DOI: https://doi.org/10.67042/njss.2016.tt0ot2x9

Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

ASSESSMENT OF NICKEL STATUS BASED ON LAND USE IN SELECTED SOIL OF SOUTHWEST, NIGERIA

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ABSTRACT

Contrary to the increased alarm that nickel is a soil pollutant, nickel is an essential micronutrient for the growth and development of legume and cereal crops. This study was carried out to assess the status of nickel (Ni) in four different soils under cultivated, fallowed, forest and dumpsite land use and determine the best extractant to be used for Nickel extraction from soil solution.

Twenty-four (24) bulk surface soil samples (0-20cm depth) were collected from the four different land use types within the University of Ibadan campus. Available nickel was determined using four different extractants (1N NH_4OAc, 0.5N CH_3COOH, 1N HCl and EDTA) and the concentrations were read using Atomic Absorption Spectrophotometer (AAS). The experimental design employed for the screen house experiment was Completely Randomized Design (CRD).

EDTA extracted the highest nickel concentration (37.73 ±1.47 mg/kg), followed by 1N HCl (31.31 ± 1.50 mg/kg) and 1N NH_4OAc (24.26 ± 1.05 mg/kg), while 0.5N CH_3COOH had the least mean value (21.71 ± 1.21 mg/kg). The nickel content in the soils were in the order: dumpsite (35.93 ± 1.63 mg/kg) > cultivated soils (27.89 ± 1.69 mg/kg) > fallow soils (27.24 ± 0.93 mg/kg) > forest soils (23.79 ± 0.98 mg/kg). Although, dumpsite soils had the highest nickel content, it was below the maximum allowable concentration of 50 mg/kg Ni. The results indicated that available nickel ranged from 15.62 to 43.80 mg/kg in all the soil of the four land use types.

EDTA is therefore recommended for Ni extraction in agricultural soils. While care should be taken when using old dumpsite soil for planting since the level of Ni could be high in such soil.

INTRODUCTION

Nickel (Ni) is considered an essential nutrient element for plant growth and development (Epstein and Bloom, 2005; Liu, 2001). Brown *et al* (1987a, 1987b and 1990) discovered and established this fact based on criteria for essential elements for plant growth. Nickel is unique among plant nutrient because of its functions in plant growth and development. This was validated by Wood *et al.* (2004c) that pecan could not complete its life cycle without Nickel (Ni). Nickel (Ni) is one the micronutrients which is required by plants only in small proportion or quantities. It is a key component of selected enzymes involved in Nitrogen metabolism and biological N fixation (Liu *et al.*, 2001). Ni is involved in symbiotic nitrogen fixation through its role as an active center of hydrogenase, a process documented in strains of nitrogen-fixing bacteria: *Bradyrhizobium japonicum, Brady rhizobium sp.* (*Lupinus sp.*), *Rhizobium tropici, Rhizobium leguminosarum, and Azorhizobium caulinodans* (Palacios, 1995 and Lopez, 2011). Low level of

Ni in agricultural soils may limit the activity of hydrogenase from *R. leguminosarum* and the effeciency of symbiotic nitrogen fixation in legumes (Ruiz-Argueso *et al.,* 2000; Malavolta and Moraes, 2007). The first evidence of yield response to Ni was reported by Roach and Barclay (1946) that a significant increase in the yield of potato (*Solanum tuberosum*), wheat (*Triticum aestivum*) and bean (*Phaseolus vulgaris*) from foliar application of dilute Ni solutions.

The evidence of the role of nickel in biological systems gives many examples of increase in yield in field grown crops in response to the application of nickel to the crops or to the soil as reviewed by Mishra and Kar (1974) and Welch (1981). Its role in plant disease resistance has also been observed (Mishra and Kar, 1974). Graham *et al.* (1985) also found that nickel supplied to the root of cowpea (*Vigna unguiculata* (L) Walp.) contained only 0.03 mg/kg Ni dry weight effectively reduced leaf- fungal infection by 50 %.

Nickel concentration in soil varies widely with its estimate ranging from 3 - 1000 ppm; for the world soils, the grand mean was calculated to be 22 ppm with the brand range between 0.2 and 450 ppm (Kabata- Pendias and Pendias, 1992; Cempel and Nikel, 2005; Bencko, 1983; Scott-Fordsmand,1997). Several studies had been done on nickel only as a soil pollutant and not necessarily as an essential nutrient element. Farmers on the other hand, put so much interest in supplying the soil and crop with macronutrients with little attention to micronutrients toxicity or deficiency. In any crop enterprise, the most limiting element is manifested in low crop productivity regardless of the degree of management excellence.

Nickel toxicities and deficiencies occurrence are widespread and currently receiving attention worldwide, especially in Agricultural soils. Therefore, this study was designed to assess the Nickel status in four soils based on land use (cultivated, fallowed, forest and dump site soils).

MATERIALS AND METHODS

Soil Sample Collection

Twenty-four (24) bulk surface soils (0-20cm) were collected in four different locations within the University of Ibadan campus. The selection of the study sites was based on Land Use. These are: Parry road to represent cultivated land (CU) and fallowed land (FA) with the coordinates of $7^0$27'10''N, $3^0$53'20''E; new postgraduate hall road to represent the dumpsite (DS) with coordinates of $7^0$43'94"N, $3^0$89'48E; and Abadina to represent secondary forest (FO) with coordinates of $7^0$27'80''N, $3^0$53'58''E.

Laboratory Methods

In the laboratory, the bulk soil samples were air-dried, crushed and passed through a 2mm sieve, bagged, re-labeled and stored. Soil chemical properties were determined as follows; Soil pH was determined in water suspension using a soil-water ratio of 1:2 using glass electrode pH meter (Udo and Ogunwale, 1978).Organic carbon by Walkley and Black method as modified by Nelson and Sommers (1996) were used. Organic matter was calculated by multiplying percent organic carbon by a correction factor of 1.72. Total nitrogen was determined using macro Kjeldahl digestion and distillation method. Exchangeable Acidity (EA) was extracted using 1M KCl methods and extracted with 0.01N NaOH, Exchangeable bases (Mg^{2+}, Na^+, K^+, and Ca^{2+}) were extracted using NH_4OAc. Ca^{2+} and Mg^{2+} were determined using Atomic Absorption Spectrophotometer, while K^+ and Na^+ were determined by flame photometer (Thomas, 1982).

Available phosphorus was extracted with Bray P-1 method of Bray and Kurtz (1945). Micronutrients (Cu, Zn, Mn and Fe) were extracted using 0.1 N HCl and read with Atomic Absorption Spectrophotometer). Particle size analysis was determined using hydrometer method as outlined by Gee and Or (2002)

Determination of Available Nickel

Four extractants were selected and used for laboratory soil test of available nickel (Ni^{2+}). These include;1N HCl, 1N NH_4OAc, 0.5 N CH_3COOH, 0.05 N EDTA.

Extraction of available nickel with the different extracting solutions was carried out as described by Mishra and Padmakar (1974).

Statistical Analysis

The data collected were subjected to simple statistics such as means and standard deviation. Also, simple correlation coefficients were used to show the relationship between Nickel soil test values obtained with four different extractants for available nickel (Ni^{2+}), to know which of the extractant was best for these soils.

RESULTS AND DISCUSSION

Results of the laboratory analysis of soil samples for chemical properties and particle size distribution of the soil studied are presented in Table 1.

Particle size distribution

Sand fraction in location CU ranged from 880.0 g/kg – 900.0 g/kg with a mean value of 890.0 ± 6.23 g/kg. The silt content ranged from 50.0 – 60.0 g/kg with mean of 58.0 ± 3.72 g/kg, while the clay has values ranging from 48.0 – 60.0 g/kg with mean of 52.0 ± 4.34 g/kg. The distribution pattern in location FA, FO and DS slightly varies from location CU, except that the clay content was a little lower in location FA. Based on the USDA textural class, these values resulted in a sand texture soils. clayey soils are rich in nickel than sandy soil according to Pasternad and Glinski, (1969) while Clay fixes nickel in tropical soils

Soil reaction and Exchanged Acidity

The results indicated that the soils ranged from near neutral to slightly alkaline. In location CU, the pH ranged from 6.8 – 6.9 with mean of 6.9 ± 0.05. The pattern was almost the same for locations FA and FO, but location DS being a dump site had a pH range of 7.6 – 7.7 with a mean of 7.7 ± 0.05. This implies that the soil pH of locations CU, FA and FO were near neutral, while that of location DS was slightly alkaline. The soil pH of this range 6.5 – 7.7 is said to be appropriate for crop production. Soil pH plays a very important role in Ni's availability in soil. At pH > 6.7 it exists in the form of poorly soluble hydroxide and at pH < 6.5 there is an increase in Ni relative soluble compounds (Brown *et al.*, 2006).

The soil Exchangeable Acidity (EA) was low. The values ranged from 0.15 – 0.15 with a mean of 0.15 ± 0 cmol/kg for locations CU and FA, while values ranged 0.15 – 0.20 with mean values of 0.17 ± 0.24 cmol/kg and 0.18 ± 0.02 cmol/kg for locations FO and DS respectively.

Organic carbon, Total Nitrogen and Available phosphorus

The organic carbon content in the soil ranged from 22.96 – 24.22 with a mean of 23.51 ± 0.47g/kg, 24.99 – 26.94 with a mean of 25.97 ± 0.63 g/kg, 26.59 – 30.05 with a mean value of 54.90 ± 0.84 g/kg for locations CU, FA, FO and DS respectively. These values translated to organic matter content of 39.49 – 41.66, 42.98 – 46.34, 45.73 – 51.69 and

91.93 – 96.18 with mean values of 40.47 ± 0.79g/kg, 44.66 ± 1.09 g/kg, 48.82 ± 2.31g/kg and 94.42 ± 1.45 for locations CU, FA, FO and DS respectively. All the soils had over 20 g/kg of organic matter content in the soil surface which suggested very high in organic matter content (FFD, 2012).

Total Nitrogen values ranged from 0.78 – 1.23, 1.57 – 1.82, 1.62 – 1.89 and 5.09 – 5.70 with mean values of 1.05 ± 0.15 g/kg, 1.69 ± 0.11 g/kg, 1.74 ± 0.09 g/kg and 5.47 ± 0.22 g/kg for locations CU, FA, FO and DS respectively. The values for location CU indicated that total nitrogen was low and this is expected as this particular location was under cultivation. The crops planted must have exhausted the Nitrogen in the soil. Again, the soil texture of this location could have contributed to the loss of nitrogen via leaching. The values for locations FA and FO showed that Total Nitrogen was moderate in these locations. While, values for location DS revealed that Total nitrogen was extremely high (FFD, 2012). This once again proves that soils of the Tropics vary high in Total Nitrogen, the variation could be due to low or high plant residues incorporation, intensive cultivation of a particular land and depletion due to the fact that nitrate are readily leached from the soil. Although, this may not solve the problem of leaching, it is advisable to always apply nitrogenous fertilizer in split so that part of it will take care of the vegetative growth while the other will take care of the reproductive phase (Idem and Showemimo, 2004). Also, in the Tropics there is a strong advocacy for application of organo-mineral fertilizer. This will not only provide the required nitrogen but also reduces leaching because it is a slow released fertilizer.

Available phosphorus in the soils ranged from moderate to extremely high. The values ranged from 8.80 – 9.24 with a mean of 8.87 ± 0.40 mg/kg for location CU, values of location FA were not different from location CU. However, available phosphorus values ranged from 10.06 – 11.98 and 53.23 – 56.76 with mean values of 10.95 ± 0.66 mg/kg and 55.49 ± 1.12 mg/kg for locations FO and DS respectively. The values indicated that the available phosphorus was moderate in location FO and extremely high in location DS. According to critical range of 7 – 20 mg/kg and critical value of 15 mg/kg (Bray P-1) (Adeoye, 1986), locations CU – FO will require phosphorus fertilizer application to raise up the phosphorus level of the soils. The high soil pH range in location DS (table 1), suggests why available phosphorus is very high because it is not being fixed in the soil. David *et al.,* 2011 and Donald 2013 reported that the Nickel availability in soil will enhance phosphorus availability (David *et al,* 2011 and Donald, 2013).

Exchangeable Bases (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}).

The soil exchangeable Ca^{2+} ranged from 2.42 – 2.69, 4.05 – 4.22, 2.79 – 2.33 and 22.75 – 24.78 with mean values of 2.57 ± 0.11 cmol/kg, 4.15 ± 0.06 cmol/kg, 2.81 ± 0.02 cmol/kg and 23.65 ± 0.77cmol/kg for locations CU, FA, FO and DS respectively. Exchangeable Mg^{2+} ranged from 0.23 – 0.26, 0.37– 0.68, 0.36 – 0.45 and 1.41 – 1.65 with mean values of 0.25 ± 0.01 cmol/kg, 0.55 ± 0.13 cmol/kg, 0.41 ± 0.04 cmol/kg and 1.56 ± 0.09 cmol/kg for locations CU, FA, FO and DS respectively. Exchangeable K+ ranged from 0.15 – 0.16, 0.25 – 0.39, 0.13 – 0.20 and 1.92 – 2.37 with mean values of 0.16 ± 0.01 cmol/kg, 0.32 ± 0.05 cmol/kg, 0.17 ± 0.03 cmol/kg and 2.08 ± 0.15 cmol/kg for locations CU, FA, FO and DS respectively. Exchangeable Na^{+} values ranged from 0.22 – 0.22 with a mean of 0.22 ± 0 cmol/kg for locations CU-FO. While values for location DS, ranged from 0.30 – 0.30

Table 1: Mean values, standard deviation and ranges of chemical properties and particle size of soil for the four locations studied

								Exchangeable Bases				Particle size			Texture
Location	Calculated	pH	Total N	Org.C g/kg	Org. M	Avail. P mg/kg	Ex. Acidity	Ca Cmol/kg	Mg	K	Na	Sand	Silt g/kg	Clay	
CU	Range	6.8-6.9	0.78-1.23	22.96-24.22	39.49-41.66	8.80-9.24	0.15-0.15	2.42-2.69	0.23-0.26	0.15-0.16	0.22-0.22	880.0-900.0	50.0-60.0	48.0-60.0	
	Mean±SD	6.9±0.05	1.05±0.15	23.51±0.47	40.47±0.79	8.87±0.40	0.15±0	2.57±0.11	0.25±0.01	0.16±0.01	0.22±0	890.0±6.23	58.0±3.72	52.0±4.34	S
FA	Range	6.8-6.9	1.57-1.82	24.99-26.94	42.98-46.34	7.58-8.93	0.15-0.15	4.05-4.22	0.37-0.68	0.25-0.39	0.22-0.22	890.0-950.0	20.0-70.0	30.0-48.0	
	Mean±SD	6.8±0.04	1.69±0.11	25.97±0.63	44.66±1.09	8.27±0.49	0.15±0	4.15±0.06	0.55±0.13	0.32±0.05	0.22±0	929.0±18.75	30.0±18.26	41.0±8.06	S
FO	Range	6.5-6.7	1.62-1.89	26.59-30.05	45.73-51.69	10.06-11.98	0.15-0.20	2.79-2.83	0.36-0.45	0.13-0.20	0.22-0.22	890.0-952.0	0-70.0	40.0-50.0	
	Mean±SD	6.6±0.07	1.74±0.09	28.39±1.34	48.82±2.31	10.95±0.66	0.17±0.24	2.81±0.02	0.41±0.04	0.17±0.03	0.22±0	926.0±23.79	27.0±25.60	47.0±3.22	S
DS	Range	7.6-7.7	5.09-5.70	53.45-55.92	91.93-96.18	53.23-56.76	0.15-0.20	22.75-24.78	1.41-1.65	1.92-2.37	0.30-0.30	890.0-932.0	20.0-70.0	40.0-50.0	
	Mean±SD	7.7±0.05	5.47±0.22	54.90±0.84	94.42±1.45	55.49±1.12	0.18±0.02	23.65±0.77	1.56±0.09	2.08±0.15	0.30±0	915.0±17.98	38.0±19.51	47.0±3.39	S

CU – cultivated
FA – fallow
FO – forest
DS – dump site
SD – standard deviation
S – Sand

with a mean of 0.30 ± 0 cmol/kg. The values for exchangeable calcium indicated that Ca^{2+} were low in location CU-FO, while it was very high in location DS (FFD, 2012). The values of Mg^{2+} showed that Mg^{2+} was very low in location CU, while location FA and FO indicated a low concentration. However, exchangeable magnesium was moderate in location DS. Exchangeable potassium values indicated that locations CU and FO were very low in K^{+}, moderate in location FA. While, locations DS values showed that exchangeable potassium was very high. The low K^{+} in soil indicates the need for potassium fertilizer. The soil Na^{+} content for locations CU-FO were low while moderate for location DS. The low values indicated that the soils have good aggregate stability with good pores distribution. The basic cations decreased in the order Ca > Mg > K > Na in locations FA and DS which was in conformity with Oputa and Udo (1980) findings. While, the order did not follow for locations CU and FO.

Micronutrients contents in the soils studied

Available Mn. Fe, Cu and Zn are presented in Table 2. Available Mn ranged from 84.80 – 118.0, 114.0 – 133.0, 78.99 – 81.40 and 42.50 – 45.25 with mean values of 105.05 ± 12.24 mg/kg, 121.32 ± 7.02 mg/kg, 80.28 ± 0.83 mg/kg and 44.53 ± 1.01mg/kg for location CU, FA, FO and DS respectively. Manganese content was the highest among the micronutrients studied in location CU-FO, but was low in location DS. Iron was the second highest after manganese and ranged from 68.51 – 79.60, 58 23 – 69.80, 150.0 – 184.0 and 1.69 – 2.90 with mean values of 75.04 ± 5.15 mg/kg, 65.67 ± 5.03 mg/kg, 170.18 ± 12.31 mg/kg and 2.28 ± 0.50 mg/kg for locations CU, FA, FO and DS respectively. Available Fe was highest at location FO and very low in location DS. Copper had the least concentration with values ranging from 0.38 – 1.13, 1.05 – 1.15, 0.46 – 0.50 and 0.12 – 0.37 with mean values of 0.98 ± 0.29 mg/kg, 1.09 ± 0.03 mg/kg, 0.49 ± 0.01 mg/kg and 0.27 ± 0.10 mg/kg for locations CU, FA, FO and DS respectively. Available copper was below the critical level in location 4, while locations CU-FO were above the critical level of 0.3 mg/kg Cu (Rhue and Kidder, 1983). The available zinc was somewhat higher than that obtained for Cu in locations CU – FO. However, the values revealed that Zn was the

Table 2: Mean values, standard deviation and ranges of micronutrients status for the four sites studied

Location	Calculated	Mn	Fe	Cu	Zn
		→ mg/kg ←			
CU	Range	84.80-118	68.51-79.60	0.38-1.13	2.21-3.33
	Mean±SD	105.05±12.24	75.04±5.15	0.98±0.29	2.67±0.51
FA	Range	114.00-133.00	58.23-69.80	1.05-1.15	4.26-6.45
	mean±SD	121.32±7.02	65.67±5.03	1.09±0.03	5.67±0.96
FO	Range	78.99-81.40	150.00-184.00	0.46-0.50	4.25-4.99
	Mean±SD	80.28±0.83	170.18±12.31	0.49±0.01	4.69±0.23
DS	Range	42.50-45.25	1.69-2.90	0.12-0.37	83.50-85.14
	Mean±SD	44.53±1.01	2.28±0.50	0.27±0.10	84.34±0.59

Table 4: Available nickel determined by four different extractants for the soils studied

Location	Calculated	1N NH_4OAc	0.5N CH_3COOH	1N HCl	EDTA
		→ mg/kg ←			
CU		29.61	20.54	23.97	36.86
		28.92	21.95	25.45	29.98
		26.55	21.25	29.62	37.32
		29.77	19.69	27.23	35
		27.81	20.81	29.93	37.4
		28.65	19.99	24.57	36.56
	Mean±SD	28.55±1.10	20.71±0.75	26.79±2.34	35.52±2.60
FA		22.32	19.17	31.48	36.66
		21.4	21	34.06	33.82
		20.11	20.05	30.67	35.68
		21.13	21.2	33.57	35.97
		19.79	19.75	31.79	34.91
		20	20.36	33.41	35.53
	Mean±SD	20.79±0.90	20.25±0.69	32.49±1.24	35.43±0.88
FO		15.24	16.68	28.84	36.53
		15.08	16.1	26.92	36.06
		17.22	15.55	29.04	34.98
		14.48	14.28	27.56	37.33
		16.77	14.32	29.78	36.75
		14.96	16.79	28.47	35.44
	Mean±SD	15.62±1.00	15.62±1.20	28.44±0.95	36.18±0.79
DS		31.67	26.54	39.84	45.81
		30.31	31.25	35.88	40.99
		33.9	28.54	36.4	42.91
		32.2	32.95	38.73	44.09
		31.19	32.18	38.22	43.5
		33.38	30.26	36.05	45.51
	Mean±SD	32.10±1.23	30.28±2.18	37.52±1.49	43.80±1.62

highest in location DS. The values ranged from 2.21 – 3.33, 4.26 – 6.45, 4.25 – 4.99 and 83.50 – 85.14 with mean values of 2.67 ± 0.51 mg/kg, 5.67 ± 0.96 mg/kg, 4.69 ± 0.23 mg/kg and 84.34 ± 0.59 mg/kg for locations CU, FA, FO and DS respectively. Available manganese and zinc were above the critical levels of 5.0 and 1.0 mg/kg for Mn and Zn respectively, (Rhue and Kidder, 1983) in locations CU, FA, FO and DS Values of iron and zinc showed that both micronutrients were above the critical level in locations CU –FO, but were below the critical levels of 2.5 mg/kg for Fe and 0.3 mg/kg for Cu (Viets and Lindsay, 1973; Rhue and Kidder, 1983).

The low available Fe and Cu obtained in location DS, suggests from (Table 1) that both micronutrients are probably fixed by high organic matter (carbon), high soil pH and possibly high available phosphorus obtained in this location (Petruzzelli and Buidi, 1976; Stevenson and Ardakani, 1972; and Brennan, 1986).

Nickel contents in the soils studied

Available nickel extracted with four different extractant is presented in Table 4. Available nickel extracted with 1N NH_4OAc ranged from 26.55 – 29.77, 19.79 – 22.32, 14.48 – 17.22 and 30.31 – 33.90 with mean values of 28.55 ± 1.10

Table 5: Correlation coefficients calculated for the four extractants

	NH_4OAc	CH_3COOH	HCL	EDTA
NH4OAc	1.000			
CH3COOH	0.829***	1.000		
HCL	0.419*	0.757***	1.000	
EDTA	0.582**	0.748***	0.756***	1.000

* Correlation is significant at P ≤ 0.05
** Correlation is significant at P ≤ 0.01
*** Correlation is significant at P ≤ 0.001

mg/kg, 20.79 ± 0.90 mg/kg, 15.62 ± 1.00 mg/kg and 32.10 ± 1.23 mg/kg for locations CU, FA, FO and DS respectively. The nickel contents extracted using acetic acid (0.5N CH_3COOH) was the least among the four extractants used with values ranging from 19.69 – 21.95, 19.17 – 21.20, 14.28 – 16.79 and 26.54 – 32.95 with mean values of 20.71 ± 0.75 mg/kg, 20.25 ± 0.69 mg/kg, 15.62 ± 1.02 mg/kg and 30.28 ± 2.18 mg/kg for locations CU, FA, FO and DS respectively. Nickel extracted by 1N HCl ranged from 23.97 – 29.93, 30.67 – 34.06, 26.92 – 29.78 and 35.88 – 39.84 with mean values of 26.79 ± 2.34 mg/kg, 32.49 ± 1.24 mg/kg, 28.44 ± 0.95 mg/kg and 37.52 ± 1.49 mg/kg for locations CU, FA, FO and DS respectively. However, EDTA extractant had the highest extractable nickel in all the four locations with values ranging from 29.98 – 37.40, 33.82 – 36.66, 34.98 – 37.33 and 40.99 – 45.81 with mean values of 35.53 ± 2.60 mg/kg, 35.43 ± 0.88 mg/kg, 36.18 ± 0.79 mg/kg and 43.80 ± 1.62 mg/kg for CU, FA, FO and DS respectively.

The highest value of available nickel was recorded with the EDTA extractant. This is expected because EDTA is known to be a chelating agent and probably extracting not from the same pool that the plants are taking. EDTA had been reported to extract more metals than any other extracting agent by Wuana *et al.*, 2010. The maximum available nickel was observed in location DS (dump site); this maybe due to the fact that organic matter of this particular location is extremely high. Shi *et al.* (2012) reported that Ni adsorption on soil organic matter (SOM) was dominant in the short term and the slow transfer of adsorbed Ni to Ni- layered double hydroxide (Ni-LDH) phases with longer reaction times. High Ni level in dumpsite could be attributed to the accumulation of industrial and municipal wastes which are major sources of Heavy metals in polluted soils. This same assertion was reported by (European Environmental Agency, 2004; Birmingham & McLaughlin, 2006; Jin *et al.,* 2009) that the release of high quantities of Ni into the environment, could be attributed to industrial sources, activities in mines or smelters, production of alloys' use of fertilizers and pesticides and dumping of wastes materials.

Correlation coefficient was calculated for the four nickel extractants and the result is presented in Table 5. NH_4OAc correlated positively with CH_3COOH (0.829***), HCl (0.419*), EDTA (0.582**). CH_3COOH correlated positively with HCl (0.757***), EDTA (0.748***). All the extractants correlated positively with each other significantly at (P = 0.001, P ≤ 0.01 and P ≤0.05). The result indicates that all four

extractants are extracting nickel from the same pool at different levels.

CONCLUSION

This study investigated nickel contents of four different soils (cultivated, fallowed, forest and dumpsite soils) using four different extractants (1N NH_4OAc, 0.5N CH_3COOH, 1N HCl and EDTA). Nickel contents in soil of locations CU-FO were below the maximum allowable concentration of 50 mg/kg (Official Gazette 48/95, 1995) using the four different extractants. While, location DS being a dumpsite had the maximum allowable Ni concentration which may be due to industrial wastes like batteries and municipal waste too.

The obtained difference among the four extractants showed a decreasing trend in this order EDTA > 1N HCl > 1N NH_4OAc > 0.5 N CH_3COOH. Since published experimental research on this micronutrient is scanty in tropical soils, more research on Nickel is recommended. Also, acetic acid could be used as the best extractant in the tropics for available nickel.

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