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RESEARCH ARTICLE

COMPARATIVE ANALYSIS OF HEAVY METALS IN CARICA PAPAYA (PAWPAW) FRUIT AND SOIL IN SELECTED URBAN, RURAL AND FORESTLAND IN OWERRI, IMO STATE

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Abstract

In most developing coun tries like Nigeria, the quest for rapid economic growth through urbanization, industrialization and modern agriculture have resulted in concomitant inflow of several contaminants (such as heavy metals) into the environment. This study assessed the comparative levels of heavy metals in pawpaw fruits and soils of urban, rural and forest land in Owerri Imo State, Southeastern Nigeria. Randomly, soil samples (0-30 cm depth) and partially ripe pawpaw fruits were collected each from urban, rural and forest land. Heavy metals (Pb, Cd, Ni, Zn, Cu, Cr, Co and Fe) were analyzed using standard methods. Data were subjected to Analysis of Variance (ANOVA) and correlation using Genstat Statistical Package Version 18. The heavy metals in the soil samples were low and varied significantly ($P<0.05$) apart from Cr, Co and Fe. With the exception of Cu, heavy metals were generally more concentrated in urban soils followed by rural and forest soils where decreasing pattern of urban (1.534 $mgkg^{-1}$) > forest (1.534 $mgkg^{-1}$) > rural (1.426 $mgkg^{-1}$) was recorded. Heavy metal concentrations of the pawpaw fruit also differed significantly ($P<0.05$) apart from Co and Fe. Similar pattern of decreasing trend (urban > rural > forest) like for the soil, was observed for pawpaw fruits apart from Cu and Cr contents that followed decreasing trend of urban > forest > rural. In addition, metal transfer factor was not uniform for the heavy metals across the sites. However, least values of metal transfer factor for Co (0.51-0.21) and Fe (0.44-0.32) suggested that Co and Fe are not easily mobilized in pawpaw tree. Positive significant relationship that Pb, Cd, Ni, Zn, Cu, Cr and Fe had with pawpaw Pb, Cd, Ni, Zn and Fe indicated strong influence of these metals on each other. There is need for occasional monitoring of these heavy metals in the soil and pawpaw fruit to prevent excessive build up of these heavy metals in the human food chain.

Introduction:-

The economic and nutritional potential of pawpaw (*Carica papaya*) has made it a fruit and vegetable of choice. Pawpaw is a common plant growing naturally in different environments including forest, rural and urban areas in

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Nigeria. It is also a fruit commonly consumed all around the world, especially in the developing world. This is due in part to its reputation for having medicinal properties (Eludoyin and Oladele, 2017). In addition, Papaya is a first rate source of vitamins A and C. It contains in small quantity thiamine, riboflavin, calcium, iron, potassium, magnesium and sodium (Bari *et al*., 2006). A number of trace elements in fruits protect the cell from oxidative cell damage as these minerals are the cofactor of antioxidant enzymes. For instance, zinc, copper and manganese are necessary for superoxide dismutases in both cytosol and mitochondria. Iron is a component of catalase, a hemeprotein, which catalyzes the decomposition of hydrogen peroxide (Machlin and Bendich, 1987).

Soil on which most plants grow and derive its nutrient is a vital resource for sustaining two human needs of quality food supply and quality environment (Solomon and Enoh, 2014). Large amount of waste substances, effluents, chemicals and energy are introduced into the environment through several sources. Some of these substances contain heavy metals such as cadmium, lead, and mercury, which are known to be toxic to man and wildlife (Ogunkunle *et al*., 2014). Olayiwola *et al.* (2017) argued that heavy metals concentration in the environment cannot be attributed to geological factors alone, but human activities do modify considerably the mineral composition of soils, crops and water. Common pollutants in the environment are mainly anthropogenic, especially caused by emissions from road traffic, previous industrial use of the sites, atmospheric deposition from industrial activities, and incinerators (Chen *et al*. 2005; Antisari *et al*. 2013). Other activities that could contribute to excessive release of these metals into the environment include burning of fossil fuels, smelting, and discharges of industrial, agricultural, domestic wastes as well as deliberate application of pesticides (Solomon *et al*, 2014).

Plants grown in polluted environment can accumulate heavy metals through their roots or through foliar absorption at high concentration causing serious risk to human health when consumed. Moreover, heavy metals are toxic because they tend to bioaccumulate in plants and animals, bioconcentrate in the food chain and attack specific organs in the body ((Akinola *et al.*, 2008; Chatterjee and Chatterjee, 2000). A number of serious health problems can develop as a result of excessive uptake of dietary heavy metals. Furthermore, the consumption of heavy metal-contaminated food can seriously deplete some essential nutrients in the body causing a decrease in immunological defenses, intrauterine growth retardation, impaired psycho- social behaviors, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer (Arora *et al*., 2008). The content of essential elements in plants is conditional, the content being affected by the characteristics of the soil and the ability of plants to selectively accumulate some metals (Divrikli *et al*., 2006). The uptake of metals from the soil depends on different factors such as their solubility, soil pH, plant growth stages, fertilizer and soil (Sharma *et al*., 2006; Ismail *et al*., 2005).

A weak point of previous researches is the absence of appropriate control when comparing urban to rural horticultural production. Most of the available cases addressed the concentration of Pb in sweet orange in Port Harcourt, and an examination of the influence of automobile workshops along major roads of Port Harcourt City on soil properties (Utang *et al*., 2013; Rakib *et al*., 2014; Weli and Iwowari *et al*., 2014; Odimegwu, 2014). Other studies include the effects of heavy metals on topsoil at the vicinity of automobile mechanic villages in Owerri, Nigeria, and the level of pollution of the soil caused by automobile workshop waste (Okoro *et al*., 2013; Ipeaiyeda and Dawodu, 2008). None of these studies have investigated the comparative levels of heavy metals in soils and pawpaw (*C. papaya*) fruits grown on urban, rural and forest soils. Navarrete and Asio (2011) cautioned that the risk posed by polluted soils is caused by the lack of awareness of people living in the area, who may not be aware about the presence of these pollutants and their health effects. Periodic monitoring of concentrations of these heavy metals in soils and in food such as fruits which are consumed by all and sundry is hence imperative to ensure that they are pollutant free. This research therefore was aimed at the comparative assessment of heavy metal concentrations in pawpaw and soil in rural, urban, and forest soils where this pawpaw is grown.

Materials and Methods:-

Study area:

The study was carried out in two communities viz; Naze and mechanic village in Owerri north and Owerri west local government area respectively both in Imo State, Southeastern Nigeria. Naze is located on latitude 5.23° N and 5.43° N, and longitude 7.03° E and 7.07° E whereas the mechanic village falls under the geographical coordinates of latitude 5.24° N and 5.27° N and longitude 7.04 ° E and 7.06° E. Mechanic village shows a high population density compared to low/moderate population in Naze. Mechanic village has average population density of about 104 people per 1km. This population density could be as a result of the activities of these labor force and their relatives (NPC, 2006). The study area has a humid tropical climate with a marked dry season (December – March), long rainy season (April to November) with double maxima generally in June and September and a high annual rainfall which averages 2000 – 2500 mm throughout the state is normally recorded. Mean annual temperature range from 26^0C to 31^0C and high relative humidity (above 80%) during the rainy season (Ofomata, 1975). Otamiri River governs the hydrology of the study area but joins the lower course of the Imo River at Rivers State, Nigeria. The geology of the area consists of plain soil, which is about 0.05 – 2.0 mm in size. This type of soil has good drainage and is well aerated, causing it to dry out quickly (Onweremadu and Duruigbo, 2007). Soils of the study area are derived from Coastal plain sand (Igbozuruike, 1975). In addition, the area has low lying to moderately high plain topography. Sand mining, gravel exploration, automobile repairs are major occupation in mechanic village, Metropolitan services such as automobile activities, agro industries, food vending, packaging activities and others are also prominent whereas dry season vegetable production and arable farming are major socio-economic activities in Naze. Figure 1 shows the map of the study area.

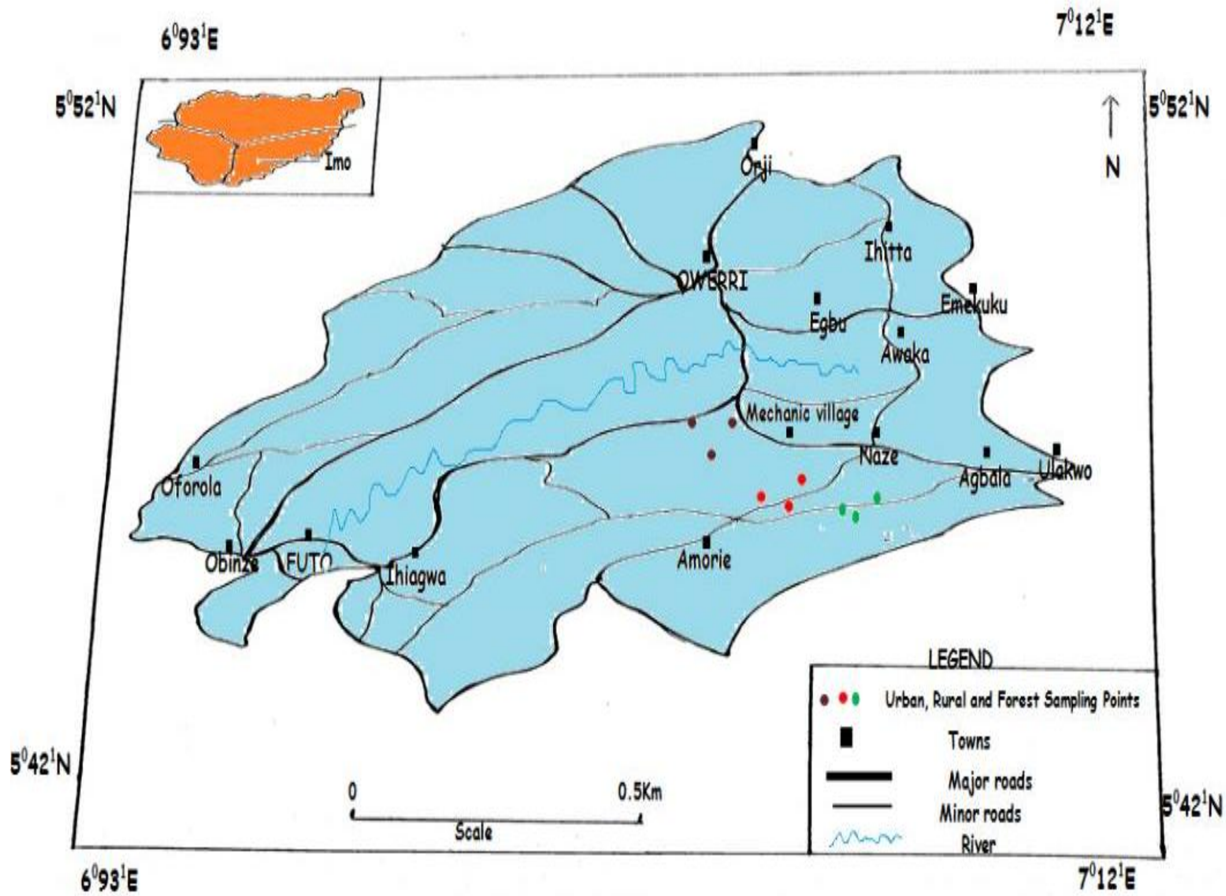


Fig 1:- Map showing the study area.

Fruit collection

Prior to sample collection, a reconnaissance was carried out to identify the areas to be studied and the fruit and soil samples were collected in August/September 2017. Partially ripe pawpaw (Carica papaya) fruits were harvested from selected pawpaw trees in rural and forest sites of Naze and mechanic village Owerri (Urban site). The fruits were bagged, properly labeled and taken to the laboratory for heavy metal analysis using standard methods.

Soil collection

The surface of the soil was cleared with a hand trowel and soil auger was used to randomly collect three (3) soil samples from 0-30cm depth (close to the pawpaw roots) in each of the rural, forest (Naze) and urban (mechanic village owerri) sites where the pawpaw (*Carica papaya*) trees were grown. Altogether, a total of nine (9) soil samples were collected, bagged, labeled properly and taken to the laboratory for heavy metal analysis using standard methods.

Laboratory analysis
After soil sample collection, the soil was air dried and sieved with 2mm sieve and soil heavy metals (Cd, Cu, Cr, Co, Fe, Pb, Zn, and Ni) were determined by standard atomic absorption spectrophotometer method as outlined by Tessier et al. (1979). Heavy metals (Cd, Cu, Cr, Co, Fe, Pb, Zn, and Ni) in the fruits were determined by dry-ashing method as outlined by Association of Official Analytical Chemists (AOAC) (2005).

Metal transfer factor (MTF)
The metal transfer factor, also referred to as 'bio-accumulation factor', an index of the ability of a vegetable to accumulate a particular metal as a function of its concentration in the soil (Ghosh and Singh, 2005) was calculated from the following equation:

$$MTF = \frac{C_{plant}}{C_{soil}}$$

where $C_{plan}$and C_{soil} were the heavy metal concentrations in edible portions of vegetables and in soils, respectively, on a dry weight basis.

Statistical analysis
Data generated from the laboratory analysis of the soil and pawpaw fruit were statistically analyzed with Genstat Statistical Package Version 18 using Analysis of Variance (ANOVA) as outlined by Steel and Torrie (1981). Means were separated using Least Significant Difference (LSD) at 5% level of probability. Degree of relationships between soil and pawpaw heavy metals was carried out using correlation analysis at $P \leq 0.05$ probability levels.

Results and Discussion:-

Table 1:- Heavy metal concentrations of the soils supporting pawpaw.

Sample	Pb	Cd	Ni	Zn (mgkg^{-1})	Cu	Cr	Co	Fe
Urban	1.76	0.64	0.506	0.42	2.281	1.845	2.148	4.328
Urban	1.422	0.71	0.816	0.522	3.041	1.324	2.864	5.771
Urban	1.882	1.108	0.93	0.733	1.52	1.23	1.432	2.886
Mean	1.688	0.819	0.751	0.558	2.281	1.466	2.148	4.328
Rural	1.304	0.4	0.352	0.182	1.426	1.437	1.633	3.521
Rural	1.008	0.576	0.176	0.248	1.901	0.958	0.218	2.348
Rural	1.33	0.611	0.41	0.3	0.95	1.916	2.177	4.695
Mean	1.214	0.529	0.313	0.243	1.426	1.437	1.343	3.521
Forest	0.464	0.248	0.24	0.078	1.534	1.163	1.562	2.453
Forest	0.619	0.166	0.16	0.104	2.045	1.018	1.083	1.636
Forest	0.31	0.331	0.32	0.052	1.022	0.776	1.042	3.271
Mean	0.464	0.248	0.24	0.078	1.534	0.986	1.229	2.453
LSD (0.05)	0.474	0.276	0.310	0.203	0.352	0.83	2.08	3.216

Heavy metal concentrations of the studied soils
Contamination of heavy metals in the environment is of major concern because of their toxicity and threat to human life and the environment. Results of the heavy metal concentrations of the studied soils are presented in Table 1. It was shown that lead concentration varied significantly ($P< 0.05$) among the soils studied. It ranged from 1.422-1.882 mgkg^{-1}, 1.008-1.33 mgkg^{-1}, and 0.31-0.619 mgkg^{-1}, with mean values of 1.688, 1.214 and 0.464 mgkg^{-1} in urban, rural and control respectively. These values were far below the threshold value of 300 mgkg^{-1} recommended for soil by European Union (CCME, 2001). However, low levels of lead have been identified with anemia as it causes injury to the blood forming systems while high levels causes severe dysfunction of the kidneys, liver, the central and peripheral nervous system (Jain *et al*., 1989), and high blood pressure (ATSDR, 1999). Cadmium on the other hand is extremely toxic at all levels and tends to bioaccumulate in organisms and ecosystems (ATSDR, 1999). In the present study, soil cadmium ranged from 0.248 mgkg^{-1} in control soil to 0.819 mgkg^{-1} in urban soils. These values were below the EU limit of 3.0 mgkg^{-1} for agricultural soils and 1.5 mgkg^{-1} set for German agricultural soils (Agbenin *et al*., 2009). Soil nickel concentration was significantly ($P< 0.05$) highest (0.751 mgkg^{-1}) in urban soils followed by rural (0.313 mgkg^{-1}) and control (0.24 mgkg^{-1}). Kasprzak *et al.* (2003) argued that global input of Ni to the human environment is from natural and anthropogenic sources including emissions from fossil fuel

consumption, industrial production, use and disposal of Ni compounds and alloys. This may explain the reason for the highest Ni value recorded in urban environment.

Zinc concentration in the studied soils ranged from 0.42-0.733 $mgkg^{-1}$, 0.176-0.41 $mgkg^{-1}$, 0.16-0.32 $mgkg^{-1}$, with mean values of 0.558, 0.243 and 0.078 $mgkg^{-1}$ in urban, rural and control soils respectively (Table 1). These range (0.078-0.558 $mgkg^{-1}$) of Zn recorded in this study were below 300 $mgkg^{-1}$, 230 $mgkg^{-1}$, 200 $mgkg^{-1}$, and 133 $mgkg^{-1}$ reported by Kabata-Pendias and Pendias (1992); Haluschak *et al* (1998); McGrath *et al* (2001) and Kimani (2007) respectively for zinc in uncontaminated soils of different countries. Zinc is an essential trace element for humans. It plays a central role in growth and development, vital during periods of rapid growth such as infancy, adolescence and during recovery from illness. Copper concentration in the soil was significantly (P< 0.05) highest (2.281 $mgkg^{-1}$) in urban soil followed by control (1.534 $mgkg^{-1}$) and rural (.1.426 $mgkg^{-1}$). European Union gave 140 $mgkg^{-1}$ as threshold level of Cu (CCME, 2001). Thus, the soils studied were below the critical level. Copper can be released into the environment by both natural sources (e.g wind, blown dust, decaying vegetation, forest fires and sea spray) and human activities (mining, metal production, wood production and phosphate fertilizer production). These may explain the reason for variation in soil copper concentrations since the different locations experience variation in these sources. Result of Table 1 further showed that chromium did not differ significantly (P< 0.05) in the studied soils. However, highest (1.466 $mgkg^{-1}$) and lowest (0.986 $mgkg^{-1}$) mean Cr were recorded in urban and control soils respectively. Similarly, highest (2.148 $mgkg^{-1}$) mean cobalt was recorded by Awokunmi *et al*. (2010) in dumpsites in South West Nigeria. Cobalt is used in many alloys, in magnets and magnetic recording media, as catalysts for the petroleum and chemical industries, as drying agents for plants and inks. These perhaps may be the reason for the significant value recorded in urban soils. Soil iron concentration on the other hand varied from 2.886-5.771 $mgkg^{-1}$, 2.348-3.521 $mgkg^{-1}$ and 1.636-3.271 $mgkg^{-1}$ with mean values of 4.328, 3.521 and 2.453 $mgkg^{-1}$ in urban, rural and control soils respectively (Table 1). Kimani (2007) reported a mean concentration of 57100 $mgkg^{-1}$ on contaminated soil. Iron is regarded as one of the essential elements for humans. Approximately 3000 to 5000 mg of iron exists in the human body (Landis and Yu, 1995). Therefore, as long as the quantity of iron in the environment is not too large, it may not be harmful to the human body.

Heavy metal concentrations of the pawpaw fruits studied

There is an inherent tendency of plants to take up toxic substances including heavy metals that are subsequently along the food chain (Singh *et al*., 2010). The result of Table 2 presented the concentration of heavy metals. It was shown that all heavy metal concentrations of the pawpaw fruits differed significantly (P<0.05) among the locations sampled apart from Cr, Co, and Fe which recorded no significant difference. Lead content of the pawpaw ranged from 1.882-1.422 mg/100g, 1.33-1.004 mg/100g and 0.619-0.31 mg/100g with mean values of 1.688, .1.214 and 0.464 mg/100g in urban, rural and control soil respectively. These fruits gotten from the different locations had Pb contents within the WHO maximum permissible level of 0.3mg/kg. The low level of Pb in these fruit species is an indication of food safety to consumers of these fruits since elevated levels of Pb is an indication of the increasing industrialization and uncontrolled development of urban areas. Cadmium level in fruits depends on plant fruit type and its affinity to uptake cadmium from the environment in which fruit plants are grown (Mausi, *et al*., 2014). In the pawpaw fruit samples, cadmium concentration was significantly highest (0.815 mg/100g) followed by rural (0.696 mg/100g) and forest (0.291 mg/100g). Cadmium is a non-essential toxic heavy metal in foods and natural waters and it accumulates principally in the kidneys and liver (Divrikli *et al*., 2006). Nickel concentration followed similar trend with Pb and Cd. Significantly (P< 0.05) highest (1.246 mg/100g) and lowest (0.477 mg/100g) values were recorded in urban and forest soils respectively. The values were lower than 2.3-37 $mgkg^{-1}$ reported in various vegetables by Premarathna *et al*. (2011). However, Sengar *et al*. (2008) reported that nickel in plants is highly mobile and is likely to accumulate in both leaves and seeds. Intake of too large quantities of nickel by humans from plants grown on nickel rich soils has higher chances of inducing the development of cancers of the lung, nose, larynx and prostrate as well as inducing respiratory failures, birth defects and heart disorders (Duda-chadak and Blaszczyk, 2008; Lenntech, 2009).

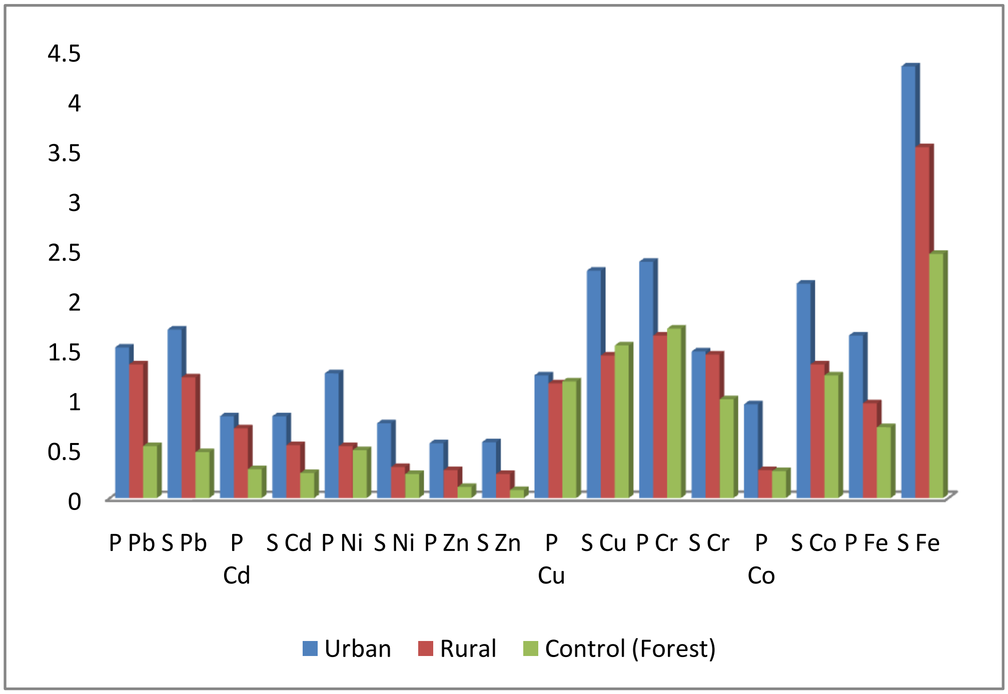
Table 2:- Heavy metal concentrations of the pawpaw fruits studied.

Sample	Pb	Cd	Ni	Zn	Cu	Cr	Co	Fe
				(mg/100g)				
Urban	1.586	0.984	1.323	0.733	1.226	1.985	0.942	1.628
Urban	1.321	0.551	1.022	0.338	1.635	2.46	0.628	1.086
Urban	1.613	0.911	1.394	0.57	0.818	2.646	1.256	2.171
Mean	**1.507**	**0.815**	**1.246**	**0.547**	**1.226**	**2.364**	**0.942**	**1.628**

Rural	1.29	0.488	0.394	0.288	1.152	1.628	0.326	0.953
Rural	1.337	0.813	0.29	0.292	1.536	1.086	0.088	1.271
Rural	1.379	0.788	0.883	0.261	0.768	2.171	0.435	0.636
Mean	**1.335**	**0.696**	**0.522**	**0.280**	**1.152**	**1.628**	**0.283**	**0.953**
Forest	0.523	0.291	0.477	0.108	1.167	1.526	0.432	0.711
Forest	0.697	0.194	0.318	0.144	1.556	1.551	0.188	0.948
Forest	0.348	0.388	0.636	0.072	0.778	2.035	0.176	0.474
Mean	**0.523**	**0.291**	**0.477**	**0.108**	**1.167**	**1.704**	**0.265**	**0.711**
LSD (0.05)	**0.387**	**0.431**	**0.262**	**0.279**	**0.029**	**0.638**	**1.669**	**1.077**

Results of Table 2 further showed low concentration of zinc. Zinc in pawpaw varied from 0.733-0.338 mg/100g, 0.292-0.261 mg/100g, 0.144-0.072 mg/100g with mean values of 0.547, 0.280 and 0.108 mg/100g in urban, rural and forest respectively. These values (0.547-0.108 mg/100g) recorded for Zn in the study area was below the values reported by Muhammad *et al*. (2008) on leafy vegetable samples of spinach (0.461 $mgkg^{-1}$) coriander (0.705 $mgkg^{-1}$), lettuce (0.743 $mgkg^{-1}$) radish (1.793 $mgkg^{-1}$) cabbage (0.777 $mgkg^{-1}$) and cauliflower (0.678 $mgkg^{-1}$). However, zinc deficiency has been largely attributable to the high phytic acid content of diets leading to poor growth, impaired immunity, and increased morbidity from common infectious diseases and increased mortality (Melaku, 2005). Copper on the other hand is an essential micronutrient which functions as biocatalysts, required for body pigmentation in addition to iron, maintain a healthy central nervous system, prevents anemia and interrelated with the function of Zn and Fe in the body (Akinyele and Osibanjo, 1982). Copper concentration was significantly ($P<0.05$) highest (1.226 mg/100g) and lowest (1.152 mg/100g) in pawpaw harvested from rural and urban soils respectively. However, the level of Cu in all fruits sampled was within the WHO permissible limit (0.2 $mgkg^{-1}$) which conforms to similar study as reported by Parveen *et al*. (2003). In contrast, higher Cu levels have been reported in watermelon and orange by Radwon and Salarna (2006) and Onianwa *et al*. (2000). The relatively low Cu level in all the fruits may be due to less deposition of Cu since soils varies in trace elements (Akinola and Ekiyoyo, 2006).

Chromium concentrations in the pawpaw harvested from different locations were low. It ranged from 1.985-2.646 mg/100g, 2.171-1.086 mg/100g, 2.035-1.551 mg/100g with mean values of 2.364, 1.628 and 1.704 mg/100g in urban, rural and forest (control) sites respectively (Table 2); chromium concentration recorded in this study were within the WHO/FAO permissible limit of 0.1 $mgkg^{-1}$ which favourably conforms to values recently reported by Akinyele and Shokunbi (2015). This finding was however in contrast to that of Sobukola *et al*. (2010) and Ogunkunle *et al*. (2014) who reported the absence of chromium in some fruits and leafy vegetables from selected markets in Lagos. Cobalt concentration of the pawpaw fruits did not vary significantly ($P<0.05$). However, highest (0.942 mg/100g) mean value was recorded in pawpaw fruit from urban soils followed by rural (0.283 mg/100g) and forest (control) (0.265 mg/100g). The daily recommended range of cobalt in human diet is 0.005 mg/day (ATSDR, 2004b). This implies that pawpaw fruits from different sites are capable of supplying the daily requirement of cobalt. Similar to Co, iron concentration in pawpaw from the different locations did not vary significantly ($P<0.05$). It ranged from 1.086-2.171 mg/100g, 0.636-1.271 mg/100g, 0.474-0.948 mg/100g with mean values of 1.628, 0.953 and 0.711 mg/100g in urban, rural and forest soils respectively. Iron values in this study were low compared to 0.65-2.76 mg/kg reported by Aweng *et al*. (2011) in fruit vegetables. Variations in heavy metal concentrations of the pawpaw from the different sites may be as a result of differences in the transfer of heavy metals from soils to plants which is dependent on three factors: the total amount of potentially available elements (quantity factor), the activity as well as the ionic ratios of elements in the soil solution (intensity factor), and the rate of element transfer from soil to liquid phases and to plant roots (reaction kinetics) (Brummer *et al*., 1986). However, changes in soil solution chemistry, such as pH, redox potential and ionic strength, may also significantly shift the retention processes of trace metals by soils (Gerringa *et al*., 2001).



Key: P=pawpaw, S=soil

Fig 2:- Comparative heavy metal status in pawpaw and soils of the different locations studied Metal transfer factor of the studied heavy metals.

Table 3:- Metal transfer factor of the heavy metals studied.

Sample	**Pb**	**Cd**	**Ni**	**Zn**	**Cu**	**Cr**	**Co**	**Fe**
Urban	0.9	1.54	2.61	1.75	1.86	1	0.43	0.37
Urban	0.93	0.78	1.25	0.65	1.85	0.54	0.22	0.19
Urban	0.86	0.82	1.5	0.78	1.86	0.46	0.88	0.75
Mean	**0.90**	**1.05**	**1.79**	**1.06**	**1.86**	**0.67**	**0.51**	**0.44**
Rural	0.98	1.22	1.11	0	1.23	0.88	0.2	0.27
Rural	1.32	1.41	1.65	1.18	1.22	0.88	0.4	0.54
Rural	1.04	1.29	2.15	0.87	1.24	0.88	0.2	0.14
Mean	**1.11**	**1.31**	**1.64**	**0.68**	**1.23**	**0.88**	**0.27**	**0.32**
Forest	1.13	1.17	1.99	1.38	1.3	0.76	0.28	0.29
Forest	1.13	1.17	1.99	1.38	1.31	0.66	0.17	0.57
Forest	1.12	1.17	1.99	1.38	1.32	0.38	0.19	0.14
Mean	**1.13**	**1.17**	**1.99**	**1.38**	**1.31**	**0.6**	**0.21**	**0.33**
LSD (0.05)	**0.223**	**0.621**	**1.365**	**1.372**	**0.015**	**0.366**	**0.531**	**0.639**

Table 3 depicts the result of the metal transfer factor which is an index of the ability of the fruit to accumulate a particular metal as a function of its concentration in the soil (Ghosh and Singh, 2005). It signifies the amount of heavy metals in the soil that ended up in the fruit (Chamberlain, 1983; Shift *et al.*, 1996). The metal transfer factor of all the heavy metals did not differ significantly apart from Pb and Cu where significant difference ($P<0.05$) was recorded among the sites studied. Lead transfer factor ranged from 0.93-0.86, 1.32-0.98, 1.13-1.2 with mean values of 0.90, 1.11 and 1.13 in urban, rural and forest sites respectively. Cadmium transfer factor was highest (1.31) in rural area (1.05). Nickel and zinc followed similar pattern of transfer factor where highest (1.99 and 1.38) and lowest (1.64 and 0.68) were observed in forest and rural sites respectively. Similarly, copper and iron had the same pattern of transfer factor of decreasing trend of urban > forest > rural. Chromium transfer factor was highest (0.88) in rural followed by urban (0.51) and forest (0.6) cobalt recorded the least (0.21-0.51) transfer factor compared to other heavy metals transfer factors. The transfer factor of Co from soil to pawpaw fruit was almost zero especially in rural and forest sites. This could be because Co contents do not mobilize in plants and lower content of the metal in pawpaw fruit as compared to the soils (Bakere *et al.*, 1994). The rate of metal uptake by the pawpaw fruits could have been affected by other factors such as plant species, soil pH, nature of soil and climate and this in turn would affect the content of heavy metal recorded (Alloway and Ayres, 1997; Uwah *et al*., 2009).

Relationship between selected heavy metals of the soils and pawpaw fruits

Table 4:- Relationship between selected heavy metals of the soils and pawpaw fruit

	s Pb	**s Cd**	**s Ni**	**s Zn**	**s Cu**	**s Cr**	**s Co**	**s Fe**
p Pb	0.959**	0.795**	0.581**	0.802**	0.046 ns	0.719**	0.666**	0.447*
p Cd	0.818**	0.815**	0.497*	0.719**	-0.230 ns	0.606**	0.692**	0.379
p Ni	0.756**	0.798**	0.854**	0.834**	-0.347 ns	0.676**	0.913**	0.563**
p Zn	0.900**	0.735**	0.612**	0.783**	-0.020 ns	0.685**	0.840**	0.351 ns
p Cu	0.304ns	0.160 ns	0.327 ns	0.378 ns	0.831**	-0.083 ns	0.209 ns	0.325 ns
p Cr	0.103 ns	0.114 ns	0.419 ns	0.148 ns	-0.153 ns	-0.136 ns	0.151 ns	0.874**
p Co	0.319 ns	0.059 ns	0.433 ns	0.279 ns	0.133 ns	0.334 ns	0.264 ns	0.625**
p Fe	0.775**	0.784**	0.630**	0.829**	0.059 ns	0.664**	0.822**	-0.031 ns

Key: s= soil, p= pawpaw, *=significant at 0.05% probability level,**= significant 0.01% probability level, ns=not significant.

Table 4 displayed the association between the heavy metals in the soil and pawpaw fruit. Lead in soil significantly and positively correlated with lead (r=0.959), Cd (r=0.818), nickel (r=0.756), zinc (r=0.900) and Fe (r=0.775) concentrations in pawpaw. This implies that increase in soil lead concentration will result in significant corresponding increase in lead, cadmium, nickel, zinc and Fe concentrations of the pawpaw fruit. Similarly, soil lead had positive strong association with Pb (r=0.795), Cd (r=0.815), Ni (r=0.798), Zn (r=0.735) and Fe (r=0.784) concentrations in pawpaw fruit. Soil also followed the same pattern of association with Pb, Cd, Ni, Zn and Fe. However, copper concentration in the soil on the other hand, had positive significant correlation with copper concentration in pawpaw, Cu (r=0.831). This shows that increase in soil copper level will result in an increase in copper concentration of the pawpaw fruit. Similar to Pb, Cd, Ni and Zn in soil, chromium and cobalt had significant positive association with lead, Cd, Ni, Zn and Fe concentrations in pawpaw. In addition, Fe concentration in soil had strong significant positive correlation with lead, nickel, chromium and cobalt concentrations in pawpaw fruit. This suggests that as soil iron increases, Pb, Ni, Cr and Co concentration of the pawpaw fruit also increases significantly.

Conclusion:-

The general result and the statistical analysis revealed significant variation of all the soil heavy metals studied apart from Cr, Co and Fe which did not differ significantly. All the heavy metals studied were within the permissible level. However, heavy metals were generally more concentrated in urban soils followed by rural and forest soils apart from copper where decreasing trend of urban > forest >rural soils. Similarly, heavy metal concentrations of the pawpaw fruit differed significantly across the different sites sampled apart from cobalt and Fe that did not vary significantly. Similar trend of decreasing pattern of heavy metals distribution like soil heavy metals was maintained by pawpaw fruits apart from Cu and Cr concentrations that followed decreasing pattern of urban > forest > rural. The values of these heavy metals were within the permissible limits. Metal transfer factor did not differ significantly for all the metals studied apart from lead and copper that varied significantly across the sites sampled. Metal transfer factor for Cu, Co and Fe was highest in urban site compared to other sites while lead, Ni and Zn transfer factors were highest in forest site, whereas, Cd and Cr transfer factors were highest in rural site compared to other sites studied. However, the lower values of metal transfer factor recorded by Co and Fe suggested that Co, and Fe are not easily mobilized in pawpaw and remains slightly stagnant in roots. There is need for regular monitoring of heavy metals in pawpaw fruits in order to prevent excessive buildup of these heavy metals in the human food chain.

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