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A Comparative Analysis of Fractionation of Potassium in Soils from Some Refuse Dumpsites in Benin City Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A study on potassium dynamics and fractionation was carried out in Benin City to determine the amount and distribution of k fraction in soil samples collected from different refuse dumpsites. The sand, silt and clay contents of the dumpsites soils varied from 83.3 to 95.3, 0.60 to 3.35 and 2.55 to 15.10%, respectively. Soils were dominantly sandy with textural classes varying from sand to loamy sand down at depth. The result revealed that the water-soluble k and Exchangeable k range from 163.8 to 643.4 mg/kg in surface soils and 271.1 to 319.8 mg/kg in sub-surface in Benin-Onitsha Bypass and Benin-Warri Bypass. The difficult exchangeable k content ranged from 93.6 to 483.6 mg/kg and 50.1 to 467.9 mg/kg .in the surface and sub-surface of the dumpsites; K content was highest in the subsurface soils than in surface soils due to high deposition of refuse from surface soils within the dumpsites. In general, distribution of K forms decreased in the order reserved K > fixed > water-soluble > Exchangeable K, Structural K > Diff. Exch. K as well as the mobility factor for each of the refuse dumpsite investigated. Similarly, the amount of the various forms of k extracted decreased as the soil pH decreased. The soil samples collected far away from the dumpsites have lower concentrations of k forms compared to those from the vicinity of the

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dumpsites. This shows that the waste dumps had higher concentration of elements, thereby interacting with the soil and enhance their dominance within the dumpsites. The particle size fraction of the refuse dump suggests the need for consideration of active soil portions for sustainable K management of the environment.

Keywords: Fractionation; potassium forms; particle size; refuse dumpsites and Benin city.

1. INTRODUCTION

Fractionation of nutrients is carried out to determine the amount of a particular nutrient associated with different soil fractions or to know the amount of various forms of elements present in soils [1]. Separation of various forms of elements in soils has been useful in studying the release pattern of elements in the soil to plant from one chemical form to another in response to changing soil conditions. According to recent definition of international union of pure and applied chemistry (IUPAC), a practice which is widely used for recognizing nutrients distribution in solid phase is known as fractionation which is a sequential application of a chemical extractor collection for consecutive and selective solubility of chemical forms of a nutrients [2,3]. Potassium is an essential mineral nutrient that plant requires in large amounts [4]. Potassium (k) directly affects crop yield and is responsible for the maintenance of osmotic pressure and cell size, which in turn influences photosynthesis and energy production along with stomata opening and carbon dioxide supply. Plants require soil k for ATP production, translocation of sugars, starch production in grains, nitrogen fixation in legumes and protein synthesis [5,4]. Dynamics of potassium in soils is characterized by equilibrium between various forms of K such as exchangeable, water soluble and non-exchangeable. Igwe et al., [6]; Ndukwu et al., [7]; Ajiboye and Ogunwale, [8] in their separate studies observed a significant variation among the various form of k with soil particle size fraction; for instance, high concentration of K forms have been reported in clay fractions of soils developed over talc in Ejiba, Kogi state, Nigeria [9]. Nutrient released from decomposition of refuse dump such as nitrates, phosphorus and potassium stimulates growth of aquatic plants and increased cations in the soil as observed by Upendra, et al., [10]; refuse dumps in urban centers are increasingly used by farmers which can be recycle as manure for better crop performance. In urban agriculture, it serves as a source of nutrients where most vegetable farmers go to take portions of the refuse dumps for use in their vegetable gardens and for other domestic crops found within the environs. Several research works has been conducted [11,9,12,5] investigating the amount and distributions of the various forms of k in soil applied either with fertilizer or amended with organic materials and so on. Although, majority of this research do not give prime attention to k source associated with refuse dumps. The objective of this study was to investigate the amount and distribution of various forms of potassium associated with different soil fractions of the refuse dumpsite in the study area with a view to enhance k potential and its availability for crop production

2. MATERIALS AND METHODS

2.1 Location of the Study Area

The three dumpsites (Benin -Akure bypass, Benin-Onitsha bypass and Benin-warri bypass) are located in Benin city metropolis, The dumpsites are in south South region of Nigeria. Main economic activities of the area include farming, trading and artisanry. Climax vegetation of the site consisted of Christmas flower (*Eupatorium odoratum*) and oil palm (*Elaeis guinensis*).

2.2 Physiography of the Study Area

The study area experiences a bimodal pattern of rainfall that fall between April to October, with peaks in July and September. This is followed by a short period of dry season; which is usually between November to February. The area has an average annual rainfall of 1250 -1350 mm with a mean monthly relative humidity of between (30 and 93%) and mean temperature of 29.8^{o}C; and this season is associated with the prevalent moisture, south-west trade wind from the Atlantic Ocean.

2.3 Geology of the Area

The study area is outcropped by the Oligocene Benin Formation which is known as the 'coastal plain-sand' It consists mainly of sands, sandstone and gravel with clays occurring in lenses. The sands and sandstones ranges from fine to coarse grained and is largely unconfined, with thickness ranging from 2.0 m to 2100.0 m [13]. The Benin Formation is composed mainly of high resistant fresh water-bearing continental sands and gravels with minor clay intercalations [14]. Groundwater occurs abundantly in the coastal plain sands (Benin Formation) and the static water level (SWL) ranges from 8.0 – 65.0 meters depending on the location and the time of the year. The Benin Formation is a good aquifer with an average annual replenishment of about 2.8 billion cubic meters per year [14]. In most areas, the sandy components form more than 90% of the sequence of the layers therefore, permeability, transitivity and storage coefficient are very high.

2.4 Soil Sample Collection and Laboratory Analysis

In order to determine the physical and chemical properties and the concentration of the various forms of potassium in the soil where these refuse dumps are domiciled; A total of 12 composite soil samples were collected at 0 -15, 15-30, and 30-45cm depths from three (3) locations and control. The soil sample were air-dried in the laboratory at room temperature, grounded to fine mixture using pestle and mortar, allowed to pass through 2-mm sieve, and characterized for physico-chemical properties and mineralogical

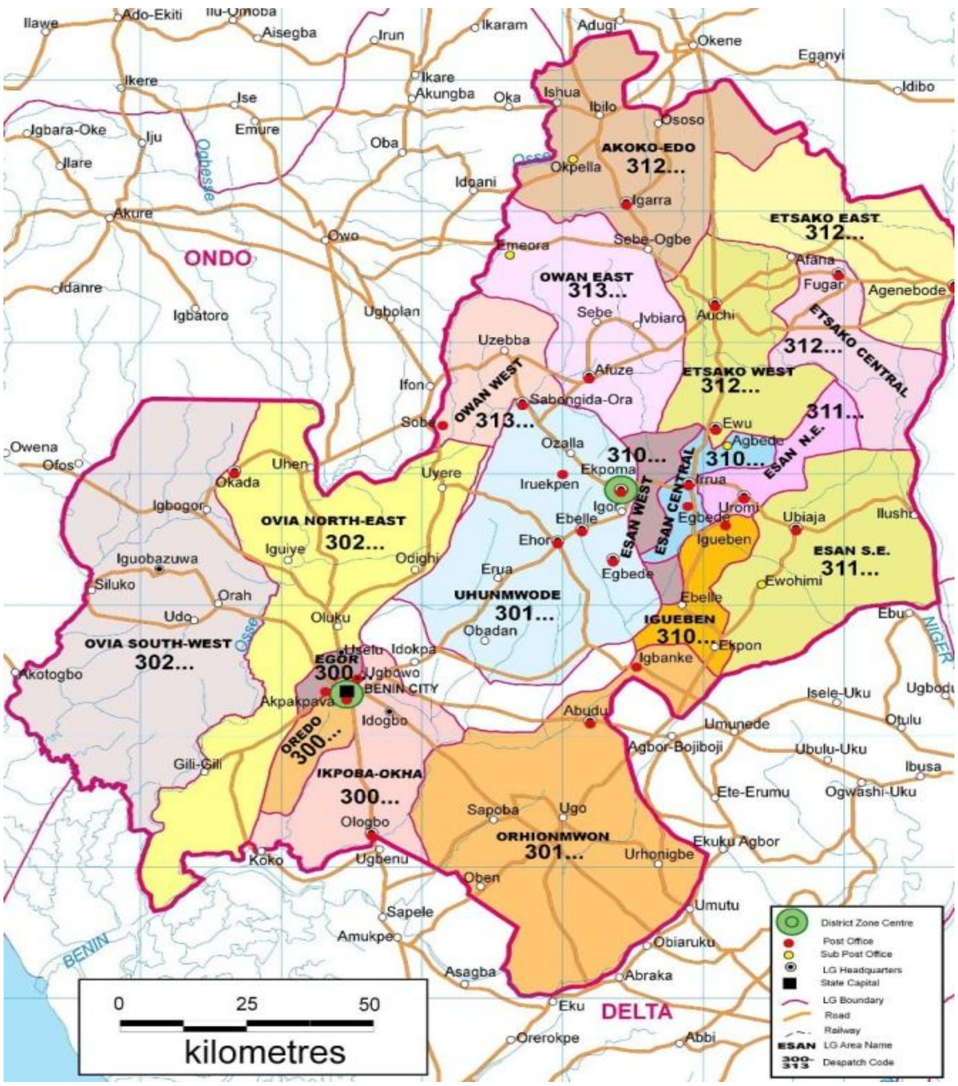

Fig. 1. showing the map of Edo State indicating the study area

compositions as follows; Particle size distribution was determined by hydrometer method [15]. Available Phosphorous (P) was determined by Bray P-I method (Anderson and Ingram, 1993). Total Nitrogen (N) was by macro-Kjeldahl method [16]. The pH in soil water suspension (1:2) was measured using combined electrode (glass and calomel) in a digital pH meter [17]. Organic carbon was analyzed by the dichromate oxidation procedures [18] method, Nitrogen by alkaline- KMnO4 method [19]. Available phosphorus in soil was determined by 0.5 *M* NaHCO3 (pH 8.5) extraction method [20]. Normal sodium acetate was used to determine cation exchange capacity of soils. Available potassium was extracted by1N neutral NH4OAc and determined by flame photometer [21]. Total Exchangeable acidity (H^+ + Al^{3+}) was by titration method [22] while cations exchange capacity was determined by summation of exchangeable cations and exchangeable acidity [23]. The various forms of potassium namely water soluble, exchangeable and non-exchangeable potassium were determined in these soil samples. Water soluble K was extracted by shaking the soil water suspension in the ratio of 1:5 for one hour then filtered and K was determined [24]. Exchangeable-K was estimated by neutral ammonium acetate (1 N) extraction in 1:5 ratios. The amount of exchangeable K was calculated by subtracting water soluble K from K extracted with neutral ammonium acetate [25]. Non exchangeable-K was estimated by boiling soil with 1N HNO_3 extractable K in 1:10 (soil: acid suspension) for 10 min. The non-exchangeable K was calculated by subtracting K extracted with neutral ammonium acetate from K extracted in hot 1N HNO_3 [26]. Mobility factor for k is computed using the formula below.

$$\text{Mobility factor} = \frac{\sum \text{water soluble potassium} + \text{Exchangeable potassium}}{\sum \text{All Forms of potassium}} \times 100$$

2.5 Statistical Analysis

Data of K forms in the soil from different dumpsites soils were subjected to analysis of variance (ANOVA) and means were compared at the *p*<0.05 level using LSD for all the parameters. Comparison of K forms were made at different soil depth. All the statistical analyses were conducted using Genstat statistical package [27].

3. RESULTS AND DISCUSSION

3.1 Soil Characterization

Table 1 presents the results of the particle size distribution of soils in the study area. The sand, silt and clay contents varied from 83.3 to 95.3, 0.60 to 3.35 and 2.55 to 15.10%, respectively. Soils were dominantly sandy with textural classes varying from sand to loamy sand down at depth; Sandiness of the soils could be due to the nature of the parent material, which is Coastal Plain Sands [28,29]. Silt and clay content were low and increased with soil depth, (Table: 1). This observation, however, agrees with earlier findings by Raji et al., [30] in Northern Nigeria; who reported that clay content increased with increasing soil depth Low silt/clay ratios indicate that the soils are highly weathered [31].

3.2 Chemical Properties of the Soil

Some chemical properties of the soil investigated is presented in Table 2. The soil pH (H_2O) was slightly alkaline in reaction and ranged between 5.0 to 8.7 in all the dumpsite soils evaluated, and was high compared to the control (4.7 to 5.9); the increase in the pH of the dumpsite soil used suggested that the soils could exhibit cation exchange. In general, high pH values were observed at the surface compared to the subsurface in all the dumpsites location and decreased with depth (Table: 2); this might be due to effect of human activities and leaching of basic cations down the soil profile. This observation is in line with Nwite, et al. [32] who reported a general decrease in pH values in the lower profile. The basic cations and organic carbon were generally low and ranged from 1.53 to 16.7, 2.96 to 28.2 and 2.69 to 22.9 mg/kg respectively for Benin-Akure Bypass, Benin-Onitsha Bypass and Benin-Warri Bypass, and increased with increasing pH of the soils, while the exchangeable acidity was the reverse (Table 3). Soil from Benin-Onitsha Bypass had higher basic cations and organic carbon followed by Benin-Warri Bypass (Table 3), probably because of accumulation of refuse compared to 1.4 to 2.81 mg/kg soils from the control and the other dumpsite. Total Nitrogen (Total N) of soil sample from Benin-Onitsha Bypass were relatively high and ranged from 0.03 to 0.08 mg/kg followed by Benin- Akure Bypass with values between 0.02 to 0.10 mg/kg compared to 0.02 to 0.05 mg/kg for the control. These observations are consistent with Agbeshie et al [33] in a tropical

Table 1. Particle size distribution of the soils

Sample/Location	Soil depth (cm)	Soil characteristics			Textural Class
		Sand %	Silt %	Clay %	
Control	0-15	88.9	2.95	8.10	Sand
	13-30	83.3	2.60	14.05	Loamy sand
	30-45	83.30	1.60	15.10	Loamy sand
Benin-Akure Bypass 1	0-15	89.3	3.10	7.65	Loamy sand
	13-30	87.8	2.55	9.60	Loamy sand
	30-45	86.8	2.10	11.00	Loamy sand
Benin-Akure Bypass 2	0-15	94.3	3.10	2.55	Sand
	13-30	92.8	2.10	5.10	Sand
	30-45	85.8	2.10	8.10	Loamy sand
Benin-Onitsha Bypass 1	0-15	95.3	1.55	3.10	Sand
	13-30	91.8	1.10	7.05	Sand
	30-45	87.3	1.08	11.6	Loamy sand
Benin-Onitsha Bypass 2	0-15	92.5	3.35	4.10	Sand
	13-30	91.3	2.60	6.10	Sand
	30-45	90.3	0.60	9.95	Sand
Benin-Warri Bypass 1	0-15	92.3	2.10	5.60	Sand
	13-30	87.3	1.55	11.10	Loamy sand
	30-45	86.3	1.60	12.10	Loamy sand
Benin-Warri Bypass 2	0-15	95.3	2.10	2.60	Sand
	13-30	85.3	2.10	12.7	Loamy sand
	30-45	85.2	1.60	13.10	Loamy sand

Table 2. Some chemical properties of soils in the study area

Sample/Location	Soil depth (cm)	pH	Total N(mg/kg)	Available P(mg/kg)	Basic cations (mg/kg)				CEC(mg/kg)	Exchangeable Acidity (mg/kg)	TOC %
					Ca	Mg	Na	K			
Control	0-15	5.9	0.05	7.70	1.40	0.84	0.25	0.22	2.71	0.21	0.64
	15-30	4.9	0.04	5.43	1.80	0.72	0.17	0.12	2.81	0.30	0.45
	30-45	4.9	0.02	2.51	0.70	0.44	0.15	0.11	1.40	0.50	0.34
Benin-Akure Bypass 1	0-15	7.2	0.06	20.63	3.33	2.27	0.20	1.10	6.90	0.10	0.86
	15-30	6.0	0.03	9.68	1.64	1.36	0.20	0.48	3.68	0.20	0.58
	30-45	5.6	0.02	4.15	1.30	1.21	0.11	0.10	2.72	0.20	0.27
Benin-Akure Bypass 2	0-15	7.5	0.10	21.12	9.10	6.68	0.24	0.72	16.7	0.10	1.38
	15-30	5.5	0.03	4.27	0.71	0.56	0.13	0.31	1.53	0.20	0.48
	30-45	5.0	0.01	2.07	0.44	0.44	0.12	0.11	2.11	0.50	0.16
Benin-Onitsha Bypass 1	0-15	7.4	0.05	20.62	9.92	1.52	0.21	1.78	13.4	0.20	0.74
	15-30	6.7	0.05	4.68	1.40	0.36	0.20	1.60	3.56	0.20	0.70
	30-45	6.5	0.03	3.74	1.04	0.26	0.18	1.48	2.96	0.10	0.48
Benin-Onitsha Bypass 2	0-15	8.7	0.08	22.7	21.7	3.36	0.65	2.53	28.2	0.09	0.96
	15-30	8.4	0.07	9.48	3.68	0.88	0.23	2.03	6.82	0.20	0.93
	30-45	7.8	0.04	3.28	2.40	0.48	0.16	1.89	4.93	0.40	0.67
Benin-Warri Bypass 1	0-15	6.9	0.02	24.19	1.34	0.56	0.12	1.87	3.89	0.10	0.29
	15-30	6.8	0.01	10.26	0.96	0.52	0.22	1.72	3.42	0.20	0.19
	30-45	6.5	0.04	2.77	0.88	0.12	0.21	1.48	2.69	0.30	0.16
Benin-Warri Bypass 2	0-15	7.6	0.05	27.9	17.7	3.04	0.25	1.90	22.9	0.20	1.25
	15-30	6.4	0.05	7.36	1.08	0.70	0.29	1.64	3.71	0.20	0.29
	30-45	6.1	0.01	3.14	1.08	0.65	0.21	1.61	3.55	0.30	0.19

Table 3. Concentration (mg/kg) and distribution of different forms of k in the study area

Sample location	Depth (cm)	Water soluble K	Exchangeable K	Difficult Exchangeable K	FixedK	Total Reserved K	StructuralK	Mobility factor
Control	0-15	167.8	105.3	35.10	234.0	417.30	78.0	26.3
	15-30	136.5	78.0	46.80	245.70	518.70	194.9	20.7
	30-45	117.0	179.4	179.40	66.30	230.01	15.60	28.5
Benin-Akure Bypass 1	0-15	744.0	971.1	269.10	600.60	284.67	85.80	165.3
	15-30	351.00	409.5	27.29	27.30	191.10	191.13	73.3
	30-45	234.00	319.78	78.01	23.42	440.70	97.51	53.3
Benin-Akure Bypass 2.	0-15	1425.4	705.90	698.10	58.51	456.30	191.10	109.0
	15-30	191.10	323.61	72.83	7.80	456.30	140.40	49.6
	30-45	93.60	89.70	15.60	132.60	288.64	66.30	17.7
Benin-Onitsha Bypass 1.	0-15	495.30	499.20	257.40	140.40	175.50	183.30	95.8
	15-30	308.10	740.91	245.70	495.33	206.70	39.00	101.1
	30-45	1637.97	1189.50	525.38	955.50	261.30	30.66	79.7
Benin-Onitsha Bypass 2.	0-15	413.36	2507.70	374.40	378.30	623.91	1505.40	88.7
	15-30	265.21	120.70	690.21	896.99	288.60	35.10	37.2
	30-45	202.80	1326.01	764.40	943.80	534.0	152.10	50.9
Benin-Warri Bypass 1.	0-15	113.10	592.80	218.40	171.60	190.70	222.31	68.0
	15-30	573,30	881.40	304.20	405.67	249.60	226.20	140.2
	30-45	877.50	1115.40	518.73	577.20	210.60	327.60	192.0
Benin-Warri Bypass 2	0-15	1173.81	585.03	557.70	358.80	284.70	659.10	73.1
	15-30	66.30	834.60	413.40	284.70	280.80	269.10	120.3
	30-45	421.20	483.62	117.00	167.70	483.60	165.53	86.8

Table 4. Comparison of various forms of k at 0-15 cm depth

Sample Location	Water Soluble K mg/kg	Exchangeable K mg/kg	Difficult Exchangeable K mg/kg	Fixed K mg/kg	Total Reserved K mg/kg	Structural K mg/kg	Mobility Factor mg/kg
Control	167.8a	105.30a	35.10a	234.00a	417.28a	78.00a	26.3a
Benin-Akure Bypass	443.1	338.5	483.6	329.6	370.4	138.4	137.2
Benin-Onitsha Bypass	163.8	204.7	93.6	78.01	364.6	81.9	92.3
Benin-Warri Bypass	643.4	588.9	388.0	255.2	237.8	440.7	70.5
LSD (P≤0.05)	13.8	0.22	0.14	0.13	1.67	0.08	0.55

Table 5. Comparison of various forms of k at 15-30 cm depth

Sample Location	Water soluble K mg/kg	Exchangeable K mg/kg	Difficult Exchangeable K mg/kg	Fixed K mg/kg	Total Reserved K mg/kg	Structural K mg/kg	Mobility Factor mg/kg
Control	136.5a	78.02a	46.80a	245.70a	518.70a	195.00a	20.7a
Benin-Akure Bypass	271.1	366.5	50.1	35.1	323.7	165.7	76.5
Benin-Onitsha Bypass	286.6	980.8	467.9	696.1	247.6	37.1	69.1
Benin-Warri Bypass	319.8	858	358.8	345.1	265.2	267.6	265.2
LSD (P≤0.05)	21.1	0.19	2.09	0.15	0.60	0.13	0.22

Table 6. Comparison of various forms of k at 30-45 cm depth

Sample Location	Water soluble K mg/kg	Exchangeable K mg/kg	Difficult Exchangeable K mg/kg	Fixed K mg/kg	Total Reserved K mg/kg	Structural K mg/kg	Mobility Factor mg/kg
Control	800.0a	117.00a	31.23a	124.83a	386.12a	144.30a	28.5a
Benin-Akure Bypass	454.3	1503.4	315.9	259.2	399.7	844.3	66.5
Benin-Onitsha Bypass	920.4	1257.7	644.5	949.6	397.8	91.4	65.3
Benin-Warri Bypass	649.3	799.5	316.8	372.4	347.1	247.6	139.4
LSD (P≤0.05)	15.6	0.13	15.2	0.12	0.17	2.63	0.17

environment in Africa. The increase in Total Nitrogen could be due to the addition of ash from the burning at the dump-site as opposed to no burning at control site [34]. Similarly, Available phosphorus content ranged from very low 2.07 to 21.12, 3.28 to 22.97 and 2.77 to 27.93 mg/kg for Benin-Akure Bypass, Benin-Onitsha Bypass and Benin-Warri Bypass. However, available P values were moderately high at the surface and decreased with depth in all the dumpsites compared to 0.02 to 0.05 mg/kg for the control (Table 2) and decreased with increased soil depth.

3.3 Forms of Potassium (K) in Different Fraction of the Dumpsites Soils in the Study Area

The data on forms of potassium (K) in the soils from different dumpsites is presented in Table 3. The result indicated that K varied in concentration from one dumpsite to another. The water-soluble K and Exchangeable K range from 163.8 to 643.4 mg/kg in surface soils and 271.1 to 319.8 mg/kg in subsurface in Benin-Onitsha Bypass and Benin-Warri Bypass (Table 4 and 5). The trend of water soluble and exchangeable K of surface and subsurface soils showed a good relation with the difficult exchangeable K. The difficult exchangeable K content ranged from 93.6 to 483.6 mg/kg and 50.1 to 467.9 mg/kg .in the surface and subsurface of the dumpsites (Table 5). Potassium forms decreased in the order reserved K > fixed > water-soluble > Exchangeable K, Structural K > Difficulty Exchangeable K as well as the mobility factor for each of the refuse dumpsite investigated. However, the content of water soluble K and exchangeable K content registered an increase over the control across depths in all the dumpsite (Table 3); this may be due to the addition of organic materials as earlier reported by Sood et al., [35]. High content of water-soluble K is recorded in Benin-Onitsha Bypass and Benin-Warri Bypass dumpsites. Both of these dumpsites were statistically different and showed increase over the control. It is interesting to note that the concentrations of soil samples collected far away from the dumpsites (control) is low compared to the ones collected within the vicinity of the dumpsites at different depths (Table 4, 5 and 6). Generally, the amount of the various forms of K extracted decreased as the soil pH decreased. This shows that the k status of the soil varies considerably; this variation may be due to the differences in the mineralogical composition of soils, parent material as well as the degree of weathering and intensity of leaching of K salts. This observation is consistent with Parker et al. [36], who reported that K concentration amongst particle size fractions could be due to differences in their mineralogical composition. Furthermore, K in the dumpsite is higher than those far away from dumpsite, and this could be attributed to the refuse load in the dumpsite; and to various sources of K in the dumpsite. Organic waste as a component of solid domestic waste has be reported to contribute significantly to pollution load in a dumpsite [37].

4. CONCLUSION

The soil samples collected far away from the dumpsites have lower concentrations compared to those from the vicinity of the dumpsites. This shows that the waste dumps had higher concentration of elements, thereby interacting with the soil and enhance their dominance within the dumpsites.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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