

Determination of Radionuclides in Designated Farmlands in Kaduna Metropolis using Sequential Extraction Procedure

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Abstract: The determination of radionuclides present in agricultural soils of some selected farmlands in Kaduna metropolis, Kaduna State, was carried out using sequential extraction technique prior to the use of Energy Dispersive X-ray Fluorescence. Thirty two (32) Radionuclides were found to be present in the soils with mobility factors ranging from 0% to 100%. The range of the physicochemical results varied from farmland to farmland with Angwan Maje (AM-groundnut farmland), Kamazo (KZO- maize farmland), Zango (ZO-vegetables farmland), Old Afaka (OA-fruits plantation/orchard) having satisfactory soil temperature of $29.88 \pm 1.06^\circ\text{C}$, $30.22 \pm 1.43^\circ\text{C}$, $33.20 \pm 0.20^\circ\text{C}$, and $36.40 \pm 0.48^\circ\text{C}$ respectively. The Electrical Conductivity values of the soils samples obtained were $9.56 \pm 6.21 \mu\text{s/cm}$, $6.1 \pm 1.39 \mu\text{s/cm}$, $22.1 \pm 5.35 \mu\text{s/cm}$ and $11.82 \pm 6.37 \mu\text{s/cm}$ respectively and were all lower than the permissible limits. pH values obtained are as follows; 5.88 ± 0.25 , 6.01 ± 0.03 , 6.54 ± 0.20 , 6.11 ± 0.30 respectively, this showed they were slightly acidic. Mean values of the Total Dissolved Solids; $4.78 \pm 3.14 \text{ mg/L}$, $3.06 \pm 0.71 \text{ mg/L}$, $11.26 \pm 2.41 \text{ mg/L}$, and $5.92 \pm 3.18 \text{ mg/L}$. Similarly, the nuclides of interest; Th, U, and Pb from AM, KZO, ZO and OA has a concentration range of $20.64\text{--}22.20 \text{ mg/L}$, $2.90\text{--}3.70 \text{ mg/L}$, and $13.30\text{--}34.59 \text{ mg/L}$ respectively. The results showed that U was within the permissible limits in Old Afaka but above the permissible limits in other farmland soils. Th was above the permissible limits in all soils which can be as a result of the low pH, High Electrical Conductivity, High Total Dissolved Solids and High Mobility factor. This study has therefore been able to reveal the interplay of the physiochemical parameters and mobility factors of the nuclides from various locations which could be responsible for the levels and bioavailability to the soil.

Keywords: Speciation, Anthropogenic, Radionuclides, Energy Dispersive X-Ray Fluorescence (EDXRF)

I. INTRODUCTION

Soil pollution is one of the most serious problems in the world, with long term consequences. Radioactivity is the common phrase for radioactive decay which describes the Spontaneity of unstable atomic nucleus to transform into a stable state by emitting ionizing particles and radiation. An unstable nucleus is characterized by an uneven ratio of protons to neutrons and it remains radioactive until the ratio is balanced[1]. The study of radionuclides in agricultural soils is of general concern because, once in the soil, most of them can recycle within the biota, similar to nutrients. The natural and artificial radionuclides that are present in the environment are

the main sources of radiation exposure for human beings and constitute the background radiation level [2].

Radionuclides enter the soil through man-made activities, such as the fallout from atmospheric testing of nuclear weapons and radiological events like the Chernobyl accident. Deposition studies of these activities indicate that radioactive particles travel around the world on streams of air. The weight of the particle and weather determine how soon they fall to the ground. Sometimes a heavy rain will bring the radioactive particles to the ground quickly. Improper disposal of radioactive material also may contribute to radionuclides in the soil. Radionuclides in the soil can move into the water, air and even our food supply. Many different agencies are involved in setting standards and monitoring to keep us safe. [3].

The study of radionuclides in agricultural soils is of general concern because once in the soil, most of them can recycle within the biota, similar to nutrients. The study of radionuclides in soils are very important especially agricultural soils, because soil is the first link in the food chain similar to nutrients therefore it has a determining effect on the radionuclides' translocation to plants and animals. The aim of the study is to determine the various radionuclides present in the agricultural soils, mobility factor and physiochemical parameters from selected farmlands in Kaduna South, Chikun Local government area of Kaduna using Sequential Extraction and Energy Dispersive X-ray Spectroscopy Techniques.

1.1. Theory of Sequential Extraction Procedure

The theory behind sequential extraction procedure (SEP) is that the most mobile radionuclides are removed in the first fraction and continue in order of decreasing mobility. Typically radionuclides of anthropogenic inputs tend to reside in the first four fractions and those found in the residual fraction are of natural occurrence in the parent rock [4]. Elements in various forms are analyzed (speciation) using sequential extraction in which the sample is subjected to successive treatment with selective leaching reagents. Aqueous solutions of reagents should mimic to some extent the natural conditions under which the elements are bound to the soil, sludge or sediment matrix is released. [5]

The aim of the study is to determine the radionuclides present in the agricultural soils, mobility factor and the physiochemical parameters from selected farmlands in

Kaduna-South, Chikun Local Government area of Kaduna using Sequential extraction and Energy Dispersive Xray Spectroscopy techniques.

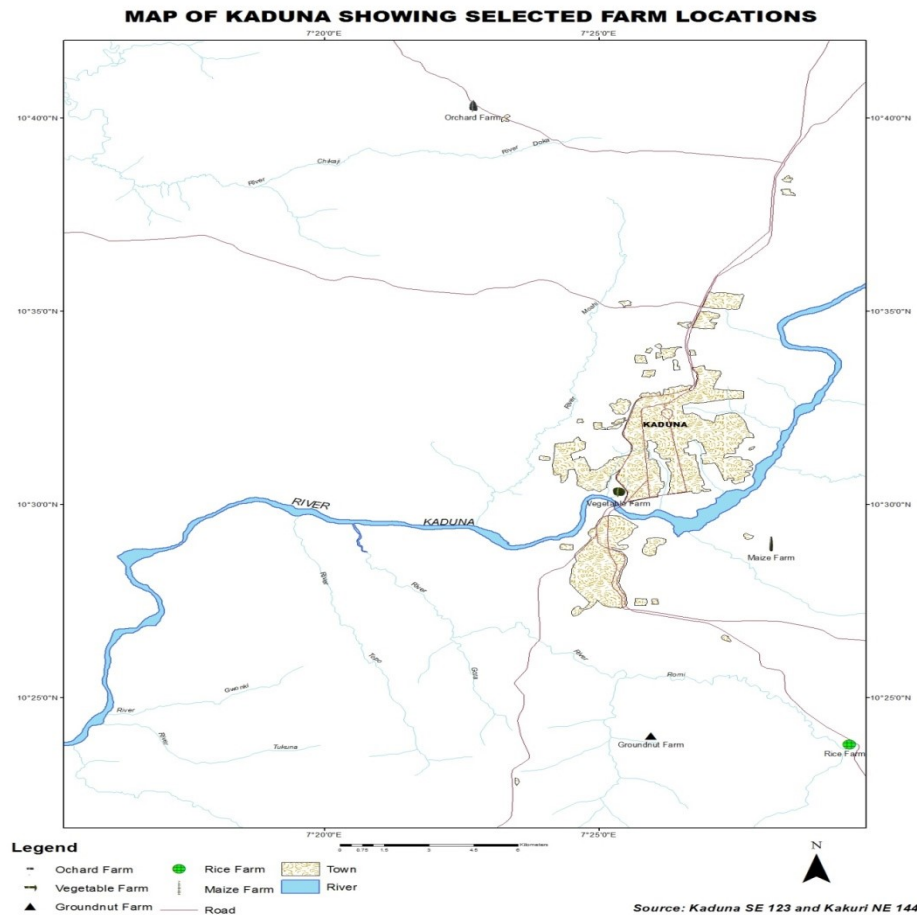


Fig 1.0 Map of Study Area

1.2. Description of Study Area

The study area is Kaduna metropolis, Kaduna is the state capital of Kaduna State in north-western Nigeria. The global location of Kaduna State is between latitude 9 and 14 north of the equator and longitude 7 and 10 east of the Greenwich meridian. It occupies a landmass of about 70,210 square kilometers on the map of Nigeria. Kaduna State has two distinct seasons. The dry season, lasts from November to Mid-April while the rainy season, which is cool and lasts between 5-6 months starts from mid-April. The State extends from the tropical grassland known as the Guinea Savannah to Sudan Savannah. Vegetation is thick and grasses about 3.6 meters tall with big trees, which grow shorter as one approaches the Sudan Savannah.

II. MATERIALS AND METHODS

2.1. Materials

The analytical glassware and instruments listed below were used in the course of this research.

conical flask (250 cm³), measuring cylinders (100 cm³), beakers (250 cm³), volumetric flasks (100 cm³, 250cm³, 500cm³, 1000cm³), test tubes (50 cm³, 100 cm³), syringes (1 ml, 5 ml), plastic sample bottles (100 cm³), Pipettes, ceramic pestle and mortar, polyethylene bags, Whatman No 40 filter paper and 1mm – 2 mm soil sieve.

Analytical Weighing Balance, Hot Plate (JENWAY), ED-XRF, pH meter (Nahita pH meter, Model 903), Orbital Flask Shaker (Bibby Stuart Scientific Orbital Shaker S01), HACH (Conductivity and TDS Meter) Model 44600, Water Bath Machine (Philip Harris SE 10), Centrifuge (Hettich Universal II).

The following Analytical reagents were used without further Purification:

Magnesium chloride (MgCl₂), sodium acetate (CH₃COONa), NH₂OH.HCl (hydroxylamine hydrochloride), acetic acid (CH₃COOH), hydrogen peroxide (H₂O₂), ammonium acetate (CH₃COONH₄), concentrated perchloric acid (HClO₄), concentrated nitric acid (HNO₃),

sodium hydroxide (NaOH), concentrated hydrogen fluoride (HF) and concentrated hydrochloric acid (HCl).

2.2. Sampling

A total of twenty (20) Soil samples were collected from four (4) different farmlands namely; Angwan Maje, Kamazo, Zango and Old Afaka in Kaduna Metropolis in the month of October, 2016. At each location, samples were taken from five different points at a depth of 0 – 30 cm with a soil auger. The farmlands co-ordinates were determined via the use of a GPS (Global Positioning System) meter and all the soil samples from the four different farmlands were stored in a polyethylene bag, labeled and transported to the laboratory for preparation and analysis respectively. (Agbaji et al., 2015)

Extraneous materials such as plant roots, stones and decaying organic matter were removed after which the pH of the soils was taken. The soil samples was then oven dried for 2-3 hours at a temperature of 105°C until water was completely removed from all soil samples and a constant weight obtained. The soil samples were then grounded into fine powder using a mortar and pestle, then sieved through a 1mm pore size mesh into a weighed beaker. The beakers containing the soil samples were weighed again to obtain the weight of all soil samples. The beakers were then covered with a paper tape to prevent the escape of gaseous radionuclides. The soil samples were stored properly in the laboratory for fourteen days to allow secular equilibrium to be established between the long-lived parent radionuclides and their short-lived daughter radionuclides.

2.3. Methodology

2.3.1 Sequential Extraction of Nuclides

The Sequential Extraction Procedure according to Vinod et al., 2013, and Li (2012) was used:

- a. *The Water Fractions (WF)*: Exactly Two (2 g) of the soil samples added into centrifuge tubes together with 20 cm³ deionized water. The pH of this soil solution was measured prior to extraction. Then the sample was placed on a shaker for 1 hour, centrifuged at 4500 rpm for 25 - 30 minutes. After centrifugation, the solution was then filtered through a 110 mm round filter paper and collected in 20 cm³ plastic bottles.
- b. *The Exchangeable fraction (EF)*: The residue obtained from the Water Fraction was transferred into a 100 cm³ and 40 cm³ of 1 mol per dm³ MgCl₂ solution at pH 7.0 was added, and agitated using a Stuart flask shaker for 1 hour. The mixture was filtered and made up to 50 cm³ volume with distilled water.
- c. *The Carbonate Fraction (CF)*: The soil sample residue from exchangeable fraction was leached with 40 cm³ of 0.1 mol per dm³ of Sodium acetate (adjusted to pH 5 with 1M acetic acid) and agitated for 5 hours using a Stuart flask shaker. After shaking,

the solution was filtered and made up to the mark with distilled water in a 50 cm³ volumetric flask.

- d. *The Easily Reducible Fraction (IRF)*: The residue from carbonate fraction was added with 50 cm³ of 0.04 mol per dm³ NH₂OH.HCl in 10 cm³ of 25% (v/v) acetic acid and heated for 6 hours in a thermostated water bath at a temperature of 96±2°C and the solution was stirred occasionally. The mixture was cooled, filtered and made up to 50 cm³ volume with distilled water and analysed.
- e. *The Organic Fraction (IRO)*: The residue from the easily reducible fraction was mixed with 15 cm³ of 0.02 mol per dm³ HNO₃ and 25 cm³ of 30% H₂O₂ and heated for 2 hours at 85 °C with intermittent agitation in a thermostated water bath. After cooling, 25 cm³ of 3.2 mol per dm³ CH₃COONH₄ was added in 20% (v/v) acetic acid and transferred to the mixture and agitated continuously at room temperature for 30 minutes. After each successive extraction, the samples were centrifuged at 4500 rpm for 20 minutes. The solution was filtered with Whatman no 40 filter paper and made up to the mark in a 50 cm³ volumetric flask with distilled water.
- f. *The Residual Fraction (RF)*: The residue from the organic fraction was washed with distilled water and the supernatant discarded. Then 5 cm³ Concentrated HF and 10 cm³ Concentrated HClO₄ were added to the residue and the sample heated in a hotplate. The digest was then filtered and the filtrate analysed for the residue bound metals ions. All filtrates was analysed using Energy Dispersive X-ray Fluorescence (ED-XRF). [6]

2.4. Preparation of Stock Reagents

The stock reagents were prepared as follows:

a. 0.25M Ammonium Acetate (CH₃COONH₄)

Ammonium Acetate Solution was prepared by dissolving 19.25 g of Ammonium acetate in a 1000 cm³ volumetric flask already filled with 500 cm³ of distilled water and made up to mark with distilled water.

b. 0.04M Hydroxylamine Hydrochloride (NH₂OH.Hcl)

Hydroxylamine Hydrochloride was prepared by dissolving 02.78 g of hydroxylamine hydrochloride in a 250 cm³ beaker containing 200 cm³ distilled water and transferred to a 1000 cm³ volumetric flask and diluted to the mark with distilled water.

c. 25% Acetic Acid (CH₃COOH)

Acetic acid was prepared by adding 25 cm³ of concentrated acetic acid in a 100 cm³ volumetric flask containing 50 cm³ distilled water and made up to the mark with distilled water.

d. 7M HNO₃

HNO₃ was prepared by adding 109.71 cm³ of concentrated nitric acid in 250 cm³ volumetric flask containing 100 cm³ distilled water and made up to the mark with distilled water.

2.5 Measurement of Physicochemical Parameters

Physicochemical parameters are indicators of pollution characteristics of a system. The following were determined: pH, Temperature, Electrical conductivity (EC), and Total Dissolved solids (TDS)

2.5.1 Determination of Soil pH and Temperature

Two (2 g) of each air-dried 1mm sieved soils was weighed into 250 cm³ beakers and 50 cm³ of distilled water was added. The electrode of the pH meter and thermometer was then inserted into the supernatant liquid and the readings were recorded [7].

2.5.2 Determination of Soil Electrical Conductivity and Total Dissolved Solids

Two (2 g) of each air-dried sieved soil was weighed into a 250 cm³ conical flask and 20 cm³ of distilled water was added and the mixture stirred. The electrode of the conductivity meter was inserted into the supernatant to read the value of the conductivity and the total dissolved solids of the soil [7].

2.6 Data Treatment (Minitab 18)

The results obtained from this study underwent both statistical and comparative analysis. The mean, standard deviation, Pearson correlation matrix and analysis of variance (ANOVA) statistical tool were implored in this study, so as to calculate the average concentrations in the above stated analysis. The standard deviation was used to calculate the precision of the

mean and the probable error of a single concentration from the average concentration. The ANOVA was used to test the hypothesis of the results from different factors and to show if either there is a significant different or not in their relationship. The World Health Organisation (WHO) recommended standards and other food regulatory agencies such as the National Environmental Standards and Regulations Enforcement Agency (NESREA) was used in this study. Natural background concentrations of the element nuclides and also radionuclides were used in determining the extent of anthropogenic input by excessive concentrations of the elements in the analysed soils.

2.6.1. Mobility Factor

The mobility of radionuclides in soil samples may be assessed on the absolute and relative content of fractions weakly bound to soil components. The relative index of metal mobility was calculated as ‘mobility factor’ [8]; [9]; [10] as cited in Yusuf, 2007) on the basis of the following equation:

$$MF = \frac{F1 + F2 + F3 + F4}{F1 + F2 + F3 + F4 + F5 + F6} \times 100$$

F1 represents the water fractions (WF), F2 represent the exchangeable fractions (EF), F3 represents the carbonate fraction (CF), F4 represent the easily reducible fractions (IRF), F5 represents the organic fractions (IRO), while the F6 represent the residual fractions (RF) respectively.

III. RESULTS AND DISCUSSIONS

The Physicochemical parameters are indicators of pollution characteristics of a system. The physiochemical results from the sampling sites is presented in table 2.0.

Table 2.0: The Results of the Physicochemical parameters obtained from the Study locations.

Variable	Locations	Mean	SE Mean	StDev	CoefVar	Median	% RSD
Temperature	AM	29.84	0.46	1.036	0.03	30.20	3.47
	KZO	30.23	0.52	1.28	0.04	30.30	4.73
	ZO	33.20	0.09	0.20	0.01	33.10	0.60
	OA	36.40	0.22	0.49	0.01	36.20	1.35
Ph	AM	5.89	0.11	0.26	0.05	6.01	4.26
	KZO	6.01	0.01	0.04	0.01	6.03	0.59
	ZO	6.60	0.10	0.20	0.03	6.51	3.16
	OA	6.112	0.1351	0.302	0.05	6.21	4.94
Electrical Conductivity(µs/cm)	AM	9.56	2.78	6.22	0.65	8.00	
	KZO	6.10	0.63	1.393	0.23	5.6	22.83
	ZO	22.10	2.40	5.36	0.24	21.5	24.25
	OA	11.82	2.85	6.37	0.54	10	53.9
Total Dissolved Solids (mg/L)	AM	4.78	1.41	3.14	0.66	4.00	65.72
	KZO	3.06	0.32	0.72	0.23	2.8	23.41
	ZO	11.26	1.08	2.41	0.21	10.8	21.43
	OA	5.92	1.43	3.19	0.54	5.10	53.83

3.1 Temperature

The temperature of the soil is the most important property of the physio-chemical parameters because it shows its effect on the chemical, physical and biological processes released to growth of plants. The temperatures of the soil samples obtained from the five sampling points AM1 – AM5 in the Angwan Maje farmland area ranged from **28.00– 30.50°C** with a mean value of $29.88 \pm 1.06^\circ\text{C}$. According to [11] the optimal soil temperature for good germination, vegetative and reproductive growth of food crops especially groundnut is $24^\circ\text{C} - 30^\circ\text{C}$, as low temperature at the time of sowing of plant seeds delays germination and increases the likelihood of seed and seedling diseases and infestation by sucking pest.. The corresponding mean temperature obtained in the Angwan Maje farmland, where groundnut crop is its major food crop corresponds with the soil temperature as reported by the researchers above. This shows that the soil temperature in the Angwan Maje sampling points falls within the optimal temperature needed for the cultivation & growth of groundnut plants in the farmland.

Similarly, Temperature of soil samples from Kamazo farmland where maize is cultivated ranged from $28.00 - 30.50^\circ\text{C}$ with a mean value of $30.22 \pm 1.43^\circ\text{C}$ which corresponds with the [12] temperature regulation for maize production. The regulatory body stated that maize crop found it difficult to grow in areas, where the mean daily temperature were less than 19.00°C and where the mean of the summer months were less than 23.00°C . They also stated that soil temperatures from 32.00°C and above were detrimentally to the growth and germination of maize seeds. [13] also highlighted that soil temperatures ranging from $24.00– 30.00^\circ\text{C}$ were highly suitable for growth of maize, while temperature below 15.00°C and above 35.00°C were not suitable; hence, the soil temperature recorded at Kamazo for the growth of maize was suitable and Satisfactory.

Zango farmland had vegetables crops such as spinach, garden egg, tomatoes and okra growing in them with soil temperatures ranging from $33.10-33.50^\circ\text{C}$ with a mean value of $33.20 \pm 0.20^\circ\text{C}$. The soil temperature however didn't fit into the recommended temperatures for satisfactory growth of the listed food crops as stated by researchers below. [14] stated that soil temperatures above the room temperatures weren't favourable for optimum growth for vegetables like tomato, which tend to do better at temperature below 25.00°C . They also iterated that day time temperature rises above 35.00°C and night-time temperatures above 30.00°C were among the many factors, why tomato flowers don't bear fruits. [15] also reported that tomatoes grown at a minimum and maximum temperature ranging from $29.00^\circ\text{C} - 38.00^\circ\text{C}$ did not produce the necessary yield as expected, as the crop was known to grow very well at cool temperature especially during the harmattan period especially in the northern region of Nigeria. However the soil temperature for the growth of spinach, garden eggs and okra tends to be favourable for its optimum

growth as it corresponds with temperature reported by [16]; [17]; [18]

The soil temperature ranging from $35.80– 37.00^\circ\text{C}$ in Old Afaka farmland tends to favour the crops grown in that area such as pawpaw, mango, cashew and banana; as the temperature correlates with soil temperature values as reported by [19] and [20]

3.2. pH

The pH value of the soil sample obtained from Angwan Maje farmland ranged **from 5.47 - 6.08** with a mean value of 5.88 ± 0.25 . Soil pH values from soil samples in Kamazo Farmland ranged from 5.96 - 6.04 with a mean value of 6.01 ± 0.03 while that of Zango farmland ranged from pH values ranging from 6.33 – 6.78 with a mean value of 6.54 ± 0.20 and Old Afaka soil samples pH values ranging from 5.69 - 6.43 with a mean value of 6.11 ± 0.30 . The pH values of all the soil samples were slightly acidic in nature.

The pH values of all the soil samples were slightly acidic in nature as recorded in Table 2.0. However, the reported pH values in this research tend to be different from other farmlands in Kaduna metropolis as Mohammed and Ayodele (2011) reported pH mean value ranging from 4.60 – 5.38 from Kabala west, Nasarawa, Mando, Kakuri, Tudun Wada, Sabo Tasha, Ungwan Muazu and Kachia. The authors attributed the low acidic pH values observed in his research to various and natural and anthropogenic activities within the sampling locations. [21] highlighted that soil pH between 5.50 - 7.00 were best for the optimum growth of plants, while pH values below 5.50 could make the soil more acidic and not considered favorable for plant growth as nutrients tend to be less bioavailable in lower pH values.

3.3. Electrical Conductivity

Analysis of the soil EC in soil samples from Angwan maje farmland revealed that the EC values ranged from $4.3-19.9 \mu\text{s}/\text{cm}$ with a mean value of $9.56 \pm 6.21 \mu\text{s}/\text{cm}$. For the Kamazo farmland, the EC values ranged from $5.0-8.2 \mu\text{s}/\text{cm}$ with a mean value $6.1 \pm 1.39 \mu\text{s}/\text{cm}$. Zango farmland had a EC value which ranged from $29.9 - 16.8 \mu\text{s}/\text{cm}$ with a mean value of $22.10 \pm 5.35 \mu\text{s}/\text{cm}$ while Old Afaka Farmland had EC values which ranged from $5.8 - 21.5 \mu\text{s}/\text{cm}$ and mean value of $11.82 \pm 6.37 \mu\text{s}/\text{cm}$. The EC values revealed that the soil profile of the farmlands were sandy as regards to their low conductivity value as soils with a high clay content has more total pore space and can easily conduct electricity than sandier soils.

3.4. Total Dissolved Solids

TDS is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular suspended form, which must be small enough to fit through a 2-micrometer filter. The analysed TDS result in all the sampled soil in the four farmlands were very low and positively corresponds with the recorded EC values in Table 4.1. The results of the ANOVA analysis on the TDS

values showed that there is indeed a significant difference ($P \leq 0.05$) in the TDS values amongst the sampled soils in the four farmlands in Kaduna metropolis.

The TDS value in the sampling point of Angwan Maje farmland ranged from 2.1 – 10 mg/L with a mean value of 4.78 ± 3.14 mg/L while that of Kamazo farmland ranged from 2.5-4.2 mg/L with a mean value of 3.06 ± 0.71 mg/L. Zango farmland ranged from 8.5 mg/L – 14.80 mg/L with a mean of 11.26 ± 2.4 and Old Afaka Farmland recorded a pH range of 5.69 – 6.43 mg/L with a mean of 6.11 ± 0.30 mg/L. The analysed TDS result in all the sampled soil in the four farmlands were very low and positively corresponds with the recorded EC values in Table 4.1. Various researches have shown that an increase in the EC will directly lead to an increase in the TDS and vice versa. This statement was however clarified by [22] who reported EC values from 253-455 mg/L from soils in Libya. The values ranging results of the ANOVA analysis on the TDS values showed that there is indeed a significant difference ($P \leq 0.05$) in the TDS values amongst the sampled soils in the four farmlands in Kaduna metropolis. Hence, the TDS values did not exceed the permissible limits according to [22].

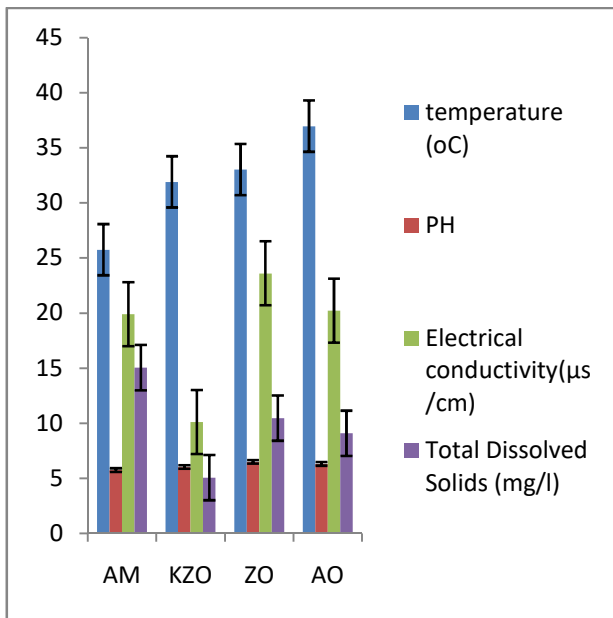


Fig 2.0 The Physiochemical Parameter results from four Sampled Soils in the four different farmlands.

Table 3.0 Angwan Maje Farmland Physico-chemical Correlation Matrix

	Temp	Cond(µs)	pH	TDS (PPM)
Temp	1			
Cond(µs)	0.022945	1		
pH	-0.22542	-0.96596	1	
TDS (PPM)	0.021591	0.999986	-0.96487	1

Table 3.1. Kamazo Farmland Physico-chemical Correlation Matrix

	Temp	Cond(µs)	pH	TDS (PPM)
Temp	1			
Cond(µs)	-0.07778	1		
pH	0.847272	0.367672	1	
TDS (PPM)	-0.07465	0.999893	0.366312	1

Table 3.2. Zango Farmland Physico-chemical Correlation Matrix

	Temp	Cond(µs)	pH	TDS (PPM)
Temp	1			
Cond(µs)	-0.64371	1		
pH	-0.43437	-0.23098	1	
TDS (PPM)	-0.54391	0.987774	-0.35911	1

Table 3.3 Old Afaka Farmland Physico-chemical Correlation Matrix

	Temp	Cond(µs)	pH	TDS (PPM)
Temp	1			
Cond(µs)	-0.69693	1		
pH	-0.82116	0.851832	1	
TDS (PPM)	-0.69173	0.999729	0.852882	1

3.5. Correlation Matrix of the Physicochemical Parameters amongst the farmlands

Correlation coefficient (r) between any two parameters, x & y is calculated for parameter such as soil temperature, pH, electrical conductivity and total dissolved solids of the sampled soils in the various farmlands. The degree of linear association between any two of the soil quality parameters as measured by the simple correlation coefficient (r) is presented in tables

- Angwan Maje:* The correlation matrix analysis as shown in Tables 3.0 – 3.3 which revealed that temperature had a low correlation with the pH and a low correlation with the TDS. Electro-Conductivity had a negative correlation with pH and a strong correlation with TDS, while pH had a negative correlation with TDS.
- Kamazo:* Temperature had a negative correlation with EC, a very strong correlation with pH and a negative correlation with TDS. EC has a positive correlation with pH and a strong correlation with TDS while the pH had a positive correlation with TDS.
- Zango:* Temperature had a negative correlation with EC, pH and TDS. EC had a negative correlation with pH and a strong correlation with TDS while the pH had a negative correlation with TDS.

d. *Old Afaka*: The correlation analysis result showed that temperature has a negative correlation with EC, pH and TDS. This result is similar to those observed in the Zango correlation result. EC had a strong correlation with pH and TDS while the pH had a strong correlation with TDS.

a strong positive correlation in the farmland analysis. This strong correlation could be as a result of the inter-relationship between the two factors, as an increase or decrease in the EC of the soil sample automatically leads to an increase/decrease in the TDS value. Kamazo farmland, showed a strong correlation with pH and in Angwan Maje farmland, it showed a very weak correlation with EC.

From the correlation matrix result on the physio-chemical activities from the farmlands, it revealed that EC and TDS had

TABLE 4.2 Showing the Summarized Nuclide concentrations and Mobility Factor from four sampled soils in four different farmlands

S/N	NUCLIDE	LOCATIONS				
		AM	KZO	ZO	OA	
1.	Cu	Total Nuclide Content	7.00 ± 0.70	22.70± 0.80	23.10± 0.70	16.89 ± 0.50
		Mobility Factor	63.50±3.00	68.12± 3.00	57.84± 3.00	87.40 ± 4.00
2.	Fe	Total Nuclide Content	13.50±0.40	8.40 ± 1.00	9.14 ± 0.70	24.6 ± 2.00
		Mobility Factor	61.30±3.00	52.20± 3.00	63.50± 0.70	24.79 ± 3.00
3.	Ni	Total Nuclide Content	6.58 ± 0.20	5.91 ± 0.20	9.67±1.00	6.07 ± 0.20
		Mobility Factor	61.56±0.50	80.30± 1.00	55.60± 0.10	40.90 ± 3.00
4.	Pb	Total Nuclide Content	29.88±1.00	34.59± 2.00	21.1 ± 2.00	13.30 ± 3.00
		Mobility Factor	49.50±3.00	87.93± 3.00	34.29± 0.40	75.50 ± 3.00
5.	Zn	Total Nuclide Content	16.20±0.20	0.70 ± 0.20	ND	1.50 ± 0.70
		Mobility Factor	66.40±1.40	93.50± 6.00	ND	98.61 ± 1.00
6.	Tl	Total Nuclide Content	12.60±0.30	3.40 ± 0.70	1.4 ± 0.01	4.45 ± 1.80
		Mobility Factor	100	100	100	100
7.	Au	Total Nuclide Content	17.60±1.80	33.60± 0.80	56.25 ± 2.0	3.83 ± 1.00
		Mobility Factor	83.90±2.00	54.65± 1.00	77.6 ± 1.20	97.67 ± 2.00
8.	Pt	Total Nuclide Content	11.90±2.00	3.08 ± 0.20	ND	11.40 ± 0.01
		Mobility Factor	60.50±3.00	100	ND	14.91 ± 0.01
9.	Ca	Total Nuclide Content	1.94 ± 1.00	ND	4.52 ± 0.10	5.80 ± 1.00
		Mobility Factor	89.41±2.00	ND	76.17± 1.50	85.80 ± 3.00
10.	Th	Total Nuclide Content	22.10±6.00	2.64 ± 0.20	ND	22.20 ± 2.00
		Mobility Factor	25.51±0.10	96.50 ± 3.0	ND	95.31 ± 4.00
11.	Br	Total Nuclide Content	6.02 ± 0.70	ND	ND	4.31 ± 0.70
		Mobility Factor	90.50±9.00	ND	ND	26.17 ± 0.01
12.	Os	Total Nuclide Content	3.78 ± 1.50	7.90 ± 0.50	3.3 ± 0.10	5.30 ± 1.00
		Mobility Factor	96.25±3.00	74.30± 1.80	31.03± 0.10	100
13.	Bi	Total Nuclide Content	5.07 ± 0.80	ND	9.4 ± 0.50	6.73 ± 2.00
		Mobility Factor	91.67±8.00	ND	100	100
14.	Si	Total Nuclide Content	2.35 ± 0.50	ND	15 ± 1.00	ND
		Mobility Factor	Nil	ND	100	ND
		Total Nuclide Content	6.16 ± 0.50	3.18 ± 0.20	2.80 ± 0.40	5.32 ± 0.80

15.	Se	Mobility Factor	78.8 ± 2.00	29.26 ± 0.1	95.90 ± 4.00	84.72 ± 3.00
16.	Re	Total Nuclide Content	18.62 ± 2.00	9.90 ± 0.60	13.80 ± 1.50	21.85 ± 1.00
		Mobility Factor	65.69 ± 3.00	38.22 ± 3.00	82.6 ± 2.00	58.18 ± 0.01
17.	Yb	Total Nuclide Content	1.95 ± 0.10	2.40 ± 0.80	3.40 ± 0.20	6.73 ± 0.50
		Mobility Factor	Nil	100	100	21.76 ± 2.00
18.	Hf	Total Nuclide Content	5.35 ± 3.00	ND	ND	20.70 ± 0.01
		Mobility Factor	94.25 ± 1.00	ND	ND	2.89 ± 0.01
19.	As	Total Nuclide Content	3.10 ± 1.00	0.87 ± 0.02	0.10 ± 0.01	1.40 ± 0.20
		Mobility Factor	100	100	100	4.31 ± 0.10
20.	Hg	Total Nuclide Content	2.40 ± 0.01	2.6 ± 0.01	ND	ND
		Mobility Factor	28.00 ± 0.01	100	ND	ND
21.	Ru	Total Nuclide Content	140 ± 6.00	110 ± 0.01	ND	185.00 ± 0.01
		Mobility Factor	61.75 ± 0.50	74.30 ± 1.80	ND	68.10 ± 0.01
22.	Ir	Total Nuclide Content	1.69 ± 0.20	3.3 ± 0.70	6.70 ± 0.70	5.4 ± 0.01
		Mobility Factor	100	100	100	100
23.	Rb	Total Nuclide Content	5.65 ± 1.00	9.00 ± 0.01	ND	0.73 ± 0.01
		Mobility Factor	100	100	ND	100
24.	Ag	Total Nuclide Content	ND	77.10 ± 2.00	18.50 ± 1.00	77.00 ± 0.01
		Mobility Factor	ND	100	47.94 ± 2.0	31.16 ± 0.01
25.	Ga	Total Nuclide Content	ND	3.2 ± 1.0	ND	ND
		Mobility Factor	ND	100	ND	ND
26.	Sr	Total Nuclide Content	ND	4.05 ± 1.00	ND	ND
		Mobility Factor	ND	100	ND	ND
27.	U	Total Nuclide Content	ND	3.70 ± 0.10	2.90 ± 0.01	ND
		Mobility Factor	ND	100	100	ND
28.	Sb	Total Nuclide Content	ND	0.78 ± 0.01	ND	9.60 ± 1.00
		Mobility Factor	ND	100	ND	52.90 ± 1.00
29.	Dy	Total Nuclide Content	ND		ND	ND
		Mobility Factor	ND		ND	ND
30.	K	Total Nuclide Content	ND	ND	3.30 ± 0.30	ND
		Mobility Factor	ND	ND	100	ND
31.	Ge	Total Nuclide Content	ND	ND	1.4 ± 0.01	ND
		Mobility Factor	ND	ND	100	ND
32.	Te	Total Nuclide Content	ND	ND	S 0.6 ± 0.02	ND
		Mobility Factor	ND	ND	100	ND
33.	Ti	Total Nuclide Content	ND	ND	0.40 ± 0.01	1.72 ± 0.50
		Mobility Factor	ND	ND	100	100

S/N	Nuclide	Mass No	Half-life	Standard Limits of radionuclides in Agricultural soils (EPA)	Locations	Conc. (mg/L)
1.	Th	232	14×10^9 yrs	1.29×10^{-9} - 8.09×10^{-10}	AM KZO ZO OA	22.10±0.01 20.64±0.20 ND 22.20±2.00
2.	U	238	4.5×10^9 yrs	1.63×10^{-11} - 5.74×10^{-10}	AM KZO ZO OA	ND 2.90±0.01 2.90±0.01 ND
3.	K	40	1.25×10^9 yrs	6.18×10^{-11}	AM KZO ZO OA	25.60±0.01 ND 3.30±0.30 ND
4.	Pb	210	5.3×10^4 yrs	2.66×10^{-9}	AM KZO ZO OA	29.88±1.00 34.59±2.00 21.10±2.00 13.30±3.00
6.	Ni	63	7.6×10^4 yrs	4.66×10^{-13} - 1.64×10^{-12}	AM KZO ZO OA	6.58±0.20 5.91±0.20 9.67±1.00 6.07±0.20

i. Thorium

The pH of a soil has a major effect on metal dynamics because it controls adsorption and precipitation, which are the main mechanisms of nuclide retention in soils. As pH decreases, the solubility of nuclides in the soil solution increases and therefore becomes more readily available to plants. The major factor that affects geochemical reactions associated with radionuclides and explains their mobility in soil is the pH value [23]; [24]. Thorium was found present in all the soil samples except Zango (ZO) farmland with Concentration of 22.10 mg/ kg, 20.64 mg/ kg, 22.20 mg/ kg; pH values of 5.88±0.25, 9.56±6.21, 6.11±0.33; temperature of 29.88±1.06, 30.20±1.43, 36.40±0.50; EC values 9.56±0.21, 6.10±0.39, 11.82±0.37; TDS values are 4.78±0.14, 3.06±0.71, 5.92±0.18 and the mobility factors 96.50±3.00, 90.51±0.10, 95.31±4.00 respectively in Angwan Maje, Kamazo and Old Afaka farmlands. The total Nuclide content of Th however ranged from 3.3-51.20 mg/ kg, these values were above the background concentration as recommended by [25].

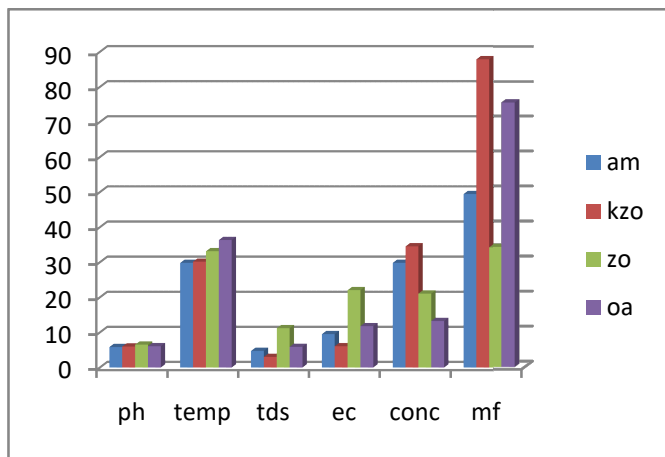


Fig 3: Plot showing the Effect of pH, Temp, TDS, EC on Thorium

From the above graph, it shows that farmland with the highest Th concentration is Old Afaka (22.20 mg/kg) which was followed by Angwan Maje (22.10 mg/kg), In 2001, [26] reported Th concentrations in soils worldwide at a range of 0.40 – 76.00 mg/kg. While [27] also reported Th concentrations ranging from 2.56 – 18.50 mg/kg for soils generally. This shows that the Th levels in all the farmlands are within the permissible limits.

ii. Uranium

High levels of uranium in soil enhance the chance of its assimilation and translocation in various parts of plants [28]. Solubility and mobility of U vary with soil characteristics and are influenced by pH, soil temperature, Total Dissolved Soils and Electrical Conductivity [29]. In this study, Uranium was only present in Kamazo and Zango Farmlands with concentrations of 3.70±0.10 mg/kg and 2.90±0.01 mg/kg respectively.

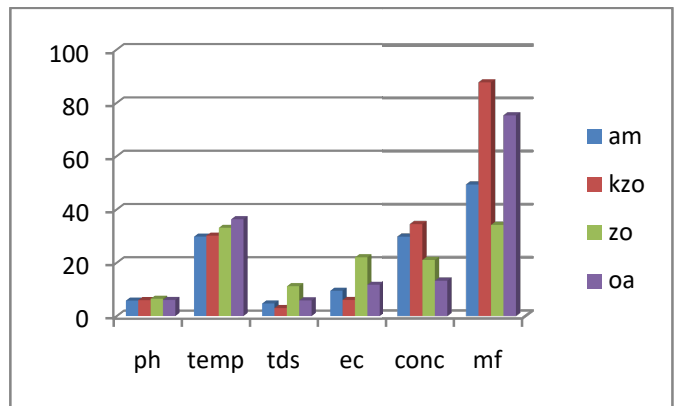


Fig. 4: plot showing relationship between the physiochemical parameters and Uranium Nuclide

According to the Canadian Council of Ministers of the Environment [30] both environmental and human health soil quality guidelines have been developed for four land uses:

agricultural, residential/parkland, commercial and industrial. Although WHO doesn't have any restricted limit for U nuclide in soils, recommendation given by CCME (Canadian Regulatory agency) based on Canadian Soil Quality Guidelines for the protection of environmental and human health, the acceptable levels of U are 23 mg kg⁻¹ for agricultural land use and for residential/parkland land use, 33 mg kg⁻¹ for commercial land use, and 300 mg kg⁻¹ for industrial land use. Therefore, the level of U in agricultural soil in the study areas was low and more likely may not cause environmental health hazards to plant, livestock and human beings. The pH value is an important geochemical parameter and is anticipated to have a significant impact on uranium leaching, precipitation, and mobilization, because it can change uranium chemical forms in soil that have different mobility characteristics. Uranium is amphoteric, meaning that it can be mobilized at either high or low pH. [31].

iii. Lead (Pb)

Lead nuclides was present in all the farmland soils having concentrations of 29.88±1.00 mg/kg, 34.59± 2.00 mg/kg, 21.1 ± 2.00 mg/L, 13.30 ± 3.00 mg/kg with mobility factor of 49.50±3.00, 87.93± 3.00, 34.29± 0.40, 75.50 ± 3.00 for AM, KZO, ZO and OA respectively.

[32]) reported Pb concentrations in soils ranging from 17 – 157 mg/kg in heavy traffic roads in Kwara State, Nigeria and attributed its increase to emissions from automobile. Similarly, [33] reported Pb concentration in agricultural soil at 22.85 mg/kg in Tanzania. While [34] reported mean Pb value ranging from 14.75 - 16.14 mg/kg in soil samples from dumpsites and a control samples value ranging from 8.35 - 8.78 mg/kg. [35] reported that Pb values above 30 mg/kg were toxic and excessive for plants absorption and animal consumption. OA had the least concentration which was within the permissible limit while AM, KZO, and ZO were above the permissible limits. The increased Pb, nuclide concentrations might be caused by sources from automobile exhaust fumes, sewage effluents, runoff of wastes and atmospheric depositions owing to high vehicular traffic.

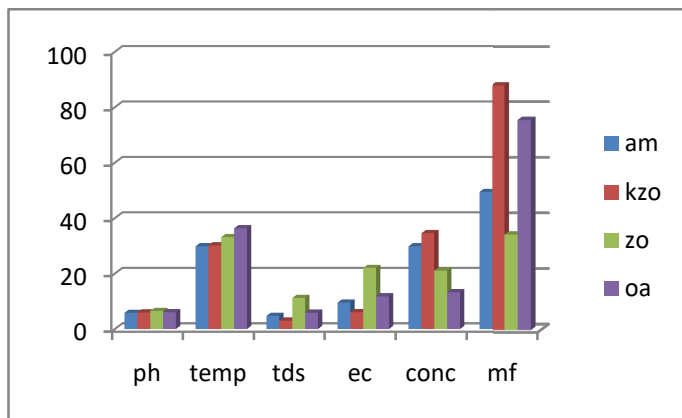


Fig. 5: plot showing relationship between the physiochemical parameters and Lead Nuclide

The mobility factors value of all the sampled soils were high and of a concern; as it means that the Pb nuclide was available, mobile and easily transported to the outer environment. Pb known as a toxic metal can be easily transported to the plants and easily consumed by animals.

IV. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The physico-chemical parameters results for the farmlands showed that the soil temperatures were optimal for plants growth except for tomatoes grown in Zango farmlands, which recommended soil temperatures were 25⁰C and below. The various sampled soils experienced low EC and TDS, while the pH was slightly acidic in nature. The speciation of the nuclides among the six geochemical phases revealed the presence of high percentages of the nuclides largely predominantly bonded in the non-residual fractions (water fractions, exchangeable fractions, carbonate fractions and easily reducible fractions) than the residual fractions (organic and residual fractions). The mobility factor percentage values showed that the most of the nuclides were most mobile and potentially available for plant uptake. The potential bioavailability of some of the nuclides in the various farmlands may pose some potential environment risk both to the plants and animals consuming the plants. The total nuclide content revealed that some nuclides such as Th, Au, Si, Se, Re, Yb, Hf, Os, As, Ag, Ir and Pt were either above the permissible limits for nuclides in farmlands or above the natural background concentration of the nuclides in soils while some others such as U, pb, etc were below the permissible limits.

4.2. Recommendations

The following recommendations should be instituted as a result of the observations as recorded in this study.

1. Phyto-remediation of soils should be employed in the planting of remediate plants to effectively absorb potentially available nuclides in the farmlands.
2. Farmlands should be situated in areas that do not have high vehicular and industrial activities.
3. Effective fertilizer application should be encouraged to increase essential elements needed for plant growth such as K, Na and K.
4. Proper monitoring of soil physio-chemical parameters, total nuclide concentrations and speciation of farmlands in Kaduna State should be encourage to curb plant toxicity by contaminated soils

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