 2005). It shows that the soil will not be suitable for cultivation of sugar cane at Gulu and IBBU farms while moderate concentration of Cr at Cece soil will support germination sugarcane buds. Cr level of 10 ppm causes reduction in dry plant weight. Other plants such as maize and tomato will only be affected by Cr toxicity above. However, plants commonly grown in the study such as maize, spinach, cabbage, sorghum, tomato, rice, and soya beans have been reported to increase

uptake and accumulation with increasing soil Cr concentration (Jain *et al.*, 2000; Shanker *et al.*, 2005). Cr also interferes with uptake of nutritionally essential elements such as Fe, K, P Mg and Mn in soybeans root due to its structural similarity, therefore causing Fe deficiency in plants.

Fe concentration observed range from 0.420 \pm 0.006 % (Cece 2) to 1.38 \pm 0.014 % (IBBU farm). concentration trend observed showed a decrease in concentration with increasing depth height. However, at Gulu top horizon gave slightly lower concentration than lower horizon. The samples contain high amount Fe. However, these concentrations may not be toxic to plants since not all of these Fe will not be available to plant for uptake because the pH is not acidic (below pH of 5). In addition, the soil may not be deficient in available Fe because the soil is not alkaline or basic as suggested by Anumalla *et al.* (2019).

Concentration range from 1.87 \pm 0.03 ppm (Cece 2) to 7.43 \pm 0.06 ppm (Gulu 2). variation was observed with increase depth height at Cece sampling site while increase in concentration was observed at Gulu with increasing sampling site. Slight increment was observed in samples collected at IBBU farm. It has been argued that excess amount of Co affects translocation of Fe. It has also been reported that increase in Co causes decrease in biomass and restricts uptake of essential nutrient (Gopal *et al.* 2003).

The range of concentration of As in the sampled locations is 0.351 \pm 0.008 ppm to 0.942 \pm 0.006 ppm. Concentration was observed to decrease generally with increase in horizon depth. The range is very low compared with permissible level by US environmental agency of 24 ppm and about 2 ppm found in bioaccessible part of United Kingdom (Palumbo-Roe *et al.*, 2005). Plants such as rice have been reported to accumulate large percentage of arsenic. FAO has recommended 1 ppm as the permissible level As in rice. The sample locations contained low concentration of As which originated from sources such as use of herbicides, insecticides and phosphate fertilizer. This also explains the erratic trend in concentration with varying horizon height and sample location

Conclusion

Thermal neutron activation analytical technique was used to determine concentrations of Cr, Co, As and Fe in arable soil of Lapai. The results showed that concentrations of element were within permissible limit for agriculture activities such as farming in all the samples locations. The results also suggest that TNAA was successfully used to determine concentration of elements in soil samples.

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