

# Some Elemental Content of Soil Within Catchment of River Jakara in Kano, Nigeria

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## Abstract

The use of untreated urban wastes and domestic sewage contaminated water for the irrigation of agricultural soils is on the rise particularly in the developing countries and is a public health concern with regards to the consumption of vegetables and fruits produced in them which may indirectly accumulate heavy metals in their edible portions. Using the atomic absorption spectrophotometry (AAS), concentrations of Ca, Mg, Na, K (essential bulk elements), Pb, Cd, Cr, Ni, Cu, Zn, Co and Fe (trace elements) were determined in 3 designated areas within the catchment area of River Jakara in Kano Nigeria. Samples were collected from two depths 0-15cm and 15-30cm to cover both dry and wet seasons. The mean concentrations of elements obtained ranged from 0.026 mg/g Cd to 46.83 mg/g Fe and occurred in the magnitude of Fe > Ca > K > Na > Pb > Zn > Co > Cu > Cr > Ni > Cd. The concentrations of the trace elements in the soils in the two depths exceeded the international recommended permissible limits establishing the pollution of the irrigation soils with the trace elements investigated. Based on the findings, it is recommended among others that the relevant organ of government should find an alternative farmland for the farmers within the catchment area of River Jakara where unpolluted waste sources can be utilized for the irrigation of vegetables.

**Keywords:** concentration, metals, pollution, soil, wastewater

## 1. Introduction

All countries of the world are faced with major problems arising out of the rapid increase in their population and Nigeria is not an exception. Nigeria has an area of 923,768 sq. km and density of 95.8 per sq. km (CBN, 1998) with a population of 140,000,542 as at the last census in 2006 (Daily Trust, 2007). In the census, Kano was declared the most populated state with a population of 9,383,682 which is 6.70% of the total population. With the increase in population, there was rapid urbanization which also resulted in agricultural development and rapid industrialization. Bye products of these developments have yielded large waste production in both volume and diversity resulting in their indiscriminate dumping in the environment thereby polluting them as they are sources of elements particularly the heavy metals.

Soils are the major sink for heavy metals released into the environment by these anthropogenic activities such as industrial, transport, agricultural which contaminate it (Wuana & Okieimen, 2011). For instance, soils in the vicinity of Surat industrial area of Western India were found to be significantly contaminated with metals like copper (Cu), chromium (Cr), cobalt (Co), vanadium (V) and zinc (Zn) at levels far above the background concentration in soil (Krishna & Govil, 2007). Assessment of soil pollution by slag from an automobile battery manufacturing plant in Nigeria, showed lead (Pb) in soil having levels higher than the permissible level while cadmium (Cd), Cr, and nickel (Ni) were within the permissible limits (Adie & Osibanjo, 2009). Nwachukwu, Feng, and Alinnor (2010) revealed that soils from Okigwe, Nekede and Orji automobile mechanic villages in Imo State, Nigeria, were also above the background levels in the 100cm soil profile for iron (Fe), Pb, manganese (Mn), Cu, Cr and nickel.

Soils within the catchment area of River Jakara in Kano, Nigeria, are used for agriculture and allow the production of crops and vegetables throughout the year which are of economic benefits to the local communities and environs. River Jakara which is used for the irrigation of the crops transports some of the urban wastes and

domestic sewage in addition to other wastes that assist accumulation of some trace elements in it and is polluted (Lawal, 2001; Dike, Ezealor, and Oniye, 2004; and Dike, Ezealor, Oniye, and Ajibola, 2013). Polluted irrigation water is a source of trace elements to soils and subsequently in the vegetables planted in them (Doyle, 1998). Application of biosolid materials (composts and sewage sludge) is a common practice utilized by the farmers. This can lead to the accumulation of heavy metals such as As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Mo, Zn, Sb, in the soil (Basta, Ryan, and Channey, 2005). Municipal wastes have also been reported (Fatoki, 2003) as a source of some trace elements such as chromium. In addition, large quantities of fertilizers are regularly added to the top soils during intensive farming to supplement the macronutrients such as Ca, Mg, K, etc for their normal growth. Jones and Jarvis (1981) reported that fertilizers also contain some of the microelements such as Cd and Pb as impurities, which after continued application may significantly increase their content.

Abundant literature materials exist on heavy metal pollution of soils through irrigation activities particularly with sewage waste. For instance, a large proportion of soil around the city Lahore, Pakistan, has been contaminated with Cadmium (Cd), Nickel (Ni), Lead (Pb), and Copper (Cu) due to the application of sewage waste for many years (Younas, Shahzad, Afzal, Khan, and Ali, 1998). Nan and Zhao (2000) observed that most croplands in the vicinity of rivers fed with industrial sewage have been contaminated by micrometals. Unlike organic contaminants which are oxidized to carbon (iv) oxide by microbial action, most metals do not undergo microbial or chemical degradation (Kirpichtchikova *et al.*, 2006) and their total concentration in soils persists long time after their introduction (Adriano, 2003). The chemical composition of soil particularly its elemental content is also environmentally important because toxic metal concentrations can reduce soil fertility, increase input to food chain which leads to the accumulation of the toxic elements in food stuffs and ultimately can endanger human health (Krishna & Govil, 2007).

These elements have carcinogenic, mutagenic and teratogenic effects in humans with long-term cumulative exposure (Das, 1990). Some elements such as Cd and Cr for instance, act as carcinogens and others such as Pb are associated with developmental abnormalities in children (Marshall *et al.*, 2003). Exposure of high Pb levels can also damage the organs responsible for sperm production in men, cause miscarriage in pregnant women, and damage the brain and kidneys and ultimately cause death (Martin & Griswold, 2009). According to Parveen, Khuhro, & Rafiq, (2003), a slight increase in the concentration of Zn may interfere with physiological processes; toxic level of Cu results in anaemia, intestinal disorders, circulatory disturbances and liver and kidney failure when its concentration crosses safe limits. Olafisoye, Adefioye, & Osibote, (2013) further stated that excess of Zn can lead to Cu deficiency, immune system disorders, fatigue, nausea, hair loss, mental apathy, and reproductive and growth disorders. Higher cardiotoxicity than general toxicity has been indicated (Donald, Rowe, & Clark, 1986) as a result of high levels of Co in the kidney, liver and testes.

The objective of this present study was to investigate some of the elements - Ca, Mg, Na, K with particular emphasis on the heavy metals namely Pb, Cd, Cr, Ni, Cu, Zn, Co and Fe in soils within the catchment area of River Jakara in Kano, Nigeria, in view of the establishment of the contamination of the river used extensively for the irrigation of vegetables with the same metals.

## 2. Sampling Sites

Collection of soil samples were made at 3 designated points (sites 2, 3 and 4) along the River Jakara based on the irrigation activities carried out on the areas (Figure1). Site 1 is at the "T" junction of Ibrahim Babangida and Taiwo roads and near the origin of the river but was devoid of irrigation activities. Site 2 is at the Abattoire and Katsina road junction where the water used for the irrigation of the vegetables receives sewage from the abattoire and domestic wastes from the residential areas in Fagge. Site 3 is at the junction of Burma and Zungeru roads and receives effluents and wastes mainly from a hospital and also effluents from car washing activities and mechanic workshops. Site 4 is at the Airport road bridge which receives domestic wastes and runoffs from dump sites particularly during the rainy season.

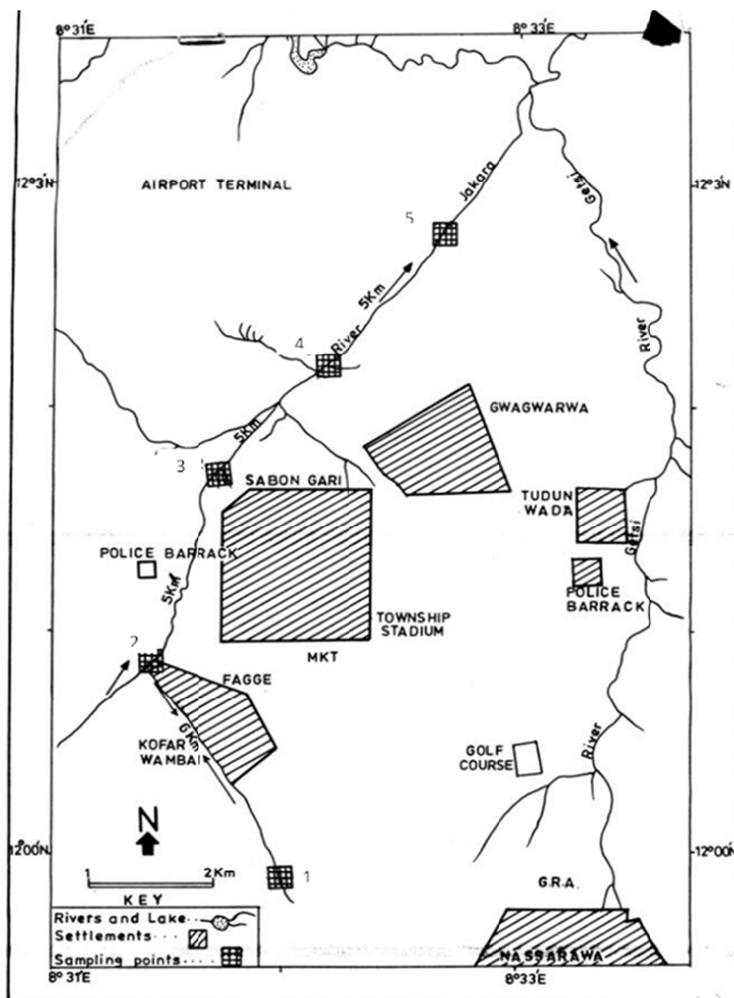


Fig. 1: Map of the study area showing the sampling points.

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### 2.1 Sample Collection and Treatment

Composite soil samples were taken at two depths 0-15cm and 15-30cm to cover both dry and rainy seasons using an auger. Samples were collected in triplicates for each site. Samples were then stored in polythene bags, taken to the laboratory and air-dried. Samples were later ground using a mortar and pestle and sieved using a 2mm sieve. Samples were further kept at  $65^{\circ}\text{C} \pm 1^{\circ}\text{C}$  for 24 hours to obtain a constant weight (Kisku, Barman, and Bhargara, 2000). Digestion of samples were carried out using  $\text{HNO}_3$  (sp. gr. 1.42) and  $\text{HCl}$  (sp. gr. 1.18 ) according to the standard method described by (Kisku *et al.*, 2000). Metal analysis was carried out using the Atomic Absorption Spectrophotometer (AAS) (UNICAM 969) at the National Research Institute for Chemical Technology (NARICT), Zaria, Nigeria.

### 2.2 Data Analysis

Variations in the concentrations of metals in soil samples were compared using the area plots and the annual means of the data obtained.

3. Results

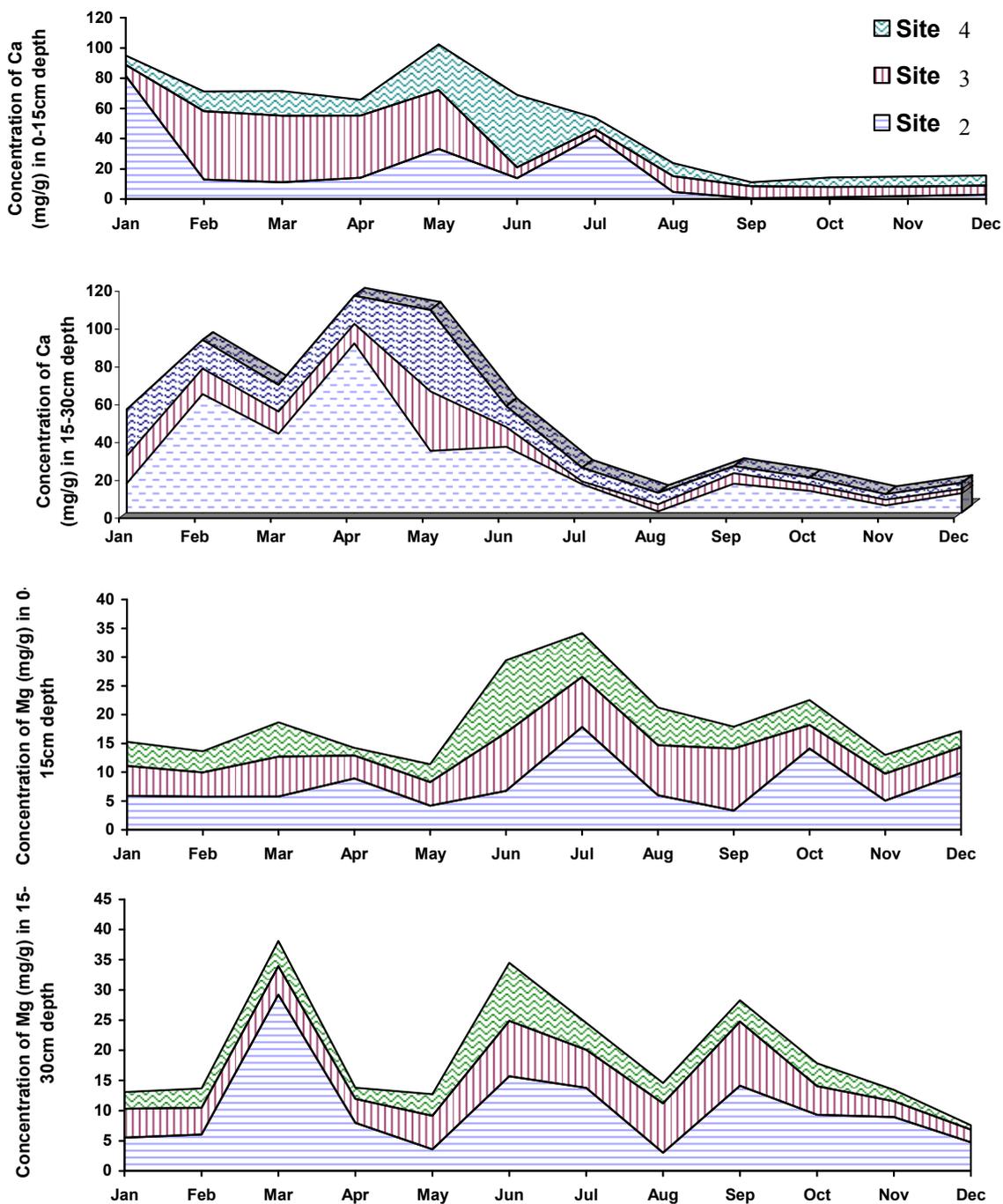


Figure 2. Area plot of Ca and Mg concentrations 0-15cm and 15-30cm depths respectively for the study period

Figure 2 illustrates the variation in Ca and Mg concentrations in each of the depths of the soil (0-15cm and 15-30cm) in the three sites sampled. In site 2, Ca was highest (81.67 mg/g) in January and lowest (0.45 mg/g) in September between the 0-15cm depth but between the 15-30cm, the highest concentration (89.39 mg/g) was in April and the lowest (0.57 mg/g) in August. At site 3 (0-15cm depth), the highest concentration of 45.30 mg/g was in February, while the lowest (4.43 mg/g) was in July but between the 15-30cm, the highest (31.54 mg/g) occurred in May and the lowest (1.42 mg/g) in July. The highest concentration (47.96 mg/g) and the lowest (2.59 mg/g) at site 4 (0-15cm depth) were in June and September respectively but between 15-30cm, the highest (43.06 mg/g) and the lowest (3.01 mg/g) were in May and November respectively.

The highest concentrations of Mg (17.83 mg/g) and the lowest (3.34 mg/g) at site 2 (0- 15cm depth) were obtained in July and September but between 15- 30cm, the highest (29.23 mg/g) and the lowest (3.01 mg/g) were in March and August respectively. In both depths at site 3, Mg was highest in September with values of 10.75 mg/g and 10.63 mg/g but the lowest (3.99 mg/g and 2.11 mg/g) was in April and December between 0-15 and 15-30cm depth respectively. Also in both depths at site 4, the highest concentration of the metal occurred in June with values of 12.57 mg/g and 9.63 mg/g and the lowest were in the same months as those at site 3 with values of 1.31 mg/g and 0.74 mg/g respectively.

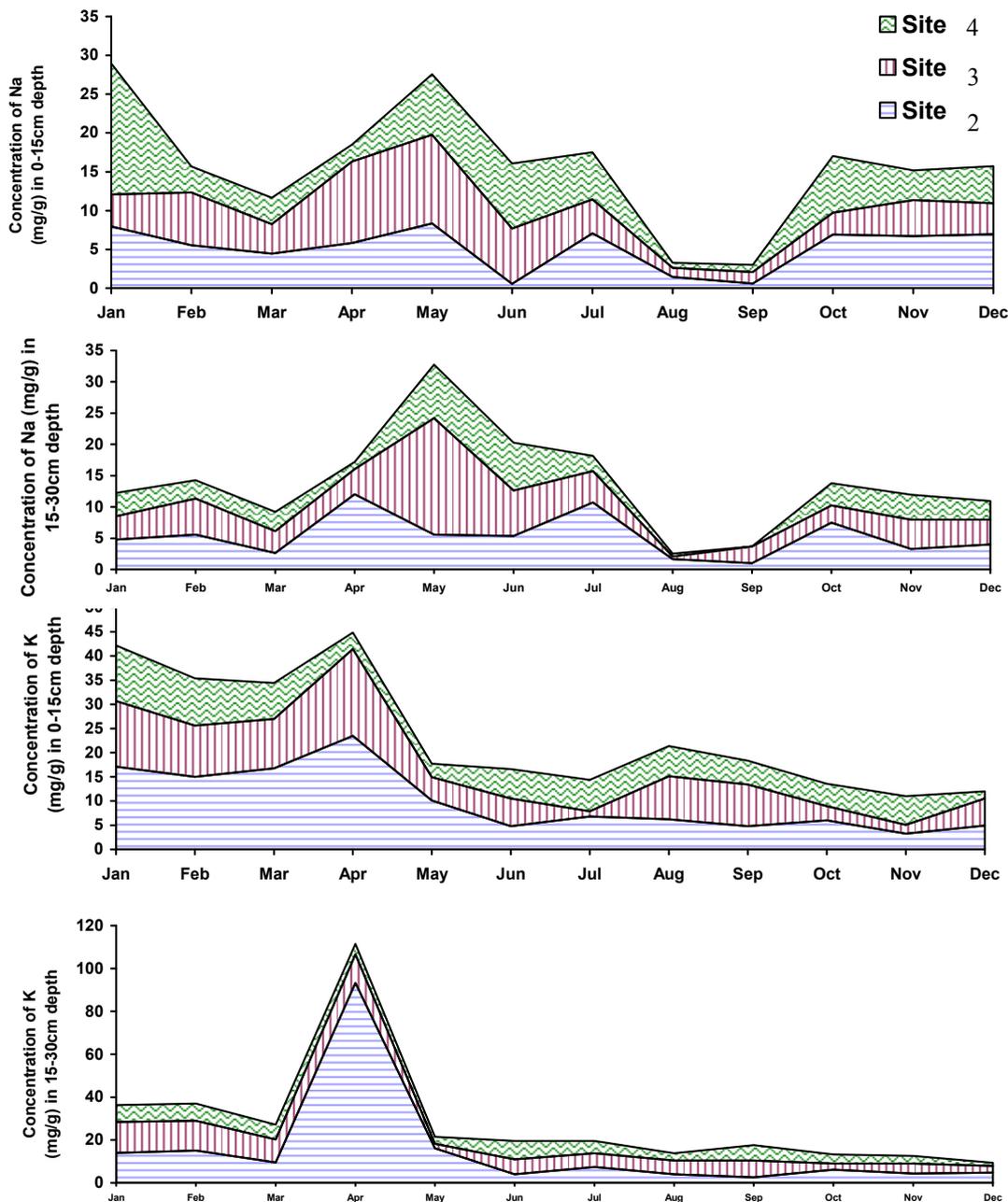


Figure 3. Area plot of Na and K concentrations 0-15cm and 15-30cm depths respectively for the study period

Figure 3 shows that Na was highest (8.35 mg/g) in May and lowest (0.58 mg/g) in June between 0-15cm depth at site 2 but between 15-30cm, the highest concentration (12.03 mg/g) and the lowest (1.02 mg/g) were in April and September respectively. In both depths at site 3, it was highest in May with values of 11.42 mg/g and 18.62 mg/g, and lowest in August with values of 1.17 mg/g and 0.41 mg/g respectively. The highest concentration (16.90 mg/g) and the lowest (0.66 mg/g) at site 4 (0-15cm depth) occurred in January August but between 15-30cm

depth, the highest value (8.59 mg/g) was obtained in May and the lowest in September when the metal was not detected in the depth.

Figure 3 also reveals that the highest concentration of K in the two depths at the two depths at site 2 occurred in April with values of 23.45 mg/g and 93.27 mg/g while the lowest were in November and September with values of 3.26 mg/g and 1.09 mg/g respectively. The highest in both depths at site 3 were obtained in January with values of 13.52 mg/g and 14.38 mg/g. The lowest (1.08 mg/g) between 0-15cm depth was in July while that of 15-30cm depth, was in May with a value of 2.08 mg/g. At site 4, (0-15cm depth) the highest (11.53 mg/g) was in January and the lowest (1.52 mg/g) in December while at the 15-30cm depth, the highest value of 8.59 mg/g was observed in June and the lowest (1.48 mg/g) also in December.

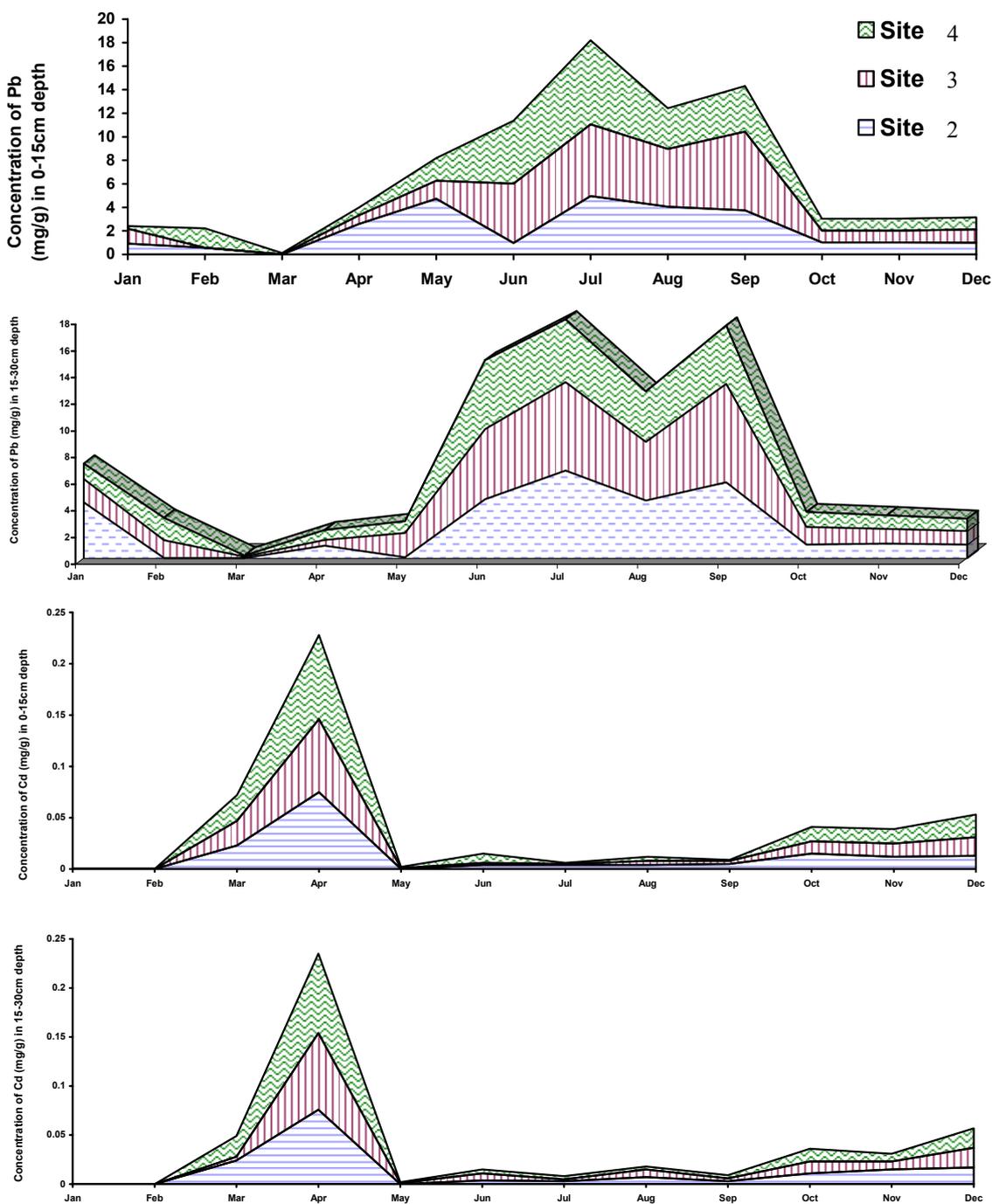


Figure 4. Area plot of Pb and Cd concentrations 0-15cm and 15-30cm depths respectively for the study period

The highest concentrations of Pb in both depths at site 2 occurred in July with values of 4.69 mg/g and 6.57 mg/g and the lowest between the 0-15cm depth was in March with a value of 0.009 mg/g. Between 15-30cm depth, the lowest was obtained in May when the metal was not detected in the depths (Figure 4). In both depths at site 3, Pb was highest in September with values of 6.69 mg/g and 6.69 mg/g. The lowest value between 0-15cm depths was in February when the metal was not detected and in March in the 15-30cm depth with a value of 0.112 mg/g. The highest concentration of Pb (7.13 mg/g) at site 4 between the 0-15cm depth occurred in July while the highest (5.16 mg/g) between the 15-30cm depth, was in June. In both depths, the lowest were obtained in March with values of 0.110 mg/g and 0.071 mg/g respectively. Fig. 4 also reveals that the concentrations of Cd were similar in the two depths in all the sites. The highest concentrations in all the sites in both depths were obtained in the same month – April with values of 0.075 mg/g, 0.071 mg/g and 0.082 mg/g in the 0-15cm depth and 0.076 mg/g, 0.078 mg/g and 0.081 mg/g in the 15-30cm. The lowest values in all the sites were also observed in the same months – January and February when the metal was not detected in both depths.

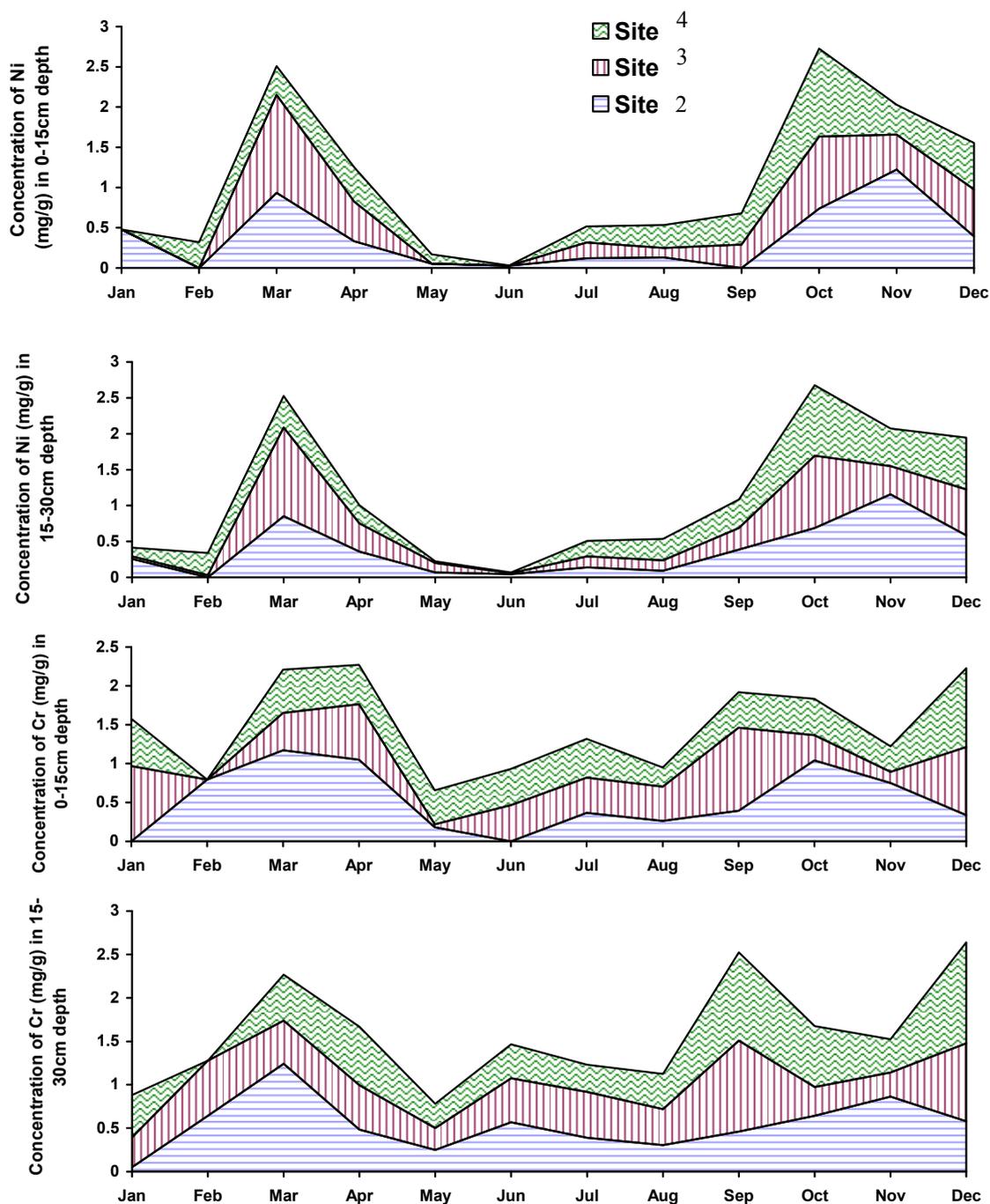


Figure 5. Area plot of Ni and Cr concentrations 0-15cm and 15-30cm depths respectively for the study period

Figure 5 presents the variations of Cr and Ni in both depths in all the sites. At site 2 (0-15cm), Cr was highest (1.17 mg/g) in March and the lowest in January and June when it was not detected but between 15-30cm depth, the highest (1.24 mg/g) was also in March and the lowest (0.051 mg/g) in January. In both depths at site 3, the highest concentrations occurred in September with values of 1.07 mg/g and 1.04 mg/g respectively. The lowest in the 0-15cm depth was in February when the element was not detected and in November in the 15-30cm depth with the value of 0.279 mg/g. In both depths at site 4, the highest concentrations (1.02 mg/g and 1.16 mg/g) were obtained in December and the lowest was in February when the element was not detected. In both depths at site 2, the highest concentrations of Ni (1.22 mg/g and 1.16 mg/g) were in November and the lowest in February when it was not detected. In both depths also at site 3, Ni concentrations were highest in October with values of 0.898

mg/g and 1.01 mg/g but the lowest the lowest between 0-15cm depths were in January, February and June when it was not detected. Between 15-30cm depths, the lowest occurred in June with a value of 0.013 mg/g. The highest values in both depths at site 4 (1.09 mg/g and 0.983 mg/g) occurred also in October. While the element was not detected in January between the 0-15cm depths, it had a concentration of 0.010 mg/g in June in 15-30cm.

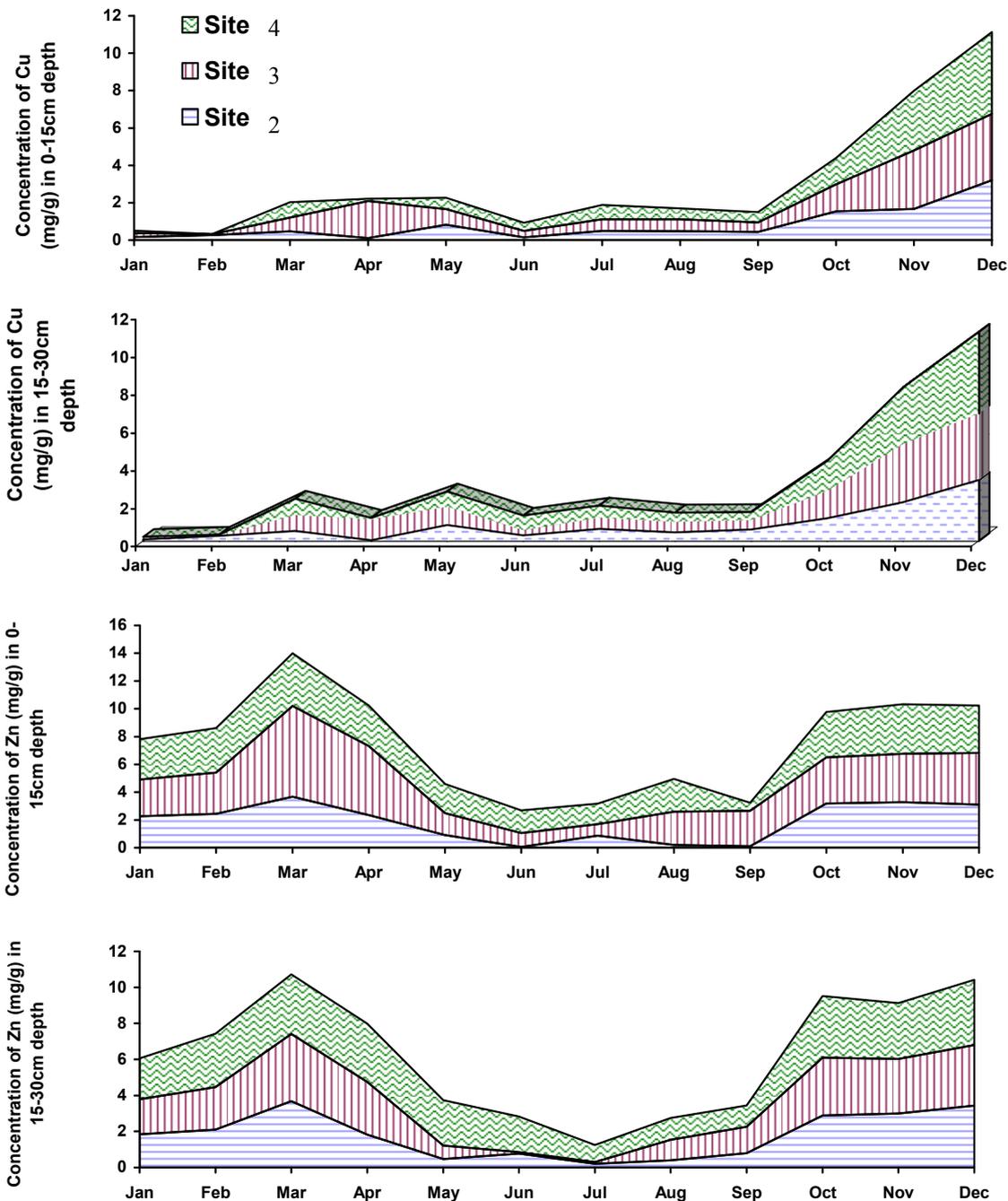


Figure 6. Area plot of Cu and Zn concentrations 0-15cm and 15-30cm depths respectively for the study period

In both depths at site 2, Cu values were highest (3.20 mg/g and 3.22 mg/g) in December and lowest in (0.103 mg/g and 0.026 mg/g) in April (Figure 6). The highest values in both depths at site 3 (3.56 mg/g and 3.52 mg/g) were also observed in December. The lowest in both depths (0.041 mg/g and 0.033 mg/g) occurred in February. The highest values at site 4 in both depths (4.37 mg/g and 4.32 mg/g) were also observed in December but the

lowest (0.018 mg/g and 0.010 mg/g) were in February and January respectively. Fig. 6 also shows that the highest concentrations of Zn at site 2 in both depths were in March with values of 3.67 mg/g and 3.68 mg/g while the lowest (0.058 mg/g and 0.206 mg/g) were in June and July respectively. The trend was similar at site 3 as the highest values in the two depths (6.52 mg/g and 3.74 mg/g) also occurred in March but the lowest (0.823 mg/g and 0.090 mg/g) were in July and June respectively. At site 4, in both depths, the highest concentrations (3.79 mg/g and 3.97 mg/g) were revealed in March and December while the lowest were in September and July with values of 0.594 mg/g and 0.945 mg/g respectively.

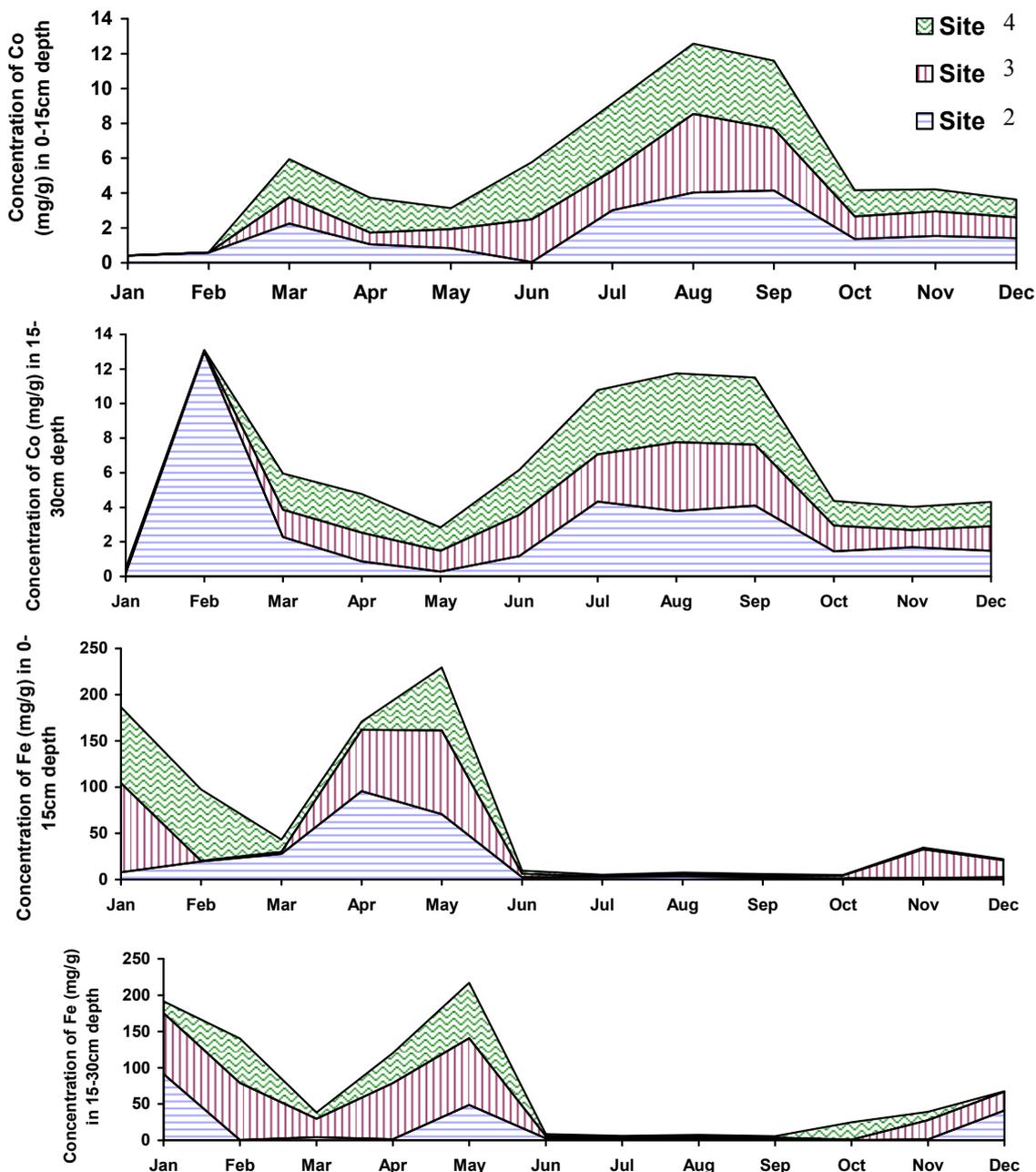


Figure 7. Area plot of Co and Fe concentrations 0-15cm and 15-30cm depths respectively for the study period

Cobalt was highest in both depths at site 2 (4.14 mg/g and 4.33 mg/g) in September and July and lowest (0.041 mg/g and 0.171 mg/g) in June and January respectively (Figure 7). At site 3 in both depths, the highest concentrations (4.51 mg/g and 3.99 mg/g) occurred in August. While the element was not detected in January

and February in the 0-15cm depth, it was in the 15-30cm in February with the lowest value of 0.590 mg/g. The highest values of Co in both depths at site 4 (4.02 mg/g and 3.97 mg/g) were also in August and while it was not detected between 0-15cm depth in January, it was in February in the 15-30cm with the lowest value of 0.043 mg/g. Fig. 7 also revealed that in both depths at site 2, Fe values were highest (95.60 mg/g and 91.91 mg/g) in April and January respectively and lowest (1.38 mg/g and 0.500 mg/g) in August. The highest values in the two depths at site 3 (96.27 mg/g and 91.80 mg/g) occurred in January and May while the lowest (0.354 mg/g and 0.591 mg/g) were in February and July respectively. The highest value at site 4 between the 0-15cm depth (82.34 mg/g) was obtained in January and the lowest (0.565 mg/g) in October but between the 15-30cm depth, the highest (76.57 mg/g) was in May and the lowest (0.995 mg/g) in December.

Table 1. Comparison of annual mean concentrations of metals in soils (mg/g) with recommended permissible limits (mg/g)

Metal	Annual Mean Values	Permissible Limits	WHO Permissible (ppm)
Ca	33.359	100 – 400	--
Mg	12.800	--	--
Na	10.091	--	--
K	17.250	20 – 400	--
Pb	4.720	0.002 – 0.02	0.1
Cd	0.026	0.00025 – 0.004	0.01
Cr	1.027	0.01 – 0.20	0.05
Ni	0.727	0.005 – 0.50	6.5
Cu	2.025	0.005 – 0.1	1.5
Zn	4.581	0.02 – 0.3	15.0
Co	4.027	0.001 – 0.06	--
Fe	46.826	7.0 – 550	0.3

Source: Allen, S.E., Grimshaw, H., Parkinson, J.A. and Quamby, C. (1974)

Concentrations of the metals in the sites occurred in the magnitude of Fe > Ca > K > Mg > Na > Pb > Zn > Co > Cu > Cr > Ni > Cd

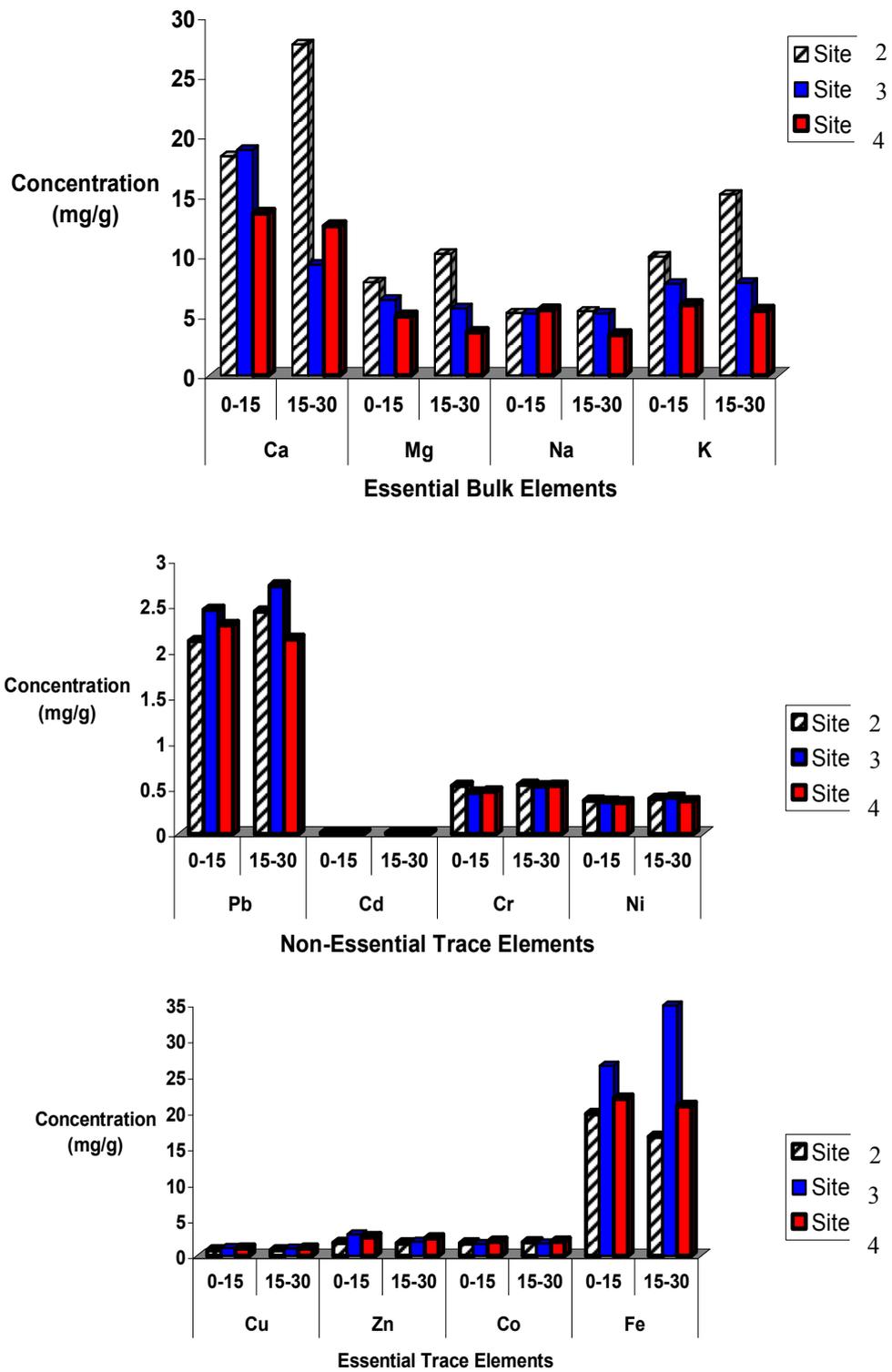


Figure 8. Annual means (mg/g) of essential and nonessential elements to plants found in soils sampled at different depths

The annual means (mg/g) of the elements in the soil at different depths presented in Table 1 and Figure 8 revealed that the concentrations of Ca, Mg, Na and K (essential bulk elements) at sites 3 and 4 were higher in the 0-15cm depth than in the 15-30cm except Na and K which showed fairly uniform concentrations at site 3. The

reverse was the case at site 2 except Na with higher concentration in the 15-30cm depth. In the non-essential trace elements, Pb was higher in the 15-30cm depth at sites 2 and 3 but lower in the same depth at site 4. In the two depths in all the sites, Cd was below detection but Cr and Ni exhibited fairly uniform levels. Similar patterns of element accumulation in the two depths were exhibited by some of the essential trace elements – Cu, Zn and Co. Iron was higher in the 0-15cm depth at sites 2 and 4 but lower in the same depth at site 3.

#### 4. Discussion

High values of Ca in all the sites in both depths from January to early rains may be related to the irrigational activities of the season in addition to its natural deposits, being the chief exchangeable cation in the soils (Abbas, 1995). River Jakara used for the irrigation is contaminated with heavy metals with values above the international recommended permissible limits for irrigation (Dike *et al.*, 2004; 2013) The Ca concentrations required for optimal growth has to be much higher in soil solutions than in balanced flowing nutrient solutions in order to protect roots against the adverse effects of high concentrations of various other cations in the soil solutions (Asher & Edwards, 1982). Irrigational practices also may have added to the contents of sodium's chief source in soil which is albite to bring about its high concentrations in both depths in the dry and early rains. Similarly the continuous use of NPK fertilizers during the irrigational farming may have added to other sources such as the abundant natural deposits of silicate materials to increase the concentration of K during the dry season. The lower concentrations of these elements during the rainy season months may be linked to dilution effects and leaching. In contrast, higher values of Mg during the rainy season in both depths may be attributed to its high solubility especially magnesium chloride. Washoffs of effluent wastes of plastic and synthetics abundant in the sites could also have contributed to its higher concentration during the season. Plastics and synthetics have been reported as major sources of magnesium (Jeb, 1996).

In each depth of each site, the concentrations of Cd, Ni, Cr, Cu, Zn and Fe were higher in the dry season than in the rainy season. This can be attributed to the irrigation activities which may again have contributed to the leaching of the cations down the profile thereby enriching the sites with these elements. Additions of sewage sludge and some kinds of compost are able to enrich soils with heavy metals (Kloke, Saveback, and Vetter, 1984). Mineral fertilizers primarily phosphate fertilizers and animal manure also used extensively on these soils during irrigation farming have been observed as major sources of these elements. This is in agreement with the findings of Fatoki (1996), Alloway and Ayres (1997), Fernandez-Jimenez, Clement-Font and Sanchez-Anton, (2003), Chinwe, Obinna, Akeem, and Alo (2010) and Oladunni *et al.* (2013) which reported that dry season soil metal contents were higher than wet season contents. Leaching of cations away from the profile during the wet season may have contributed to their lower concentrations in the soil during the period.

The concentrations of Pb and Co in contrast were higher in the wet season than in the dry season in each depth of each site. Fadama soils are reputed to have at least 25 percent clay and a silt plus clay content of at least 40 percent (Ogbalor, 1991). At higher pH values, metals are generally desorbed from organic and clay particles thus becoming more mobile in the soil (Ojeka and Achi, 2004). Though pH values of fadama soils always fall within the acid range (Esu, Ibanga, and Lambin, 1987; Abubakar, Ramalan and Mudiare, 1999), those in site 3 in particular may have increased and hence the marked highest concentration of Pb in the site during the period. Furthermore, the site in addition to the sewage which it receives in common with the other sites, also receives wastes from the mechanic and soldering workshops close to the vicinity. De Temmerman, Vanongeval, Boon, Hoenig and Geypens (2003) stated that Pb in fuel has made it the most widespread pollutant. Lead may also have been made available in the site during the wet season due to runoffs from fuel, car exhaust deposits, used batteries and crankcase oil from the mechanic workshops and discharge from soldering around the vicinity. For Co and some other elements, increasing amounts is a function of increasing clay contents (De Temmerman *et al.*, 2003). The rain may have contributed to the leaching of the Co(cation) from the clay down the profile thereby increasing its concentration during the season. The soil conditions in the dry season may not have favored the mobility of the elements thereby bringing about their lower concentrations observed during the period.

In the comparison of the annual means, the elements, particularly the non-essential and essential trace elements did not show marked differences in their concentration in the two depths indicating that both depths were influenced mainly by the anthropogenic supply of the elements. At these depths which fall within the top soil, elements could readily be available for uptake by plants roots. Kisku *et al.* (2000) reported that most of the metals are retained in top soil and their concentration only decreases with increase in depth. The concentrations of the elements in the two depths in all the sites occurred in the order of Fe > Ca > K > Mg > Na > Pb > Zn > Co > Cu > Cr > Ni > Cd. Calcium, K, Mg and Na are essential bulk elements and are expected to be present in the soil in large amounts. The concentrations of Fe, though high in the soils were within the international acceptable limits. Some trace elements such as Cd, Ni, Pb etc exist in soils with low concentrations (Cheng, Zhang, Yao, Wu, and

Xu, 2006). Cadmium is soluble in soil and under oxidized conditions and under reducing conditions, it precipitates as cadmium sulphate (Zueng-Sang, 2000) which may be responsible for its lowest concentrations in the soil. The concentrations of Cd though low and that of Pb, Cr, Ni, Cu, Zn and Co, were higher than the recommended permissible limits (Table 1). Ranta (1994); Lombi, Sletten, and Wenzel, (2000); Nan and Zhao (2000); De Temmerman *et al.* (2003); Ekwumemgbo (2002); Kim, Gimba, Kagbu and Harrison (2004); Cheng *et al.* (2006); Elgawad, Mohammed, Shendi, and Ghabour (2007); and Behbahania and Mirbagheri (2008) also observed high concentrations of some or all of these elements in various soil samples studied.

## 5. Conclusion and Recommendations

The results of the study show that while Ca, Mg, Na and K concentrations of the top soil within the catchment of River Jakara in Kano, Nigeria, were high but within their limits as essential bulk elements, it was contaminated with all the trace elements (Pb, Cd, Cr, Ni, Cu, Zn and Co) investigated except Fe which points to its pollution. This is attributed to the extensive irrigational activities being carried out at the sites which has contaminated them resulting in the accumulation of these elements such that their concentrations (except Fe) exceed the international permissible limits. The continued use of these soils for the irrigation of vegetables and fruits consumed by the inhabitants of Kano and its environ could present a public health risk particularly with regard to the concentrations of the heavy metals in their edible portions. The higher concentrations of these toxic elements in soils need to be monitored for heavy metal enrichment. In this regard, the relevant organ of government should therefore find an alternative farmland for the farmers within the catchment area of River Jakara where unpolluted waste sources can be used for the irrigation of vegetables. Where this not feasible, a common effluent treatment plant should be installed to allow the treatment of all the effluents before properly discharging them into the river or alternatively, soil management may be applied by the farmers. For example, suitable remediation methods may be identified and applied. There is also need to carry out investigations on the vegetables produced within the catchment of River Jakara in Kano, Nigeria to ascertain their degree of contamination if any.

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