Research Article

Flame Atomic Absorption Spectrophotometric Determination of Heavy Metals in some Agricultural Soils of Kwali Area Council, Abuja, Nigeria

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Received: 13 July 2020; **Accepted:** 20 July 2020; **Published:** 17 August 2020

Citation: Akannam, Perpetua Okwukwe, Kakulu Samuel E. Flame Atomic Absorption Spectrophotometric Determination of Heavy Metals in some Agricultural Soils of Kwali Area Council, Abuja, Nigeria. Journal of Environmental Science and Public Health 4 (2020): 216-228.

Abstract

The concentrations of heavy metals Lead, Cadmium, Zinc, Copper and Nickel were determined in selected top agricultural soils of Kwali Area Council of Abuja, Nigeria using Flame Atomic Absorption Spectrophotometric technique. The HNO3-HCL method was used in the sample preparation and a precision of 5%,3%,4%, and 8% for Lead, Zinc, Copper, and Nickel were obtained respectively. The soil pH varied from mildly acidic to near neutral (5.53-6.95) from the various locations and these are considered as normal for agricultural production. The trend of the concentration is in order of Zn>Ni>Cu>Pb>Cd. The ranges of the concentrations are as follows:(N.D-7.25), (N.D-0.17), (3.10-22.90), (1.00-9.70), (1.95-32.80) for Pb, Cd, Zn, Cu and Ni respectively. Generally, all the metals in the study sites recorded higher levels than the control sites. Metal-metal correlation was carried out using Pearson's product moments. Most elemental pairs show no significant correlation with each other. This revealed that each paired element has no common contamination sources.

The metal levels in the soils of the study area were generally lower than most metal levels in soils approved for agricultural purposes. This shows that the area would not impact negatively on metal levels in crops. The study has provided a baseline study in the metals concentrations in the soils of the area.

Keywords: Heavy metals; Agricultural soil; Kwali Area Council

1. Introduction

Human evolution has led to immense scientific and technological progress. Global development (industrialization), however, raises new challenges, especially in the field of environmental protection and conservation [1]. Nearly every government around the world advocates for an environment free from harmful contaminants. Ironically, it is the economic, agricultural and industrial developments that are often linked to the pollution of the environment [2]. Since the beginning of the industrial revolution, soil pollution by toxic metals has increased dramatically. The disposal of coal and wood ashes, industrial installations, and commercial products which corrode and decompose on land together account for about 55 to 80 percent of the pollution in soils [3].

Soil represent a major sink for metals released into the environment from a variety of anthropogenic activities such as agricultural practices, transport, industrial activities and waste disposal [4 5, 6]. Heavy metals are natural constituents of the Earth's crust but human activities have altered the balance and biochemical and geochemical cycles of some of them [5, 6]. Once in soil, some of these metals will persist in soils for a long time because of their fairly immobile nature leading to environmental pollution in aquatic systems [7]. Environmental risk due to soil pollution is of particular importance for agricultural areas because heavy metals, which are potentially harmful to human health, may enter the food chain in elevated amounts which may affect food quality and safety [4, 5, 8]. Thus, pollution of soils by heavy metals poses a threat to a country's food production. Heavy metal toxicity has an inhibitory effect on plant growth, enzymatic activity, stoma function, photosynthetic activity and also damages the root system [9].

Total metal content of soil is useful for geochemical purpose but their speciation (bioavailability) is of more interest agriculturally and this entails the identification and quantification of the different, defined phases in which the metals occur which can help assess how strongly they are retained in the soil. [6, 8, 10]. The different chemical forms in which they are present in soil influence their reactivity and hence their mobility and bioavailability [4, 6, 8]. Bioavailability of metals depends greatly on the characteristics of the particles surface, on the kind of strength of the bond and on the properties of the solution in contact with the solid samples. Metal ions in solids and sediments are partitioned between the different phase's present. In addition, metal ions are retained on these solid phases by different mechanisms (ion exchange, outer and inner-sphere surface complexation (adsorption), precipitation or co-precipitation). Sediment samples have been found as a carrier of most metals and some elements may be recycled through biological and chemical reactions within the water column. In soil, there is a concern to know the metal bioavailability and toxicity to plants, animals and man, the efficiency of the soil as a sink for metals and potential capacity of a metal to be mobilized from the soil [11]. There is a growing public concern over the potential accumulation of heavy metals in agricultural soils globally owing to rapid urban and industrial development and increasing reliance on agrochemicals in the last decades. Therefore, it is critical to clarify the status of agricultural soils and quantify their metal concentrations as well as ascertain the safety of the food that the land supports.

2. Methodology

2.1 Study area

Kwali is a local government in Abuja (Federal Capital of Nigeria). Kwali Area Council has a total land mass of about 1,700 square kilometers. The Area Council is situated at the South-Western part of FCT. It lies between latitude 8.87^{O} N and longitude 7.01^{O} E [12].

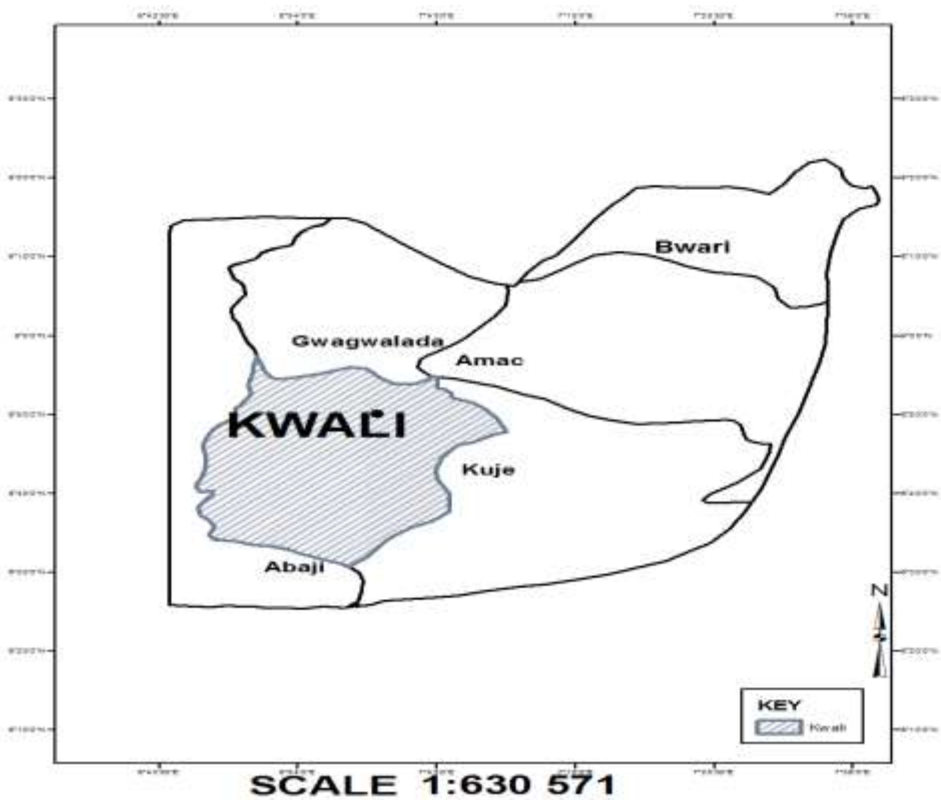

Figure 1: Map of six area councils in FCT showing Kwali.

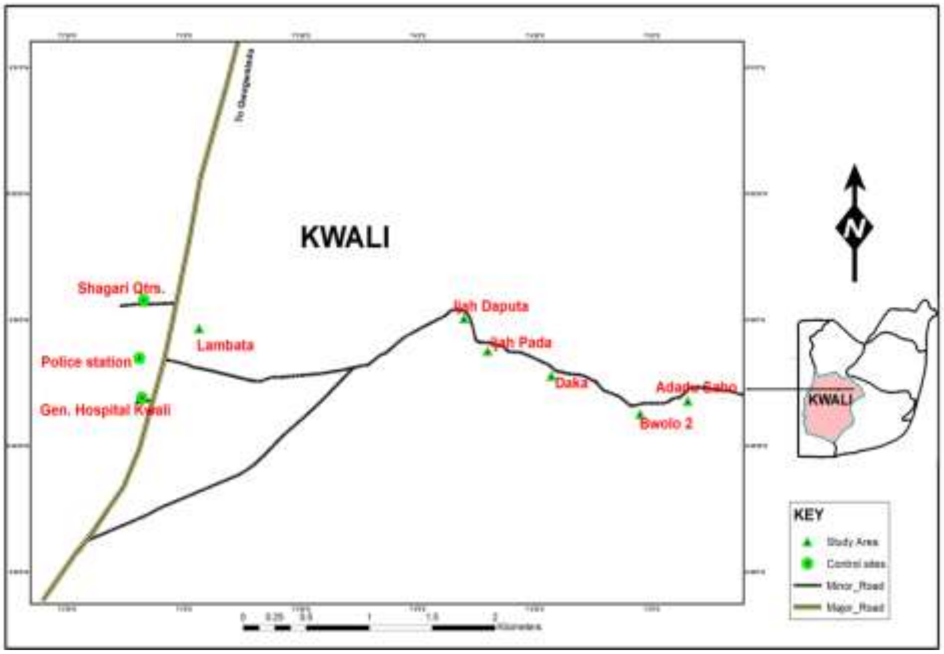

Figure 2: Map of Kwali area council showing the sampling locations.

2.2 Sample collection and preservation

Soil samples were collected from some twenty- one sites of Kwali Area Council of Abuja. Control soil samples were obtained from locations in the area which are not used for agriculture. The soil samples (0-15cm dept) were collected from the vicinity of the farms at 50 meters' interval. Three samples were collected from each site at a distance of about 4m by 4m in a triangular form using a stainless steel knife and poured into polythene bags labelled with site locations. The soil samples were air-dried for 72 hrs, ground in a mortar and passed through <2mm sieve and stored in clean acid treated polythene bags [13]. A description of the sampling sites is listed in (Table 1).

S/N	Areas	Code	Address of the sample sites
1.	Lambata	La_1	Lambata site 1
2.	Lambata	La_2	Lambata site 2
3.	Lambata	La_3	Lambata site 3
4.	Daka	Da_1	Daka site 1
5.	Daka	Da_2	Data site 2
6.	Daka	Da_3	Daka site 3
7.	Ijah Daputa	ID_1	IjahDaputa site 1
8.	Ijah Daputa	ID_2	IjahDaputa site 2
9.	Ijah Daputa	ID_3	IjahDaputa site 3
10.	Bwolo	Bw_1	Bwolo site 1
11.	Bwolo	Bw_2	Bwolo site 2
12.	Bwolo	Bw_3	Bwolo site 3
13.	Ijah Pada	IP_1	IjahPada site 1
14.	Ijah Pada	IP_2	IjahPada site 2
15.	Ijah Pada	IP_3	IjahPada site 3
16.	Adadu Sabo	AS_1	Adadu Sabo site 1
17.	Adadu Sabo	AS_2	Adadu Sabo site 2
18.	Adadu Sabo	AS_3	Adadu Sabo site 3
19.	Control	CTL_1	Back of Gen Hospital
20.	Control	CTL_2	Back of Police Station
21.	Control	CTL_3	Shagari Quarters

Table 1: Identification of sampling sites.

3. Experimental

3.1 Reagents used for analysis

All reagents used were of analytical grade manufactured by BDH, England. They were not subjected to any further purification before use.

3.2 Sample preparation

The methodology reported by [14] with slight modification was used in the preparation of the samples for metal determination. 5.0g of sample was weighed into a 250cm^3 beaker. 18.0 cm^3 of aqua regia (HNO_3 and HCl) were added to each sample. Each beaker was covered with a watch glass and digestion carried out on a hot plate in a fume chamber for about an hour. The beaker was allowed to cool. The digests were then filtered and washed into a 25 cm^3 volumetric flask and diluted to volume with distilled deionized water. The digests were then analysed for the heavy metals by Flame Atomic Absorption Spectrophotometer (FAAS) manufactured by Thermo scientific ICE 3000, AA02134104Vi.30. Determination of the pH of the soil samples was carried out using JENWAY 4330 laboratory pH meter manufactured by the Jenway instrument UK as described by Bashour and Sayeh [15].

4. Results and Discussion

S/No	Sample Code	Pb	Cd	Zn	Cu	Ni	Ph
1.	Lai	ND	ND	5.85	2.68	28.50	6.15
2.	La_2	4.95	ND	4.10	3.30	32.80	6.24
3.	La_3	ND	ND	3.48	1.00	6.30	6.24
4.	Da_1	4.50	ND	12.25	6.60	18.00	5.70
5.	Da_2	6.50	0.17	18.75	7.30	1.95	6.45
6.	Da_3	7.25	ND	11.05	6.90	2.50	5.53
7.	ID_1	ND	0.13	5.25	3.30	3.30	6.10
8.	ID_2	ND	0.07	4.00	4.55	3.00	6.71
9.	ID_3	ND	0.07	3.50	3.45	3.00	6.07
10.	Bw_1	5.25	ND	5.25	6.75	2.90	6.61
11.	Bw_2	3.25	0.07	5.63	4.00	2.20	6.30
12.	Bw_3	3.25	0.13	8.00	4.90	3.00	5.97
13.	IP_1	7.25	0.17	22.90	9.70	3.70	6.95
14.	IP_2	7.25	ND	12.30	7.70	4.68	6.76
15.	IP_3	5.75	0.07	7.60	6.90	3.36	6.07
16.	AS_1	4.95	0.13	8.10	4.25	2.75	5.54
17.	AS_2	5.50	0.13	10.00	7.90	4.90	5.70
18.	AS_3	6.15	0.17	3.10	5.35	3.60	5.63
19.	CTL_1	3.88	0.17	7.00	4.00	1.25	6.54
20.	CTL_2	3.88	ND	8.50	4.25	3.40	5.58
21.	CTL_3	4.75	0.13	6.80	5.70	4.65	6.61

Table 2: pH and heavy metal concentration (µg/g) in the agricultural soil from the various sampling points.

Area (location)	Value	Pb	Cd	Zn	Cu	Ni	pH
Lambata	Range	ND- 4.95	ND	3:48-5.85	1-3.30	6.30-32.80	6.15-6.24
	Mean	1.65	ND	4.47	2.32	22.53	6.21
Daka	Range	4.50 – 7. 25	ND – 0.17	11.05-18.75	6.60-7.30	1.95 -18.00	5.53 – 6.45
	Mean	6.08	0.05	14.01	6.93	7.48	5.89
Ijah Daputa	Range	ND	0.07 – 0.13	3.50-5.25	3.30-4.55	3-3.30	6.07-7.17
	Mean	ND	0.09	4.25	3.76	3.10	6.29
Bwolo	Range	3.25-5.25	ND-0.13	5.25 – 8.00	4.00 – 6.75	2.20-3	5.97-6.61
	Mean	3.91	0.06	6.29	5.21	2.70	6.29
Ijah Pada	Range	5.75 – 7.25	ND – 0.17	7.60 – 22.90	6.90 – 9.70	3.36 – 4.68	6.07 – 6.95
	Mean	6.71	0.08	14.26	8.10	3.91	6.59
Adadu Sabo	Range	4.95-6.15	0.13 – 0.17	3.10 – 8.10	4.25 – 7.90	2.75 – 4.90	5.54 – 5.70
	Mean	5.53	0.14	7.06	5.80	3.75	5.62

Table 3: Statistical summary of pH and heavy metal concentration (µg/g) in each location in the study area.

	Soil Sample		**Control Soil**	
Metal	**Mean ±std deviation**	**Range**	**Mean ±std deviation**	**Range**
Pb	3.98±2.21	ND-7.25	4.17 ± 0.50	3.88-4.75
Cd	0.07± 0.02	ND – 0.17	0.10 ± 0.07	ND – 0.17
Zn	8.39 ± 4.57	3.10 22.90	7.43 ± 0.92	6.80 - 7.00
Cu	5.35 ± 2.09	1.00- 9.70	4.65 ± 0.91	4.00- 5.70
Ni	7.24 ± 7.67	1.95-32.80	3.1 ± 1.71	1.25-4.65

Table 4: Statistical Summary of the Results of Heavy Metal Concentration (µg/g) in the Agricultural Soils of the Study Area and the Control.

4.1 Metal levels in the soils

The Metal Levels in the Soils are Summarized in Table 2. In agricultural soil of Kwali Area Council, apart from Cd and Pb the concentrations of the metals in the study area were found to be higher than the concentrations of the metals in control soils (Table 2). This has further revealed that the agricultural activities in the study area have had an impact on the levels of these metals. The mean abundance of the metals in the soils of Kwali is in the order Zn>Ni>Cu>Pb> Cd (Table 4).

4.1.1 Lead: The Pb concentration from the study area ranged from N.D- 7.25 µg/g dry weight (Table 4). The mean value recorded was 3.98±2.21µg/g dry weight and the highest concentration of 7.25 µg/g dry weight was recorded in both Daka and Ijah Pada (Table 2). The lowest concentration was found in Bwolo with a concentration of 3.25 µg/g dry weight. (Table 2). No lead levels were found in the soils of Ijah Daputa. (Table 2).

The Lead mean concentration showed that atmospheric fallout, fertilizers and peat could be likely sources of Pb in these soils [16]. Thus, the natural Pb content of soil is inherited from the parent rocks. However, due to widespread Pb pollutants most soils are likely to be enriched in this metal especially in top horizons [17]. Qnder et al. [18] in a similar study reported that the addition of artificial fertilizer and pesticides causes an increase of lead levels in agricultural soil.

4.1.2 Cadmium: The Cd concentration from the study area ranged from N.D-0.17µg/g dry weight with a mean concentration of 0.07 ± 0.02 µg/g dry weight (Table 4). The highest concentration of Cd from the study area was 0.17 µg/g dry weight, this was recorded in Daka, Ijah Pada and Adadu Sabo while Ijah Daputa, Bwolo and Ijah Pada also recorded the lowest concentration of 0.07 µg/g dry weight. No Cadmium levels were found in the soils of Lambata (Table 2).

The concentration of Cadmium in the study area shows little or no difference when compared with the levels of the control sites. The sources of Cadmium from this study area could be attributed to natural sources, atmospheric deposition and fertilizer application [19]. Among many other factors, the chemical composition of the parent rock as being determined as the main factor determining the Cd content of soil, and the average content of Cd in soil lies between 0.07ppm to 1.1ppm [20].

4.1.3 Zinc: The Zn concentrations from the study area ranged from 3.10 – 22.90 µg/g dry weight with a mean concentration of 8.39 ± 4.57 µg/g dry weight (Table 4). The highest concentration of zinc 22.90 µg/g dry weight was recorded in Ijah Pada while the lowest concentration of 3.10 µg/g dry weight was found in Adadu Sabo (Table 2).

Zinc sources recorded in the study area could be attributed to wastes from animal husbandry, impurities in fertilizers, peat, wood ashes and atmospheric fallouts [16]. Several researchers such as Andreu and Gimeno [21] as well as Alloway and Ayres [22] had stated that agricultural chemicals or materials such as impurities in fertilizers, pesticides and wastes from intensive poultry production constitute the very essential non-point sources of metal pollutants such as Zinc in soils.

4.1.4 Copper: The Cu concentrations from the study area ranged from 1.00 – 9.70 µg/g dry weight with a mean concentration of 5.35 ± 2.09µg/g dry weight (Table 4). The highest concentration of copper 9.70 µg/g dry weight was recorded in Adadu Sabo while the lowest concentration 1.0 µg/ dry weight was found in Lambata (Table 2).

The Copper mean concentration may also be traced to the use of agricultural and animal waste, disposal of wood ashes, application of sewage and organic waste, fertilizer and peat [16]. Some local or incidental Cu input to soils may arise from corrosion of Cu alloy construction materials (e.g electrical wires, pipes).

The major sources of Cu pollution present halos in which Cu concentrations in soils decrease with distance which is especially pronounced in a down ward direction [17]. Soil Cu content differs according to the soil type and pollution sources. Kabata-Pendias and Gondek [23] have reported that the normal content of Cu in plants ranges from 2 to 20 ppm, but in most plants the normal Cu content is in a narrower range of 4-12 ppm.

4.1.5 Nickel: Nickel concentrations in the study area ranged from 1.95 – 32.80 µg/g dry weight with a mean concentration of 7.24 ± 7.67 µg/g dry weigh (Table 4). The highest concentration of Nickel 32.80 µg/g dry weight was recorded in Lambata while the lowest concentration of1.95 µg/g dry weight was found in Daka (Table 2). The Nickel mean concentration may be ascribed to the use of agricultural and animal waste, disposal of wood ashes, fertilizer and peat [16].

Nielsen, et al. [24]. in a similar study on agricultural soils reported that nickel content in the soil could be attributed to the natural source, application of sludge and phosphate fertilizer. Nickel toxicity is generally seen in soil irrigated with waste water. Nickel recently has become a serious pollutant that is released in the emission from metal processing operations and from the increasing combustion of coal and oil [17]. Nickel is absorbed easily and rapidly by plants. The critical level for Ni in soil is around 2.0-50 ppm [9].

4.2 pH of soil

The highest soil pH was recorded in ljah Pada with pH of 6.95 while the lowest soil pH was recorded in Daka with a pH value of 5.53 (Table 2).

4.3 Correlation

4.3.1 Pearson correlation matrix: (Table 5) shows the correlation matrix, lower triangle listing the Pearson's product moments correlation co-efficient as calculated from (Table 2).

Area (location)	Pb	Cd	Zn	Cu	Ni
Pb	1	-	-	-	-
Cd	-0.037	1	-	-	-
Zn	0.214	-0.058	1	-	-
Cu	0.209	-0.040	0.17	1	-
Ni	-0.078	0.09	-0.003	-0.105	1

Table 5: Correlation matrix, lower triangle.

Most elemental pairs showed no significant correlation with each other. This signify that each paired element has no common contamination sources.

4.3.2 Comparison with global mean concentrations: The Lead, Cadmium, Copper and Zinc levels in the study area were lower than levels reported for similar studies in Nigeria and other parts of the world (Table 6). The mean value for Nickel in all literature reviewed were found to be much higher than the Ni value obtained for this study, except for the soils of Niger and Keffi with values 1.9 and 6.02µg/g respectively (Table 6). This could be attributed to the use of agricultural and animal waste, sewage and organic waste and fertilizers and peat. [16].

Location	Parameters	Pb	Ni	Cd	Cu	Zn	References
Kwali, (2015)	Mean±SD Range	3.98±2.21 ND - 7.25	7.24±7.67 1.98-32.80	0.07±0.02 ND – 0.17	5.35±2.09 1.00-22.90	8.39±4.57 3.10-22.90	This Study
Niger (2012)	Mean±SD Range	18±7.5 7.7-30	1.9±0.96 ND-3.8	-	15±5.7 4.4-34	28±22 5.4 -106	[25]
Keffi (2012)	Mean±SD Range	12.74±0.51 11.80-13.50	6.02±0.42 5.50-6.40	0.76±0.05 0.70-0.84	9.74±0.05 9.00-10.40	16.02±0.50 15.00-16.60	[26]
Lagos (2004)	Mean±SD Range	21.0±1.0 20.0-22.0	37.0±2.0 35.0-38.8	-	33.6±0.7 32.5±17.5	289.7±14.7 273-301	[27]
Turkey (2004)	Mean±SD Range	28.1±7.9 20.2-36.0	96.6±67.3 26.8-16.1	1.7±1.0 1.0-2.8	35.5±17.5 20.4-54.4	140.1±86.6 70.3-237	[28]
Romania (1987)	Mean	25.21	32.07	0.07	-	-	[29]
France (1997)	Mean±SD Range	25.3±1.0 24.1-26.1	26.4±0.4 25.9-26.6	-	24.3±0.8 25.2-23.9	52.7±0.3 52.5-53.0	[30]
Thailand (2003)	Mean	30.20	54.80	0.79	22.30	85.20	[31]

Table 6: Comparison of mean concentrations (µg/g) in top agricultural soils of the study area with other places and regions of the world.

5. Conclusion

The levels of some heavy metals in the agricultural soils of Kwali Area Council were studied. The mean abundance of these metals studied is Zn> Ni> Cu>Pb> Cd. Most metals were not correlated to one another. The levels of metals were generally lower than the Maximum Acceptable Limits (MAL) of metals in soils showing that the soils of Kwali Area Council are suitable for agricultural purposes. The study showed pH variation from mildly acidic to near neutral point from the various locations with overall mean pH value of 6.15±0.35 which could be considered as normal for agricultural purposes. The assessment of the heavy metals Pb, Cd, Zn, Cu and Ni of the study area have revealed that the agricultural activities have had impact on the soils of the study area. This study has provided a baseline data or levels for heavy metals in agricultural soils of Kwali such as Cu, Zn, Cd, Pb and Ni.

Acknowledgments

My sincere praise is due to almighty God for his mercies, blessings and protection on me throughout this programme. My profound gratitude goes to my supervisor, Prof. S.E Kakulu for his patience, encouragement, constructive criticism and understanding in the course of this research work. Special thanks go to all the staff of Science and Technology Complex, Sheda, Abuja where I carried out most of the metal analysis especially to Dr Stella A. for her special assistance rendered to me during the course of the analysis. I would like to acknowledge the contributions of Dr Chris Obudu of Dept. of Vet. Medicine University of Abuja., Alex Echibe, Sir John Oru Eta, Barrister Peter Enya and Dr. Adedeji S. A. and to the memory of my loving mother who was ever supportive.

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