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Major and Trace Elements Composition in *Guiera senegalensis* Plant from the Vicinity of a Kaolin Milling Plant in Alkaleri Bauchi State Nigeria Using Neutron Activation Analysis (NAA)

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Authors' contributions

This work was carried out in collaboration between all authors. Author AOA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ONM and HMM managed the analyses of the study. Authors IIN and PMD managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted to determine the concentration of major and trace elements in samples of *Guiera senegalensis* from the vicinity of a Kaolin milling plant in Alkaleri Bauchi State. Twenty four samples were collected (12 samples each in both dry and wet seasons) at different sampling points within the vicinity of the Kaolin milling plant. Neutron activation analysis (NAA), Nigeria Research Reactor-1 (NIRR-1) was used in the analysis of the samples. The results showed the mean concentrations of Ca as 7552.4±1884.6 mg/Kg in dry season and 6390±1720 mg/Kg in wet season, Mg as 2229.8±970.8 mg/Kg in dry season and 1015±56.7 mg/Kg in wet season, Na as 53.51±11.9 mg/Kg in dry season and 30.9±8.1 mg/Kg in wet season, K as 6453.5±2066.4 mg/Kg in dry season

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and 6113±4349.3 mg/Kg in wet season, Cu as 2.14±3.20 mg/Kg in dry season and concentrations in wet seasons were below detection limits, Mn as 805.5±448 mg/Kg in dry season and 839.5±695 mg/Kg in wet season, Fe as 171.3±99.3 mg/Kg in dry season and 224±116 mg/Kg in wet season, Zn as 21.14±11.8 mg/Kg in dry season and 11.62±5.02 mg/Kg in wet season, Co as 1.25±0.9 mg/Kg in dry season and 1.30±0.91 mg/Kg in wet season and V as 2.13±2.21 mg/Kg in dry season and concentrations in wet seasons were below detection limits. The concentration of the elements determined is in the order of Ca>K>Mg>Mn>Fe>Na>Zn>Cu>V>Co. The ANOVA test of significant showed the pair wise mean concentrations of elements between samples obtained in dry and wet season are significantly different in most sampling points for Mg, Na, K, Fe, Zn and V while Ca, Cu, Mn and Co showed no significant difference in most of their pair wise mean seasonal concentrations ($P < 0.05$).

Keywords: Major elements; Guiera senegalensis; Kaolin; NAA; milling plant.

1. INTRODUCTION

Guiera senegalensis, a shrub of the savannah re-gion of west and central Africa is widely used in traditional medicine for the remedy of many ailments/diseases. Its leaves extract is being used against dysentery, diarrhea, gastrointestinal pain and disorder, rheumatism and fever [1,2]. *Guiera senegalensis* is a shrub and can grow to a height of 3 to 5 m depending on the habitat [3,4]. *G. senegalensis* leaves are widely used in the treatment of pulmonary and respiratory complaints, coughs, as a febrifuge, colic and diarrhea, syphilis, beriberi, leprosy, impotence, rheumatism, diuresis and expurgation [5,6,4]. The plant has been found to contain carbohydrates, steroids, flavonoids, saponins, alkaloids, tannins and mucilage [7,2,4]. Calcium is essential in the formation of bones and teeth. Calcium is involved in vascular contraction, vasodilation, muscle function, nerve transmission, intracellular signaling and hormonal secretion [8]. Deficiency of serum Calcium affects one or more of these functions such as hypocalcemia has been linked to higher risk seizures due to its relationship with nerve transmission and intracellular signaling [8]. Magnesium is needed for more than 300 biochemical reaction in the body [9]. It helps to maintain normal nerve and muscles function, support a healthy immune system, keeps the heart beat steady and heals bones remain strong [9]. Defficiency of Mg in the body include hyperexcitability, muscular symptoms, fatigue, loss of appetite, apathy, poor memory and reduced ability to learn [10]. Mg plays important role in carbohydrate metabolism and its deficiency may worsen insulin resistance, a condition that often precedes diabetes, or may be a consequence of insulin resistance [10]. Sodium helps control blood pressure and regulates the function of muscles and nerves, which is why sodium concentrations are carefully controlled by the body. Low levels of sodium, called hyponatremia, can cause muscle spasms, cramps, headache, irritability, restlessness, nausea and fatigue [11]. WHO recommends a reduction in sodium intake <2 g/day sodium (5 g/day salt) in adults to reduce blood pressure and risk of cardiovascular disease, stroke and coronary heart disease in adults and the recommended maximum level of intake of 2 g/day sodium in adults should be adjusted downward based on the energy requirements of children relative to those of adults to control blood pressure in children [12]. Potassium is a main blood mineral electrolyte, others are Sodium and Chloride which carries a tiny electrical charge within the cell [13]. K along with Na regulates the water balance and acid-base balance in blood and tissue. K is very important in cellular biochemical reaction and energy metabolism; it participates in the synthesis of protein from Amino acid in the cell [13]. Deficiency of Potassium is much more common especially with aging or chronic disease. It may cause hypertension, congestive heart failure, Cardiac arrhythmia, fatigue, depression and other mood change [13]. Copper enzymes are widely distributed within the body; they perform several diverse functions including transport of oxygen and electrons, catalysis in oxidation reduction reactions and the protection of the cell against damaging oxygen radicals, at least ten enzymes are known to be dependent upon copper for their function [14]. Mn is an essential nutrient necessary for a variety of metabolic functions including those involved in normal human development, activation of certain metalloenzymes, energy metabolism, immunological system function, nervous system function, reproductive hormone function, and in antioxidant enzymes that protect cells from damage due to free radicals [15,16,17]. Mn also plays an essential role in regulation of cellular energy, bone and connective tissue growth, and blood clotting. Mn is an important cofactor for a variety of enzymes, including those involved in neurotransmitter synthesis and metabolism [18,17]. Iron functions as haemoglobin in the transport of oxygen [19]. Iron exists in the blood mainly as haemoglobin in the erythrocytes and as transferrin in the plasma [19]. It is transported as transferrin; stored as ferritin or haemosiderin and it is lost in sloughed cells and by bleeding [20,19]. Zinc plays a vital role in the maintenance of immune functions, including cellular and humoral immunity and zinc deficiency affects multiple aspects of innate and adaptive immunity [21]. Zn functions as a cofactor and is a constituent of many enzymes like lactate dehydrogenase, alcohol dehydrogenase, glutamic dehydrogenase, alkaline phosphatase, carbonic anhydrase, carboxypeptidase, superoxide dismutase, retinene reductase, DNA and RNA polymerase [19]. It is needed for tissue repair and wound healing, plays a vital role in protein synthesis and digestion, and is necessary for optimum insulin action as zinc is an integral constituent of insulin. It is an important constituent of plasma [19]. Cobalt is an essential element which occurs in both inorganic and organic forms. Organic form is essential and necessary for the human body but its excess or deficiency will influence it unfavourably, while the inorganic forms of cobalt present in ion form are toxic for the human body. Cobalt is a necessary component of vitamin B12 (hydroxocobalamin) and a fundamental coenzyme of cell mitosis. Moreover, cobalt is very important for forming amino acids and some proteins to create myelin sheath in nerve cells [21,22,23]. Cobalt also plays a role in creating neurotransmitters, which are indispensable for correct functioning of the organism [21,22,23]. The salts of cobalt stimulate the synthesis of erythropoietin, which is the most important function in the activation of different stages of erythropoiesis, which, in turn, is connected with the formation of erythrocytes in bone marrow [24,23]. Deficiency of cobalt is strongly related to disturbances in vitamin B12 synthesis, so it might cause anaemia and hypofunction of thyroid and increase the risk of developmental abnormalities and failure in infants [22,23]. However, excess of this metal might increase the action of thyroid and bone marrow, which might, in turn, lead to overproduction of erythrocytes, fibrosis in lungs, and asthma [25]. A functional role of simple vanadium compounds (vanadate in particular) in humans, is likely, an assumption which is based on the similarity between vanadate and phosphate, the vanadate-dependent haloperoxidases are of particular interest since they mimic, or model, enzymes involved in phosphate metabolism, where the protein binding domain for phosphate is blocked by vanadate [26]. So far vanadium compounds have not yet found approval for medicinal applications. The antidiabetic (insulin-enhancing) effect of a singular vanadium complex, *bis*(ethylmaltolato) oxidovanadium (IV) (BEOV), has revealed encouraging results in phase II a clinical tests [26].

This research is aimed at determining the concentration of major and trace elements in the *Guiera senegalensis* from the vicinity of the Kaolin milling Plant with the view to ascertaining the health implications of the activities of the milling plant to the medicinal plant.

2. MATERIALS AND METHODS

2.1 Study Area

Alkaleri is a town in Alkaleri Local Government Area of Bauchi State, Nigeria. It is on the A345 highway in the north of the area at 10°15′58″N 10°20′07″E / 10.26611°N 10.33528°E. Fig. 1. shows the vicinity of the Kaolin Milling Plant in Alkaleri with the sampling location.

2.2 Samples Collection and Preparation

Samples of *Guiera senegalensis* was collected from the vicinity of Kaolin milling plants. Samples were collected from twelve sampling sites (Fig. 1. and Table 1). The branches about 30-40 cm and parts of roots were collected and placed in a polypropylene bag. The sample collected was washed thoroughly with tap water then with distilled water to remove soil and dirt. It was then dried in the lab at room temperature. The dried plant samples were pulverized using porcelain pestle and mortar then sieved with 2 mm mesh.

2.3 Sample Preparation for NAA Analysis

The method described by [27] with some modification was adopted. A polyethylene bags and rabbit capsules were cleaned by soaking in 1:1 HNO_3 (Nitric acid) for 3 days and washed with de-ionized water to sterilize and oven dried. The plant samples were weighed with a four-digit Melter model weighing balance in the range of 250 mg to 300 mg encapsulated, heat sealed in

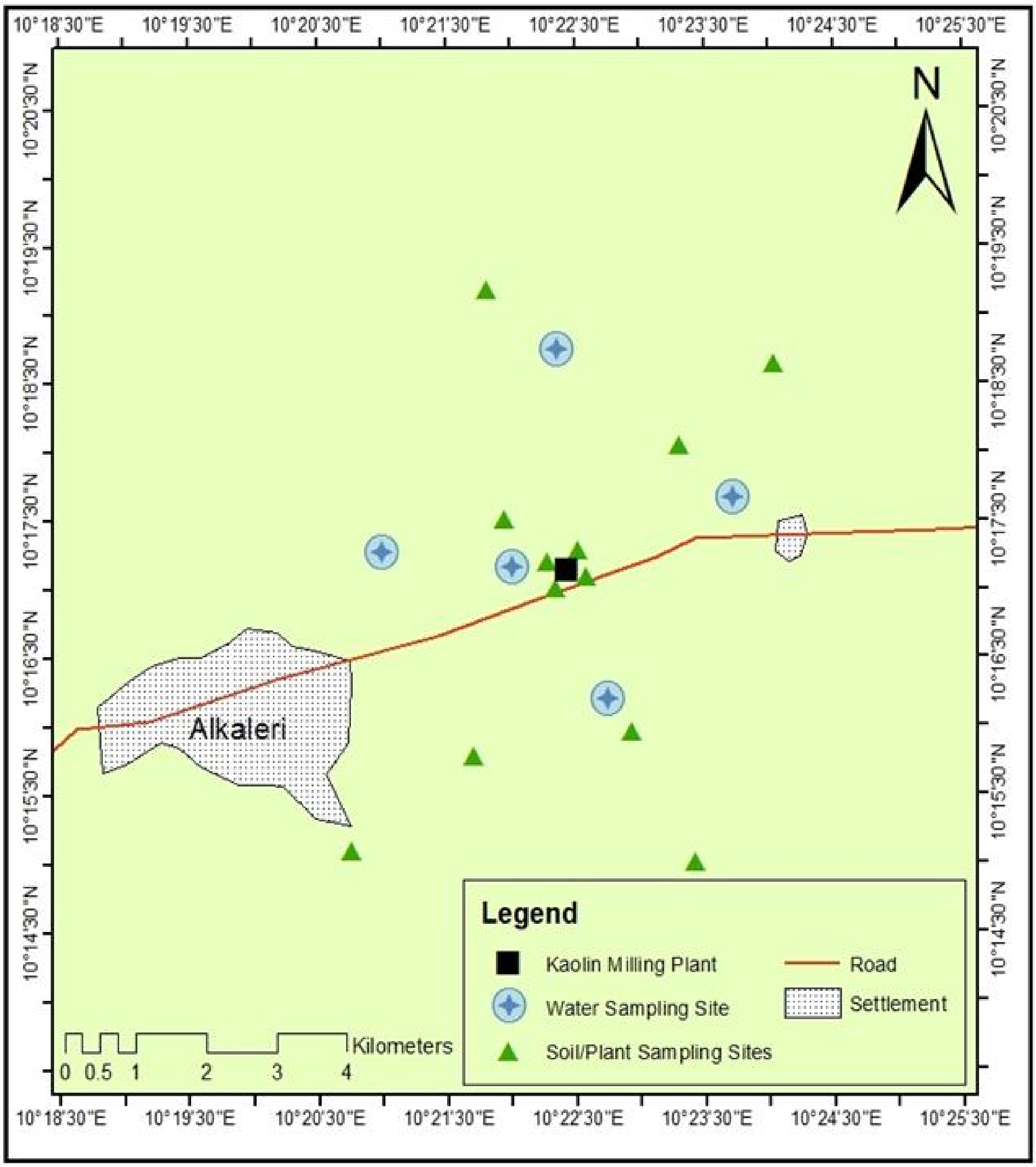

Fig. 1. Map of study area showing sampling sites

a polyethylene material and package finally into a polyethylene vial as adopted for Nigeria Research Reactor-1 (NIRR-1) at Centre for Energy Research and Training ABU, Zaria [27].

2.4 Sample Irradiation

The protocols for sample irradiation were performed in two irradiations stages as described by [27,28]. Arrangements of elements with short life are determined using the short live protocol. Samples packaged in the vials are sent to the reactor irradiation sites using the rabbit system (pneumatic transfer system) at a time and the neutron flux was determined by theoretical expression based on estimated activity of the sample [27]. The first irradiation was designed to capture short half-lives radionuclide, the second irradiation was designed to capture long half-life-radionuclide in the inner channel of the Miniature Neutron Source Reactor (MNSR) operating at full power of 30 kW thermal with a neutron flux of 2.5 x 10^{11} n/cm^2 s and irradiation period of 600s.

Table 1. Sampling location/points at the vicinity of a Kaolin milling Plant

Sampling points	Direction from milling plant	Distance from milling plant
PS1	Northwest	0 Km
PS2	Northwest	2 Km
PS3	Northwest	4 Km
PS4	Northeast	0 Km
PS5	Northeast	2 Km
PS6	Northeast	4 Km
PS7	Southwest	0 Km
SP8	Southwest	2 Km
PS9	Southwest	4 Km
PS10	Southeast	0 Km
PS11	Southeast	2 Km
PS12	Southeast	4 Km

The long irradiation entailed wrapping samples in polyethylene films and stacks packing each inside the 7cm^2 rabbit capsule and heat-sealed for irradiation for 6 h at maximum value of thermal neutron flux of 5 x 10^{11} n/cm^{2}s. The flux is kept constant by monitoring the neutron flux reading from a fission chamber connected to the micro-computer-controlled room. After the samples have been irradiated they were retrieved via the same pneumatic transfer of the rabbit to the control chamber where they were collected and kept in a glass chamber. Finally the identification of gamma ray of product radio-nuclides through their energies and quantitative analysis of their concentration were obtained by using the gamma ray spectrum analysis software WINSPAN 2004.

Standard reference material (SRM) 1547 (NIST PEACH LEAVES) was analyzed along with the samples for method substantiation and quality control purposes. Neutron activation analysis is a non-destructively analytical technique [29]. The instrumental neutron activate analysis technique (INAA) was used for the analysis using NIRR-I at the Centre for Energy Research and Training ABU Zaria.

2.5 Statistical Analyses

Analysis of Variance (ANOVA) Techniques was adopted to test for significant difference in the seasonal mean variation and Pearson Correlation Coefficient was used to determining the interdependence of the Elements analyzed. Analyses were performed using the statistical package SPSS 16.0 for windows [30].

3. RESULTS AND DISCUSSION

Table 2a and 2b showed the mean concentration ± standard deviation of the elemental contents in the samples of *Guiera senegalensis* within the vicinity of Kaolin milling plant in Alkaleri, Bauchi state. Figs. 2-11 showed the distributions of the major and trace Elements contents in samples of *Guiera senegalensis* within the vicinity of Kaolin milling plant in Alkaleri, Bauchi state.

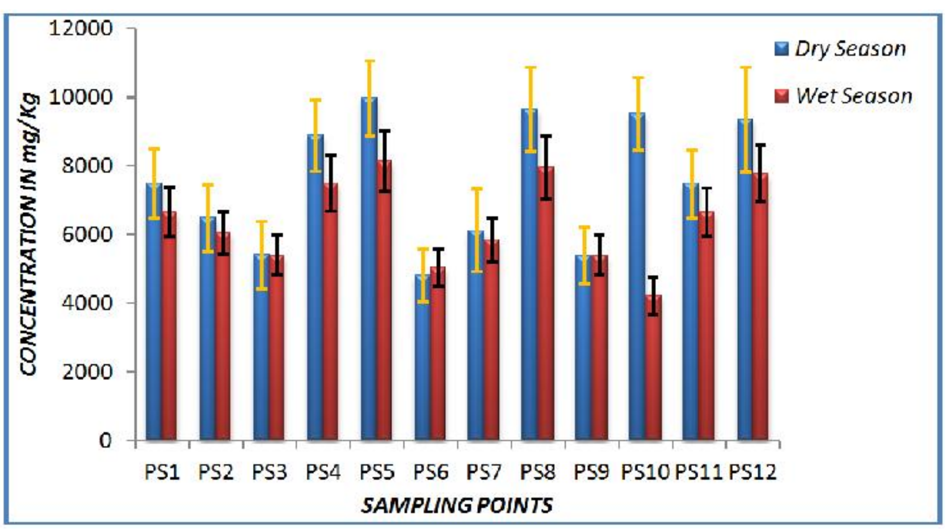

Fig. 2. Distribution of Ca in plant samples within the vicinity of Kaolin milling plant

Table 2a. Major Elemental Content (mg/Kg) In Plant Samples in the Vicinity of Kaolin Milling Plant

Samples	Season	Ca	K	Mg	Na
PS1	**Dry**	7506±1001	7160±310	2567±800.4	68.4±2.1
	Wet	6667.1±716	1009± 11.0	996±414	36.5±0.4
PS2	**Dry**	6489±989	8248±342.9	1235±530.5	55.68±1.9
	Wet	6053±618.3	9462±98.7	1078±448.1	30.2±0.3
PS3	**Dry**	5403±973.2	6161±298.8	1962±716.7	52.21±0.2
	Wet	5401±580	1050±11.5	1030±428.2	28.5±0.3
PS4	**Dry**	8891±1032	7518±325.6	2372±731.3	61.9±2.15
	Wet	7500.1±805.5	9842±107.4	1007±418.6	33.3±0.35
PS5	**Dry**	9972±1088.1	5350±1511.2	3420±841.1	32.01±10.0
	Wet	8151.6±875.4	1974±21.5	2778±750.7	52.35±0.17
PS6	**Dry**	8151.6±875.4	5555±288.7	2778±750.7	52.35±0.17
	Wet	5047.1±542.0	1086±11.9	984±409	28.6±0.3
PS7	**Dry**	8034±1196.7	9692±346.4	2329.5±786.9	69.9±2.3
	Wet	5838.8±5838.7	8707±95.0	1069±444.4	37.2±0.39
PS8	**Dry**	9660±1221.4	4266±487.7	3191±596.9	50.24±2.30
	Wet	7961±923.2	11540±119.5	987±410.3	48.8±0.51
PS9	**Dry**	5402±823.4	1935±385.4	2781±1098.3	41.05±3.27
	Wet	5400.5±579.9	1276±13.9	983±408.6	23±0.02
PS10	**Dry**	9514±1054.6	5899±592.5	2821±821.0	44.92±2.88
	Wet	4223±533.5	8060±97.0	950±394.9	24.9±0.02
PS11	**Dry**	7491±986.1	8166±806.3	2346±821	45.32±3.07
	Wet	6658.1±715.0	9504±103.7	1008±419	25.1±0.26
PS12	**Dry**	9351±1522.5	7492±843.5	BDL	68.08±3.78
	Wet	7777.8±835.2	9855±107.5	1142±474.7	36.3±0.3

Concentration is Mean±SD   BDL= Below Detection Limit

Table 2b. Micro elemental content (mg/Kg) In Plant Samples in the Vicinity of Kaolin Milling Plant

Samples	Season	Co	Fe	Mn	Zn	Cu	V
PS1	**Dry**	1.29±0.03	102.7±42.4	553.2±8.6	21.8±3.4	4.10±2.5	1.12±0.6
	Wet	1.23±0.05	324.4±78.7	355±2.2	13.03±2.7	BDL	BDL
PS2	**Dry**	1.92±0.07	78.2±47.3	945.7±11.5	16.9±4.6	BDL	1.15±0.7
	Wet	1.85±0.07	353±88.3	1000±6.1	BDL	13±2.70	BDL
PS3	**Dry**	2.58±0.07	156.1±80.5	797.3±11.1	25.6±6.2	7.50±4.5	BDL
	Wet	2.5±0.1	261.8±63.5	756±4.6	11.6±2.4	BDL	BDL
PS4	**Dry**	0.41±0.05	123.5±74.8	458.7±7.1	13.1±4.2	2.52±1.5	1.01±0.4
	Wet	0.36±0.01	300±72.7	200±1.2	16.4±3.4	BDL	BDL
PS5	**Dry**	0.88±0.07	343.5±13.1	1708±177.5	24.8±4.4	9.04±5.5	1.80±0.7
	Wet	0.82±0.07	42±10.2	2252±13.7	11.9±2.5	BDL	BDL
PS6	**Dry**	0.99±0.05	53±32.1	952.8±11.6	11.0±4.0	BDL	0.49±0.3
	Wet	0.93±0.04	382.7±92.8	1012±6.1	17.3±3.6	BDL	BDL
PS7	**Dry**	2.59±0.07	329.1±116.9	670±6.6	43.2±5.0	BDL	6.69±3.3
	Wet	2.51±0.1	58.9±14.3	547±3.3	4.7±1.0	BDL	BDL
PS8	**Dry**	0.33±0.04	196.9±119.3	412±3.6	15.0±3.3	BDL	2.71±1.3
	Wet	0.28±0.03	215±48.5	123±0.7	17.4±3.5	BDL	BDL
PS9	**Dry**	0.15±0.05	65.61±39.8	1547±13.3	BDL	BDL	6.13±2.4
	Wet	0.1±0.0	367.9±89.2	1987±12.0	1.6±0.3	BDL	BDL
PS10	**Dry**	0.72±0.04	207.8±50.1	334.8±2.9	33.9±3.6	BDL	1.43±0.9
	Wet	0.65±0.02	291.5±70.7	18.3±0.1	8.5±1.8	BDL	BDL
PS11	**Dry**	0.71±0.04	130.8±64.3	348.3±3.0	33.4±4.5	2.5±0.2	3.01±1.6
	Wet	0.65±0.02	291.5±70.7	18.3±0.1	8.5±1.8	BDL	BDL
PS12	**Dry**	2.43±0.07	267.8±70.0	937.9±8.1	15.1±5.1	BDL	BDL
	Wet	2.35±0.09	130.8±31.7	987±6.0	15.7±3.3	BDL	BDL

Concentration is Mean±SD   BDL= Below Detection Limit

Fig. 2 showed the distribution of Ca in plant samples within the vicinity of Kaolin milling plant. Ca has a dry season mean concentration of 7552.4±1884.6 mg/Kg with a variability coefficient of 25% and wet mean concentration of 6390±1720 mg/Kg with a variability coefficient of 26.9%. The dry season highest concentration of Ca (9972±1088 mg/Kg) was found at PS5 and the lowest concentration of Ca (4815±447.8 mg/Kg) was found at PS6. The wet season highest concentration of Ca (8151.6±875.4 mg/Kg) was found at PS5 and the lowest concentration of Ca (4223±308 mg/Kg) was found at PS10. The pair wise mean seasonal variation between the dry and wet season showed no significant difference in 66.7% of all the samples ($P < 0.05$). Recommended dietary Intake (RDI) of Calcium is 700-1300 mg per day for children, 1000-1200 mg per day for adult and 1000-1300 mg per day for pregnant and lactating woman [31]. The concentration of Ca in *Guiera senegalensis* leaf according to [2] is 219.03 ppm which is lower than the mean concentration of the samples in this study.

Fig. 3 showed the distribution of Mg in plant samples within the vicinity of Kaolin milling plant. Mg has a dry season mean concentration of 2229.8±970.8 mg/Kg with a variability coefficient of 43.5% and wet mean concentration of 1015±56.7 mg/Kg with a variability coefficient of 5.6%. The dry season highest concentration of Mg (3420 ± 841.1 mg/Kg) was found at PS5 and the lowest concentration of Mg (1235 ± 530.5 mg/Kg) was found at PS2. The wet season highest concentration of Mg (1142 ± 474.7 mg/Kg) was found at PS12 and the lowest concentration of Mg (947± 393.7 mg/Kg) was found at PS5. The dry season concentration of Mg was below detection limit in PS12. Pair wise mean seasonal variation between the dry and wet season showed the level of Mg were statistically significant in 75% of all samples ($P < 0.05$). Mg showed significant negative correlation with Co ($P < 0.05$). RDI of Magnesium is 400-420 mg per day for male, 310-320 mg per day for women, 350-360 mg per day for pregnant women and 30-240 mg per day for children [32]. The concentration of Mg in *Guiera senegalensis* leaf according to [2] was found to be 1315.57 ppm higher than the mean concentration of Mg in wet season but lower than the mean concentration in wet season.

Fig. 4 showed the distribution of Na in plant samples within the vicinity of Kaolin milling plant. Na has a dry season mean concentration of 53.51±11.9 mg/Kg with a variability coefficient of 22 % and wet mean concentration of 30.9±8.1 mg/Kg with a variability coefficient of 26.2 %. The dry season highest concentration of Na (69.9 ± 2.3 mg/Kg) was detected in PS7 while the lowest concentration of Na (32.0±10.0 mg/Kg) was found in PS5. The wet season highest concentration of Na (48.8±0.50 mg/Kg) was detected in PS8 while the lowest concentration of Na (18.6±0.19 mg/Kg) was found in PS5. The pair wise mean seasonal variation between the dry and wet season showed the level of Na was statistically significant in 91.7% of all the samples ($P < 0.05$). Na showed significant positive correlation with K ($P < 0.05$). The concentration of Na in *Guiera senegalensis* leaf according to Mohammed [2] was found to be 1400.0 ppm. The concentration of Na found in the samples of *Guiera senegalensis* in this study are far less than the one according to [2].

Fig. 5 showed the distribution of K in plant samples within the vicinity of Kaolin milling plant. K has a dry season mean concentration of 6453.5±2066.4 mg/Kg with variability coefficient of 32% and wet mean concentration of 6113.8±4349.3 mg/Kg with a variability coefficient of 71.1 %. The highest dry season concentration of K (9692 ± 346.4 mg/Kg) was found in PS7 and the lowest concentration of K (1935 ± 385.4 mg/Kg) was found in PS9. The wet season highest concentration of K (11540 ± 119.5 mg/Kg) was detected in PS8 while the lowest concentration (1009±11.0 mg/Kg) was found in PS1. The pair wise mean seasonal variation between the dry and wet season showed the level of K were statistically significant at more than 91% all the sampling points ($P < 0.05$). K showed significant positive correlation with Na, Co, and Zn ($P < 0.05$). RDA of K is 4.7 g per day for adult and 5.1 g per day for breast feeding women [33]. The concentration of K in *Guiera senegalensis* leaf according to [2] was 5200.0 ppm is slightly lower but almost in agreement with the results in this study.

Fig. 6 showed the distribution of Cu in plant samples within the vicinity of Kaolin milling plant. Cu has a mean concentration of 2.14±3.20 mg/Kg with variability coefficient of 149 %. Dry season highest concentration of Cu (9.04±5.47 mg/Kg) was found in PS5 and lowest concentration (2.49±0.15 mg/Kg) was in PS11. Dry season concentrations of Cu were below detection limit in 7. The concentrations of Cu in samples collected during the wet season were all below detection limits. The pair wise mean seasonal variation of Cu between the dry and wet season showed no significant difference in 75% of all the samples ($P < 0.05$). The recommended daily allowance of copper 2 - 3 mg/day, daily intakes of copper during pregnancy and breast feeding should be 3 - 4 mg per day [14]. The concentration of Cu in *Guiera senegalensis* leaf extract according to [2] is 19.80 ppm. The concentration of Cu in this study are lower than the concentration of *Guiera senegalensis* leaf extract according to [2].

Fig. 7 showed the distribution of Mn in plant samples within the vicinity of Kaolin milling plant. Mn has a mean concentration of 805.5±448.3 mg/Kg with variability coefficient of 55.7% and wet season mean concentration of 839.5±695 mg/Kg with variability coefficient of 82.7%. The dry season highest concentration of Mn (1708±177.5 mg/Kg) was found in PS5 while the lowest concentration (334.8±2.9 mg/Kg) was found in PS10. The wet season highest concentration of Mn (2252±13.65 mg/Kg) was detected in PS5 while the lowest concentration (18.3±0.1 mg/Kg) was found in PS11. The pair wise mean seasonal variation between the dry and wet season showed no significant difference in the level of Mn at 58% of all the sampling points ($P < 0.05$). Recommended Daily Intake (RDI) for Mn is 3 µg/day- 600 µg/day in infants, 1.2 - 1.5 mg/day in children, 2.3 mg/day for adult men and 1.8 mg/day for adult women.

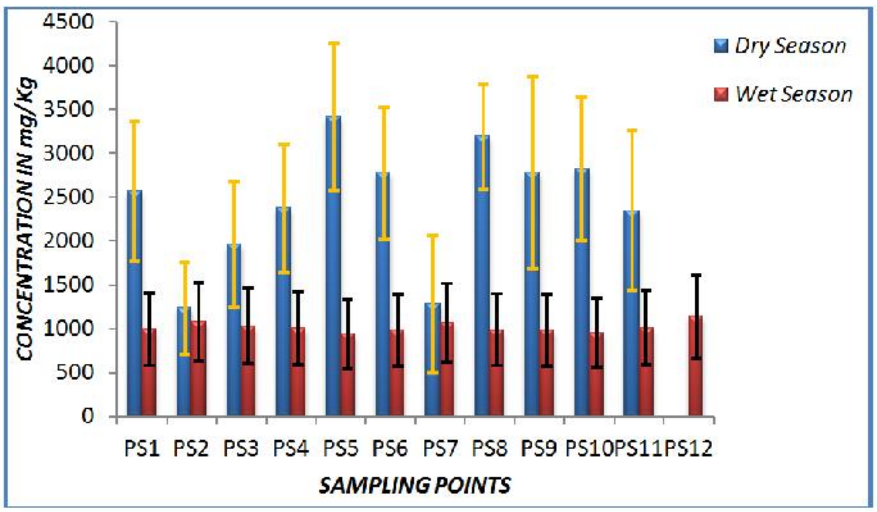

Fig. 3. Distribution of Mg in plant samples within the vicinity of Kaolin milling plant

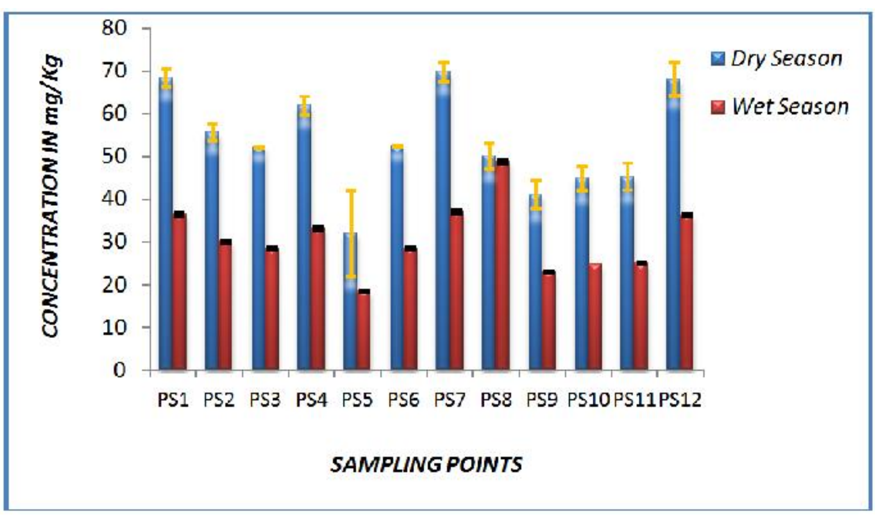

Fig. 4. Distribution of Na in plant samples within the vicinity of Kaolin milling plant

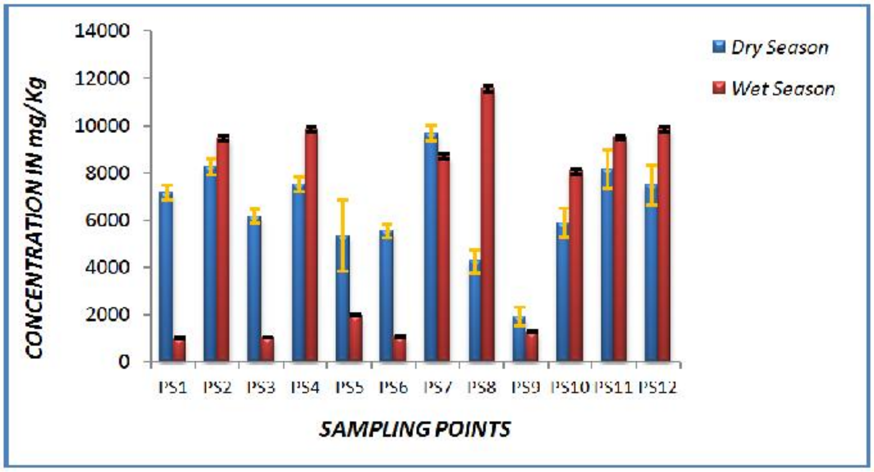

Fig. 5. Distribution of K in plant samples within the vicinity of Kaolin milling plant

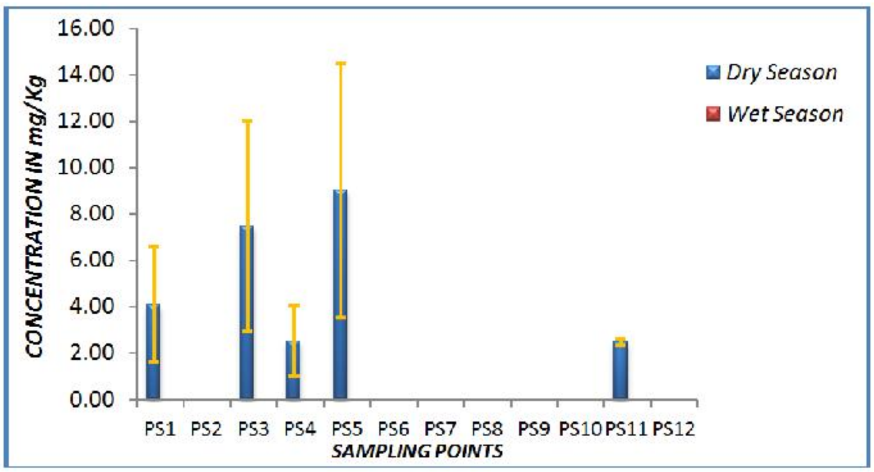

Fig. 6. Distribution of Cu in plant samples within the vicinity of Kaolin milling plant

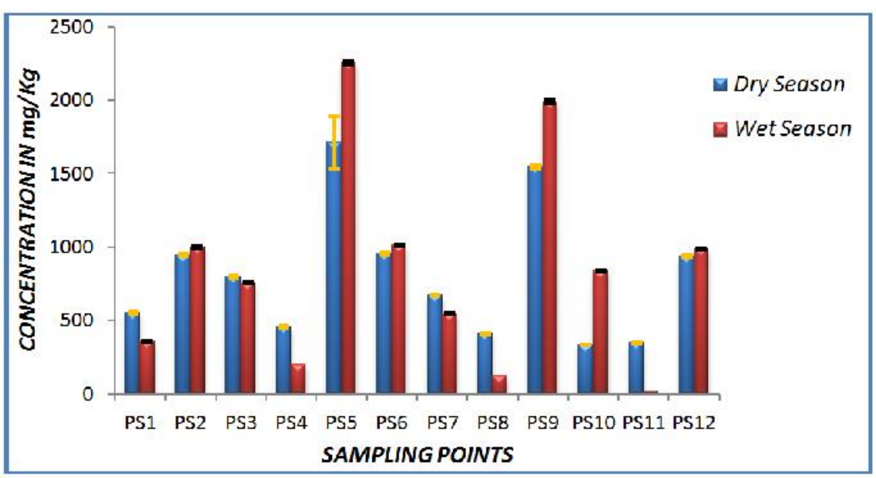

Fig. 7. Distribution of Mn in plant samples within the vicinity of Kaolin milling plant

Fig. 8 showed the distribution of Fe in plant samples within the vicinity of Kaolin milling plant. Fe has a dry season mean concentration of 171.3±99.3 mg/Kg with variability coefficient of 58% and wet season mean concentration of 224±116.5 mg/Kg with variability coefficient of 52%. The dry season highest concentration of Fe (343.5±13.1 mg/Kg) was found in PS5 and the lowest concentration (53.0±32.1 mg/Kg) was in PS6. The wet season highest concentration of Fe (382.7±92.8 mg/Kg) was detected in PS6 while the lowest concentration (42±10.2 mg/Kg) was found in PS5. The pair wise mean seasonal variation between the dry and wet season showed the level of Fe at 9 sampling points were statistically significant ($P < 0.05$). Recommended dietary intake of Iron are 9 mg/day for infants, 8-10 mg/day for children, 8-11 mg/day for adult male, 15-18 mg/day for adult female, 27 mg/day pregnant women and 9-10 mg/day for Lactating women [34]. The concentration of Fe in *Guiera senegalensis* leaf extract according to [2] is given as 497.36 ppm which is higher than the concentration of Fe in this study.

Fig. 9 showed the distribution of Zn in plant samples within the vicinity of Kaolin milling plant. Zn has dry season mean concentration of 21.14±11.8 mg/Kg with a variability coefficient of 56% and wet season mean concentration of 11.62±5.02 mg/Kg with variability coefficient of 43.2 %. The highest dry season concentration of Zn (43.15±3.3 mg/Kg) was detected in PS8 and the lowest concentration of Zn (11.01±4.0 mg/Kg) was found in PS6. Concentration of Zn was below detection limit in PS9. The wet season highest concentration of Zn (17.2±3.6 mg/Kg) was detected in PS6 while the lowest concentration (8.49±1.8 mg/Kg) was found in PS11. The pair wise mean seasonal variation between the dry and wet season showed the level of Zn at 7 sampling points were statistically significant ($P < 0.05$). Zn showed significant positive correlation with K ($P < 0.05$). Recommended dietary intake of Zinc are 2-3 mg/day for infants, 3-5 mg/day for children, 8-11 mg/day for adult male, 8-9 mg/day for adult female, 11-13 mg/day pregnant women and 12-14 mg/day for Lactating women [20].

Fig. 10 showed the distribution of Co in plant samples within the vicinity of Kaolin milling plant. Co has dry season mean concentration of 1.25±0.90 mg/Kg with variability coefficient of 72 % and wet season mean concentration of 1.30±0.91 mg/Kg with variability coefficient of 70 %. The dry season highest concentration of Co (2.59±0.07 mg/Kg) was found in PS7 while the lowest concentration of Co (0.15±0.05 mg/Kg) was found in PS9. The wet season highest concentration of Co (2.51±0.1 mg/Kg) was detected in PS7 while the lowest concentration (0.1±0.0 mg/Kg) was found in PS9. The pair wise mean seasonal variation between the dry and wet season showed the level of Co at 10 sampling points showed no significant difference ($P < 0.05$). Co showed significant negative correlation with Mg ($P < 0.05$) and significant positive correlation with K ($P < 0.05$). Cobalt daily intake in adults is 3 µg where the content of cobalt is 0.012 µg [23].

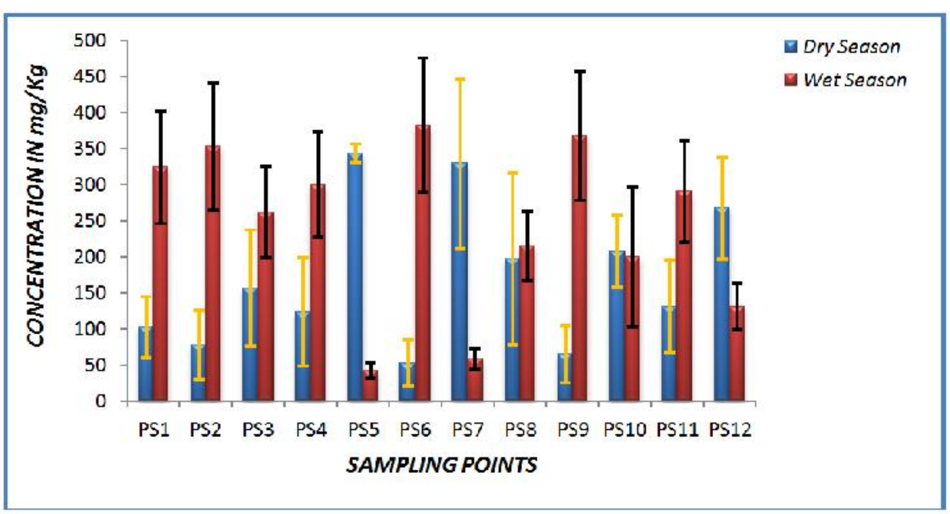

Fig. 8. Distribution of Fe in plant samples within the vicinity of Kaolin milling plant

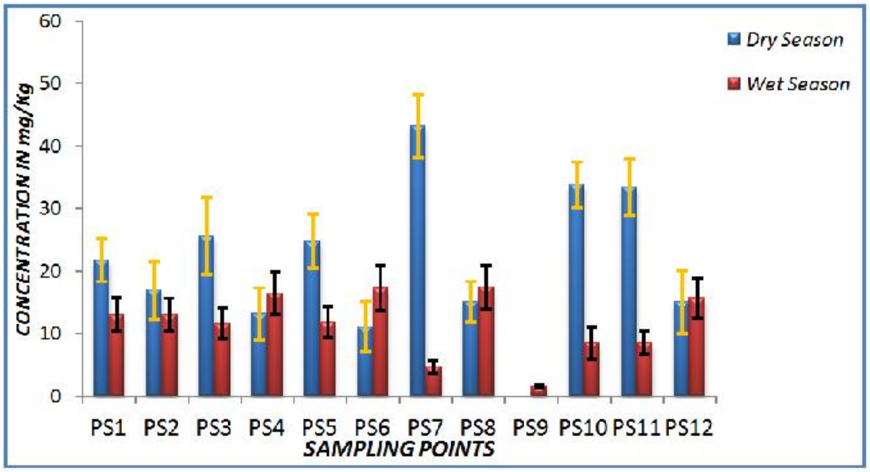

Fig. 9. Distribution of Zn in plant samples within the vicinity of Kaolin milling plant

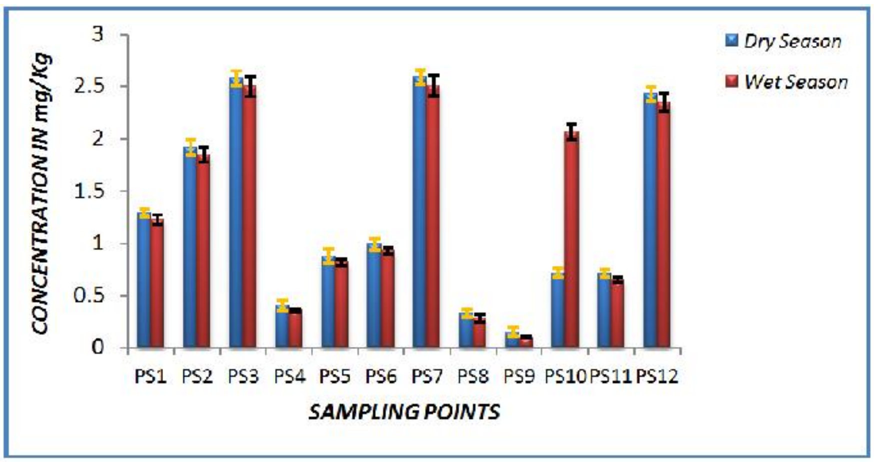

Fig. 10. Distribution of Co in plant samples within the vicinity of Kaolin milling plant

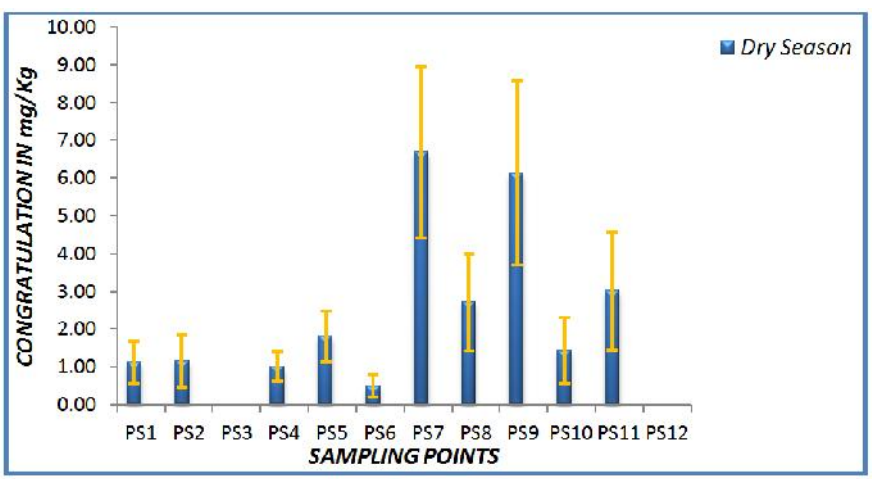

Fig. 11. Distribution of V in plant samples within the vicinity of Kaolin milling plant

Fig. 11 showed the distribution of V in plant samples within the vicinity of Kaolin milling plant. V has dry season mean concentration of 2.13±2.21 mg/Kg with a variability coefficient of 103.7 %. The highest dry season concentration of V (6.69±2.26 mg/Kg) was detected in PS7 and the lowest concentration of (0.49±0.29 mg/Kg) was found in PS6. The concentration of V was below detection limit in 2 samples of dry season and all samples of wet season. The pair wise mean seasonal variation between the dry and wet season showed the level of V were statistically significant at 6 sampling points ($P < 0.05$). V showed negative correlation with K and Co ($P < 0.05$).

4. CONCLUSION

The levels of some major and trace elements in *Guiera senegalensis* – A local medicinal plant has been established for both dry and wet season. The ANOVA test of significant showed the mean concentrations of elements between samples obtained in dry and wet season are significantly different in most sampling points for Mg, Na, K, Fe, Zn and V while Ca, Cu, Mn and Co showed no significant difference in most of their pair wise mean seasonal concentrations ($P < 0.05$). The samples analyzed contained appreciable amount of the elements. Ca, Mg, K, Fe and Mn in considerably high amount, Na and Zn in moderate concentration and trace amount of Cu, Co and V. These elements play important roles in maintaining human health in addition with the secondary metabolites constituents of the Plant. The activity of the Kaolin milling plant did not post any adverse effect on the mineral composition of the medicinal plant. *Guiera senegalensis* can be said to be wholesome with regard to the mineral elements. This work also demonstrated the application of Neutron activation analysis as a useful tool in Multi-elemental analysis which produced results which was validated with standard reference material SRM 1547 (NIST PEACH LEAVES).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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