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Determination of Some Heavy Metals and Physicochemical Parameters of Soil, Vegetable and Some Fruits Grown in Mgbuodohia, Rumuolumeni, Port Harcourt

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Abstract Heavy metals concentration were determined in soil, fruits and vegetable samples collected from cultivated farmlands in Mgbuodohia, Rumuolumeni. The samples were prepared, and analyzed for heavy metals using Atomic Absorption Spectrophotometer (AAS). The physico-chemical parameters such as pH, electrical conductivity, salinity, total organic carbon (TOC), total organic matter (TOM),nitrogen content and particle size of the soil samples were determined using standard methods. The results showed that heavy metals concentrations in soil samples around pawpaw, pineapple, coconut fruits and okra had the following ranged; Pb (BDL-0.89) mg/Kg, Cd (0.01-1.00) mg/Kg, Cr (0.32-4.02) mg/Kg, Fe (0.24-4.60) mg/Kg, Cu (0.74-2.66) mg/Kg, Zn (0.34-0.636) mg/Kg. In the fruits; Pb (BDL-0.06) mg/Kg, Cr (BDL-3.57) mg/Kg, Fe (1.84- 6.82) mg/Kg, Cu (0.15.82) mg/Kg, Zn (0.40-0.83) mg/Kg, and Cd (BDL-0.24) mg/Kg. The physico-chemical properties had the following ranged; pH(6.2-6.6), electrical conductivity (2.9-4.6) µs/cm, sanility (9.0-24) mg/Kg, moisture (14.69-21.40) %, TOC (1.71-2.63) %, Total nitrogen (0.08-0.11) %, TOM (2.94-4.04) %, sand (67-73) %, silt (11-12) % and clay (15-22) %. The results revealed that zinc had the highest transfer factor (TP) in the fruit samples examined, while chromium and lead had the lowest. The results revealed that anthropogenic activities within the vicinity of Mgbu-odohia community may have influenced the high concentrations of chromium and cadmium in the samples. The concentration of cadmium and chromium were above, while others were below the permissible limit set for heavy metals in food by World Health Organisation (WHO), and Food and Agricultural Organisation (FAO).

Keywords Heavy metals, Physico-chemical Parameters, Fruits, Soil, Anthropogenic

Introduction

Mgbuodohia in Rumuolumeni is a host to varieties of fruits and vegetables which attracts considerable interest for commercial production. Coconut (*Coco nucifera*), pawpaw (*Carica papaya)*, pineapple (*Ananas comosus*), and okra (*Albe mucus esculentus)* are among the major fruits and vegetable grown in the area. Mgbuodohia community is known for commercial production of okra and the okra market is situated at the Nigerian Naval base bus stop at Nkpor village only during the harvesting season. These plants have similar root system which enables them to thrive well in the area, the root of coconut and pineapple is fibrous, while pawpaw and okra have adventitious and tap root which does not go deep into soil. The quality of fruits is determined by consumers on the basis of visual appearance such as forms, color, size, texture, flavor and aroma. However, fruits contain organic and inorganic substances which might be either toxic or beneficial to human. Some elements are essential to animals' metabolism as they are readily assimilated and accumulated in environmental matrices. However, when they bioaccumulate in organisms at elevated concentrations they becomes toxic [1-2].

Exposure of non-essential elements such as cadmium (Cd), mercury (Hg) and lead (Pb) could have negative effect on human health [3]. The consumption of crops harvested from contaminated soil that contained these toxic heavy metals are assimilated and bioaccumulates in the human body system and such buildup may reach elevated levels [4].

Fresh fruits and vegetables are very important ingredients in the diet of humans because they contain many vitamins, mineral salts, water and essentials elements such as calcium, iron, and sulphur [5]. They are quite useful for the maintenance of health, prevention and treatment of various disease [6]. Regular consumption of fruit reduced risk of cancer, cardiovascular diseases (especially coronary heart disease), stroke, cataracts, and some of the functional declines associated with aging [7]. In Rivers State and the Niger Delta at large, there are many human activities such as bunkery, discharge of industrial and domestic waste that introduced heavy metals and petroleum products to the environment, which pollute both the terrestrial and aquatic compartments of the environment.

Therefore, it is on the basis of this that this research was carried out to investigate the physico-chemical parameters and heavy metals concentration in soil and some commonly cultivated crops from farmlands in Mgbuodohia.

Material and Methods

Study Area

Mgbuodohia community is located in Rumuolumeni, Obio/Akpor Local Government Area of Rivers State. There is no oil exploitation activities in the area. However, due to the numerous human activities in the area, the environment has been contaminated with petroleum products. Mgbuodohia community is one of the coastal settlements in Rivers State that receive illegal petroleum products from the artisanal refineries located in the riverine areas of the state. The major occupations of the inhabitants are agriculture, fishing and trading. The community is bordered on the south by Sapiem Oil Servicing Company, on the east by Agip oil Company and Rivers State University, on the north by Nkpor community and on the west by Avoen oil Company.

Sample Collection

Soil and fruit samples were collected from farmlands very close to Saipem Oil Servicing Company, Mgbuodohia community. Samples were randomly collected at each point and mixed together to form composite samples. A plasticsterilized hand trowel was used to collect the soil samples from the three locations at the depth of 10cm and stored in clean polythene bags. On the other hand, fresh coconut (*Coco nucifera*), pawpaw (*Carica papaya)*, pineapple (*Ananas comosus*) and vegetable okra (*Albemucu esculentus*) were harvested and transported to the laboratory for pre-treatment and analyses.

Sample Preparation

The coconut (*Coco nucifera*), pawpaw (*Carica papaya)* and pineapple (*Ananas comosus*) fruit samples and vegetable okra (*Albemucus esculentus*) were washed thoroughly with distilled water, peeled, and sliced with a stainless knife to smaller particles. The soil samples were air dried and ground in a clean mortar and sieved in a 60 µm sieve.

The samples were digested according to the method of Nelson and Summers [8].

The concentration of Pb, Cd, Fe, Cu, Cr and Zn were determined in all the samples using the Atomic Absorption Spectrophotometer. The standards were prepared by diluting concentrated stock solution of 1000 mg/L for Fe, Cr, Cu and Zn and 1000 mg/L for Pb and Cd in deionized water.

Physico-chemical parameters of soil samples

Standard methods were used to determine the physico chemicals parameters. The pH was measured in water suspension using the glass electrode coupled pH meter. The percent organic carbon (%OC) was measured using wet oxidation method [9]. The percent organic matter (%OM) was determined using Loss-On-Ignition (LOI) method according to Nelson and Summers [8]. Moisture content was determined using the Karl Fischer titration method.

The Kjeldahl distillation method was used to determine the total nitrogen [10]. The conductivity of the soil and the soil salinity were measured using the conductivity meter after calibrating the instrument. Particle size distribution also known as mechanical analysis was determined by hydrometer method [11] using sodium hexametaphosphate as dispersant.

Determination of Transfer Factor (TF)

The ability of a metal specie to migrate from the soil into plant roots is known as transfer factor (TF). Therefore, transfer factor is the ratio of heavy metal concentration in plant to the soil from where the plants were harvested. It indicates the absorption potentials of heavy metals from the soil [12]. Plant takes in heavy metal from soils through ionic exchange, redox reactions, precipitation-dissolution etc. Thus,

$$TF = \frac{Cfru\ it}{Csoil}$$

Where, C_{fruit} = metal concentration in fruit tissue (mg/Kg)

C_{soil} = metal concentration in soil (mg/Kg)

Results and Discussion

The results of the physicochemical parameters and heavy metals are showed in Tables 1 -3, while Table 4 showed the transfer factor.

Table 1: Physicochemical parameters of the soil around paw-paw, pineapples coconut and Okra grown in Mgbuodohia farmland.

Parameters	Samples			
	Paw-paw	**Pineapple**	**Coconut**	**Okra**
pH	6.5 ±6.0	6.4 ± 6.2	6.2 ± 6.0	6.6± 6.3
Electrical conductivity µs/cm	29 ± 27	46 ± 38	38 ± 35	27 ± 24
Salinity	24 ± 20	9.0 ± 7.8	9.5 ± 7.8.	8.7 ± 7.2
Total organic carbon %	2.24± 1.8	1.71 ± 0.82	2.33 1.1	2.63 ± 1.23
Total organic matter	3.79 ± 2.1	2.95 ± 1.87	4.04 ± 3.2	3.51± 2.70
Moisture content	14.69± 12.12	18.95 ± 16.27	20.50 ±18.25	21.40± 19.50
Total nitrogen (%)	0.11 ± 0.52	0.08± 0.01	0.12 ± 0.20	0.19 ± 0.13
Particle size distribution (%) sand	70 ± 82	67 ± 66	73 ± 70	68 ±57
(%) silt	12± 9	11± 8	12 ± 10	11 ± 9
(%)	18 ±16	22 ±20	15 14	20 ± 18

Table 2: Concentrations (mg/Kg) of heavy metals in soil samples around the fruit from Mgbuodohia

Sample Identity	Pb	Cd	Cr	Fe	Cu	Zn
Pawpaw Soil	< 0.001	0.41±0,34	0.31± 2.5	0.24 ±0.11	1.14±0.11	0.55 ±0.33
Pineapple Soil	0.28± 0.17	1.01± 0.84	3.68± 2.5	2.89 ±0.48	0.74±0.32	0.49± 0.32
Coconut Soil	0.34± 0.27	0.42± 0.29	4.02± 3.92	2.37± 1.72	1.63±0.96	0.63± 0.42
Okra	0.01 ±0.00	0.01± 0.00	2.82± 2.14	4.60 ±3.02	2.66±0.96	0.34± 0.22

Table 3: Concentrations (mg/Kg) of heavy metals in fruits and vegetable samples from Mgbuodohia

Sample Identity	Pb	Cr	Fe	Cu	Zn	C
Pawpaw	< 0.001	< 0.001	3.16± 2,03	0.15±0.07	0.40±0.21	0.58±0.43
Pineapple	0.06±0.02	1.69±0.92	1.84±0.92	0.47±0.32	0.59±0.27	0.1±0.15
Coconut	< 0.001	3.57±3.01	2.57±1.87	0.82±0.54	0.83±0.02	0.241±0.01
Okra	0.01 0.00	0.02±0.00	6.82±4.68	0.74±0.44	0.66±0.35	BDL

Table 4: Transfer Factor (mg/Kg) in fruits and vegetable samples collected from Mgbuodohia

Sample	Pb	Cr	Fe	Cu	Zn	Cd
Pawpaw	-	-	12.917	0.136	0.720	1.409
Pineapple	0.221	0.460	0.636	0.639	1.202	0.198
Coconut	-	0.888	1.085	0.503	1.311	0.566
Okra	0.01	0.00	0.41	0.15	1.94	0.00

Table 5: International guidelines for permissible of some heavy metals

Elements	USEPA	NAFDAC	WHO
As	6.0	NA	6.0
Ca	NA	NA	NA
Cd	0.005	0.1	0.005
Cu	0.1	0,1	1.0
Cr	0.1	0.05	0.05
Fe	0.3	1.0	0.3
Hg	0.002	0.01	NA
Mn	0.005	0.05	0.1
Pb	NA	NA	1

NA: Not available

The physicochemical parameters are shown in Table 1. The results revealed that samples had the following pH; 6.5, 6.4, 6.2 and 6.6 for soil sample of the fruits, paw-paw, pineapple, coconut and okra respectively. The results revealed that the pH of the soil samples are slightly acidic since their values ranged from 6.2–6.6. The observed pH were similar to those observed by Tropath and Misra [13] for dumpsite. Soil pH has the greatest influence on availability of nutrients to plant and the type of organism found in the soil. The pH also affects the solubility of metal and its availability to plants occurred mostly at low pH [14]. The pH values obtained fall within the range recommended by WHO and USEPA and lower than the results obtained by Tropath and Misra [13] in contaminated soil of municipal waste dumpsite at Allahabad in India

Soil organic matter (OM) and organic carbon (OC) are indicators of how healthy a soil is. They are used to express the organic richness of soil environment. They have a powerful effect on soil development, fertility and available moisture. The amount of organic matter in any soil determines the nutrient content and any changes will affect the quality and quantity of soil fertility [15]. The values for total organic matter (TOM) of the soil samples were 3.79, 2.95, 4.04 and 2.63% for soil samples 15 m around the paw-paw, pineapple, coconut and okra plants respectively. The total organic carbon (TOC) of the soil samples were 2.24, 1.71, 2.33 and 2.63 % for soil samples of paw-paw, pineapple, coconut and okra respectively. The values obtained for TOM and TOC were lower than those reported by Walkey and Black [9], Amos *et al*., [16], for soil samples obtained from dumpsite. The low values obtained in this study indicated that the soil is not healthy for agricultural purposes. Therefore consumption of crop planted on this soil may have negative effect on the consumer which may cause acute or chronic toxicity problems. On the other hand, the moisture content for the samples were 14.69 %, 18.95 %, 20.50 % and 21.40 % for pawpaw, pineapple, coconut and okra. Elevated levels of moisture content is commonly observed when it is used in cooking, the volume of the soup usually increase drastically, indicating that the water content of the okra have been added to the initial volume of the soup.

The total nitrogen of the soil samples from the study were; 0.11, 0.08, 0.11 and 3.51% for soil samples of paw-paw, pineapple, coconut and okra respectively. Nitrogen is essential for proper growth of plants. The inorganic forms of nitrogen (NH_4^+, NO_2, and NO_3^-) are less than 5% of the total nitrogen in soil [17]. Nitrogen is available to plants as either ammonium (NH_4^+-N) or nitrate (NO_3^- -N). When nitrogen occurs in the soil, it undergoes diverse transformation before it could be used by plants [18].

Mineralization converts organic nitrogen present in soil organic matter, crop residues, and manure to inorganic nitrogen. When bacteria interact with the organic nitrogen, NH_4^+-N is released.

The amount of water remaining in a soil drained to field capacity and the amount that is available are functions of soil type [15]. Sandy soil usually retain very little water, while clay will hold the utmost amount. Therefore,

soil that have high percentage of sand as observed in this study will retain very little water and such soil may not be good for cultivation of crops.

Salinity refers to the amount of salt in the soil, whereas Electrical Conductivity (EC) is influenced by the salinity in the soil. Sandy soil or soil with higher percentage of sand often exhibit low electrical conductivity and low salinity. Silt often has moderate electrical conductivity and salinity whereas clay soil or soil with higher percentage of clay possesses high salinity and high electrical conductivity [19]. The electrical conductivity of the soil samples were; 29, 46, 38 and 27(µs/cm) for paw-paw, pineapple, coconut, and okra respectively. On the other hand, salinity of the soil samples were; 24.0, 9.0, 9.5 and 8.7 mg/Kg for soil samples of paw-paw, pineapple, coconut and okra respectively. The low concentrations obtained for electrical conductivity and salinity in this study indicated that the soil samples consist of high percentage of sand and low percentage of clay and silt. The variation of Physicochemical is shown in the Fig 2 below:

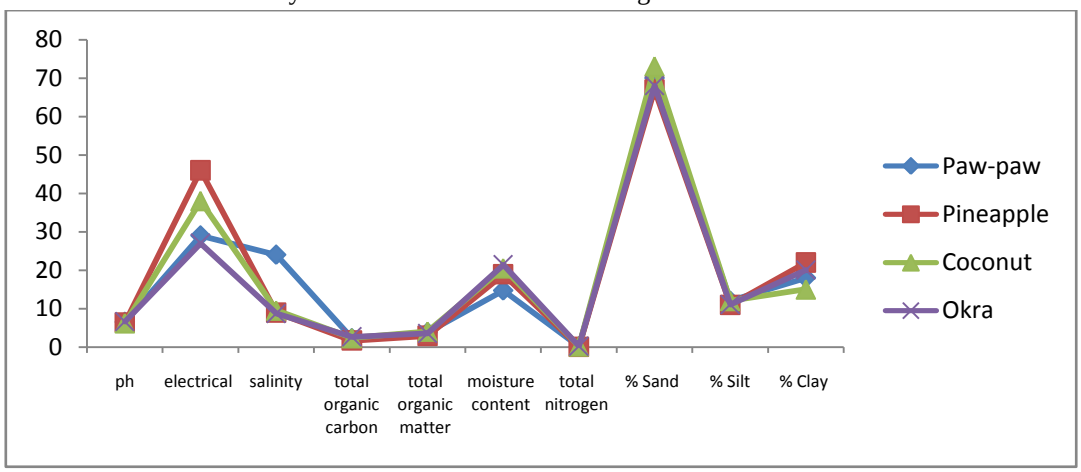

Figure 1: Variation of physicochemical parameters of the soil around paw-paw, pineapples, and coconut and okra grown in Mgbuodohia farmland

The concentration of heavy metals; Pb,Cr, Fe, Cu, Zn, and Cd were determined in soils of about 15 m around the plants and the fruits samples. The results of the concentration of heavy metals in soil samples from a cultivated farmland in Mgbuodohia are presented in Table 2. The results revealed that concentration of heavy metals of the soil around paw-paw plants were< 0.001, 0.41, 0.31, 0.24, 1.14 and 0.55 in mg/Kg for lead, cadmium, chromium, iron, copper and zinc. However, the following concentration 0.2, 1.006, 3.68, 2.89, 0.74 and 0.49 mg/Kg were obtained for pineapple sample, while those of coconut tree were 0.34, 0.4, 4.02, 2.37, 1.63 and 0.63 mg/Kg and okra were 0.01, 0.01, 2.82, 4.60, 2.66, and 0.34 mg/Kg for lead, cadmium, chromium, iron, copper and zinc respectively.

In soil sample around pawpaw plant, it was observed that copper had the highest concentration (1.14) mg/Kg, while lead had the least concentration (0.001) mg/Kg. In soil sample of pineapple plants, chromium had the highest concentration (3.68) mg/Kg, while lead has the least concentration (0.28) mg/Kg. In soil sample of coconut, chromium has the highest concentration (4.02) mg/Kg, while lead has the lowest concentration (0.34) mg/Kg. Elevated concentration of chromium and copper obtained could be attributed to the fact that these heavy metals occurred naturally in the soil and rocks. Chromium occurred in the soil in its elemental form and has variable oxidation number of +2, +3,+4 ,+5 and +6 which accounted for the high concentration of chromium in the soil [20]. Moreover, the high concentration of copper in the soil sample around pawpaw may be attributed to the soil organic matter. Copper is a metal that is usually adsorbed to the organic-negatively charged group and it is often dissolved in the soil solution as Cu^{2+} ion and form organic copper complexes. Hence copper ions have strong affinity for soil organic matter [21].

The results of the concentration of heavy metals in fruit samples; pawpaw, pineapple, coconut and okra are presented in Table 3. The results showed that the concentration of heavy metals in paw-paw were as follows; < 0.001, < 0.001, 3.16, 0.15, 0.40 and 0.58 mg/Kg for lead, chromium, iron, copper, zinc and cadmium respectively. Pineapple had the following concentrations 0.06, 1.69, 1.8, 0.4, 0.59 and 0.19 mg/Kg for lead, chromium, iron, copper, zinc and cadmium. However, for coconut, the following concentrations were obtained

< 0.001, 3.57, 2.57, 0.82, 0.83 and 0.24 mg/Kg, while okra had the following 0.01, 0.02, 6.82, 0.74, 0.66, mg/Kg and BDL for lead, chromium, iron, copper, zinc and cadmium respectively.

The concentration of lead in the fruits varies from < 0.001-0.06 mg/Kg and it occurred in the following order; pawpaw =coconut<okra<pineapple. Lead occurred in the environment in two oxidation states Pb^{2+} and Pb^{4+} of which Pb^{2+} is the dominant specie. In humans, lead interferes with the activities of several enzymes involved in the biosynthesis of haem [22] and acute intoxication in human include; tiredness, restlessness, headaches, abdominal cramp while chronic lead toxicity includes sleeplessness, join pains, high blood pressure and gastrointestinal may appear in adult at blood lead levels of 50-80µg/ml [23].

Iron ranged from 1.84-6-82mg/Kg and is the most abundant of all the heavy metals in the study, the highest concentration (6.82) mg/Kg occurred in okra. Iron is among the essential metals required for metabolism of human cells. However, elevated concentrations in tissue of an organism occurs as a result of bioaccumulation which may result to acute or chronic effects. Iron is an important component of blood, it forms part of red blood cells and assist in carrying oxygen in human body to form hemoglobin.

Copper concentration occurred in the range of 0.146- 0.811mg/kg and the highest concentration was recorded in coconut and the least in pawpaw. Copper is among the essential element in human body. However, elevated concentration is toxic to human resulting to irritation of the eyes and mouth, vomiting, diarrhea and stomach cramp. The concentration of copper obtained in this study was above the recommended limit set by WHO, USEPA and NAFDAC. However, similar result was reported by Kpee and Marcus [24], in vegetables grown in Gokana metropolis in the Niger Delta of Nigeria. Contrary, elevated levels of heavy metals were reported by Kpee and Edori [25], Tropath and Misra [13], Amusan *et al* [19] in fruits harvested from some dumpsites in parts of Nigeria and Allahabad in India.

Zinc occurred in the ranged 0.40-0.83 mg/Kg and zinc is one of the essential elements that help in the metabolism of human tissues. Despites its essentialities, excessive concentrations can result to adverse health effects such as; anemia, nausea, blockage of arteries and vomiting in children [16]. The variation of heavy metals in soil samples is shown in the Fig 2 below:

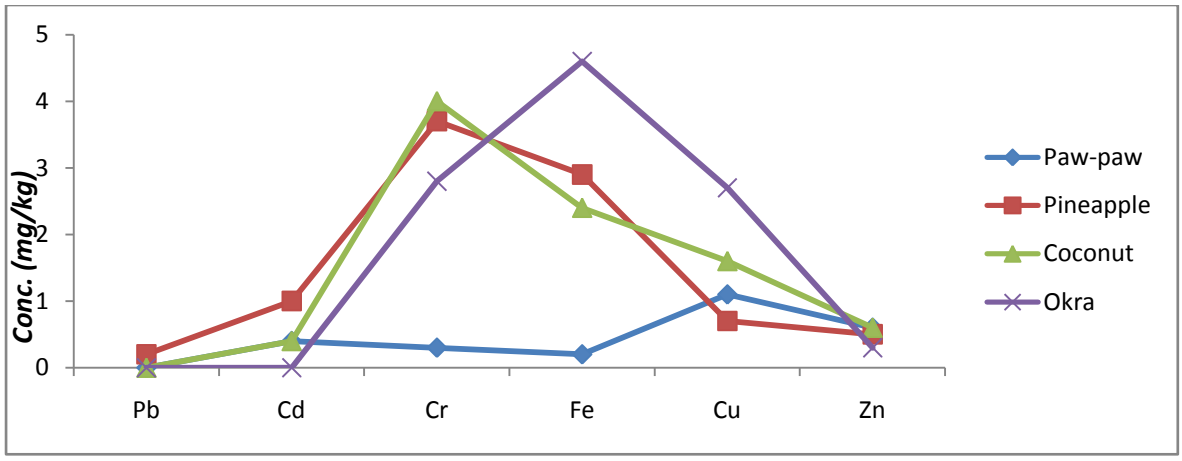

Figure 2: Variation of concentrations (mg/kg) of heavy metals in soil samples from Mgbuodohia farmland

On the other hand, cadmium occurred in the range 0.199- 0.586mg/Kg. Cadmium is not required at any concentration in human body. The values of Cd in Table 3 revealed that significant concentrations of cadmium occurred in the samples. Ingestion of cadmium concentration in man increases ageing. Human organs such as liver and kidney can store 50-85%, while 30-60% can be store in the kidney. Cadmium can also affect DNA synthesis, microbial DNA repair, gene mutation and chromosomal abnormalities in mammalian cell culture, high plants and animals [26].

The concentration of chromium (Cr) ranged from < 0.001-3.57 mg/Kg. Chromium is used in fumigation, chromium metals production and corrosion control [27]. In the soil Cr^{3+} is predominant and the mean functional absorption value of 5% and 25% has been estimated for the gastrointestinal absorption of organic chromium in food [28]. The daily chromium requirement for adult is estimated to be 0.5-2µg for absorbable Cr^{3+}. Ingestion of

1-5g of chromate results in several acute effects such as gastrointestinal disorder, hemorrhagic, diathesis, and convulsion [29]. The variation of heavy metals in fruit is shown in the Fig. 3 below

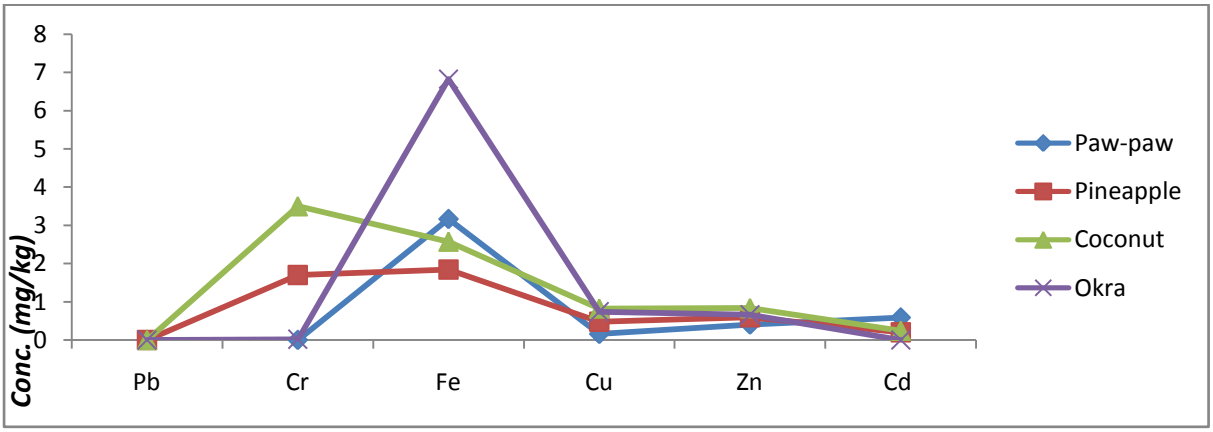

Figure 3: Variations of concentrations (mg/kg) of heavy metals in fruit samples from Mgbuodohia farmland

Table 4 showed transfer factor (TP), which is the ratio of the concentration of heavy metals in fruit divided by the concentration in the soil. Table 4 revealed that iron had the highest TP in all the samples and iron had the ranged 0.636-16.54 mg/Kg. The transfer factor for the heavy metals in the fruits occurred in the following order paw; Pb<Cr<Cu<Zn<Cd<Fe, pineapple; Cd<Pb<Cr<Fe<Cu<Zn, coconut; Pb<Cu<Cd<Cr<Fe<Zn, and okra; Cd=Cr<Pb<Cu< Fe<Zn. The results revealed that iron had the highest TP in the four samples examined, while cadmium and lead had the lowest transfer factor. Generally, the results revealed that low levels of heavy metals were obtained in the study, especially for the non-essential metals Pb and Cd, they occurred in the order Pb<Cd<Cr<Cu<Zn<Fe. The results revealed that the concentration of heavy metals except Pb and Cr in the soil samples of pawpaw were above permissible limits set by USEPA and NAFDAC.

Conclusion

This study revealed that anthropogenic activities which occurred aroundMgbuodohia community had impacted on the levels of heavy metals and the physicochemical parameters. The low concentrations of TOM and TOC obtained indicated that the soil would not be good for cultivation of crops. Similarly, low concentrations wasobtained for electrical conductivity and salinity of the soil samples revealed that the soil samples consist of high percentage of sand and low percentage of clay and silt.

The concentrations of lead, iron, copper and zinc in the samples were below the permissible limit set by; USEPA, WHO and NAFDAC except for few samples that were slightly above the permissible limits set by international organization.

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