NIGERIAN AGRICULTURAL JOURNAL
ISSN: 0300-368X
Volume 54 Number 1, April 2023 Pg. 74-82
Available online at: http://www.ajol.info/index.php/naj
https://www.naj.asn.org.ng

Quality Assessment of Pesticide-Contaminated Area in Umudike Environment, Abia State, Nigeria

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Abstract
In recent years, the use of agrochemicals like pesticides has caused great harm to environmental safety. Taking a site in a National Root Crops Research Institute, Umudike that use pesticides to control weed invasion and pest attack, soil samples were collected separately from each particular depth at 0-10 cm, 11-20 cm, and 21-30 cm depth at eighteen different sampling points while plant samples were collected from *Zea mays*, *Colocasia esculenta*, *Manihot esculenta*, and *Telfairia occidentalis*, and the contents of Cu, Cr, As, Ni and Zn, were tested using atomic absorption spectrometer. Results show that values of pH and organic matter in soil decreased with an increase in soil depth. A positive relationship exists between soil pH and Cu ($r= 0.250$), soil pH and Cr ($r= 0.262$), soil pH and As (0.143). A very strong positive relationship exists between soil pH and Zn in plants ($r= 0.616$, $p<0.01$), organic matter in soil and Zn in plants ($r= 0.893$, $p<0.01$) while a very strong relationship exists between electrical conductivity in soil and Cu in plants ($r= 0.769$, $p<0.01$), electrical conductivity and Cr in plants ($r= 0.784$, $p<0.01$). The mean concentration of Cu, Cr, As, Ni, and Zn in soil and plants were 3.97 and 1.82 mg/kg, 1.01 and 0.98 mg/kg, 1.68 and 0.91 mg/kg, 0.89 and 0.42 mg/kg, and 9.66 and 6.17 mg/kg, respectively. The values of As in *Colocasia esculenta* (0.91 mg/kg) exceeds the permissible limit of FAO/WHO. The use of such arsenic-contaminated cocoyam leaves for wrapping food items could be a route of entry of As in the human system. It is therefore recommended that Research Institute should be using bio-pesticide such as *Azadirachta indica* oil (*Azadirachtin*) and fungi of the *Metarhizium acridum* family that have been approved by FAO/WHO for control of weed and insect pests.

Keywords: Pesticides, heavy metals, soil, plants, contamination

Introduction

Plants are attacked by various pests and to check these pests, different pest control methods are employed globally including chemical pesticides, sex pheromones, and entomo-pathogenic insect pesticides (Sulistiyono *et al*., 2008; Goh *et al*., 2011; Ye *et al*., 2014). The application of chemical pesticides is the prime method used by farmers to control pests (Ray *et al*., 2021). Pesticides are a class of xenobiotic compounds that have been used to destroy or repel unwanted animals, insects, and plants (weeds) for several decades and they consist of a wide range of compounds such as rodenticides, insecticides, herbicides, molluscicides, nematicides among others (Lei *et al*., 2020). Pesticides are used extensively in commercial farming in Nigeria (Ogbonna *et al*., 2013) and their application is expected to increase in the coming years. All classes of pesticides are of great global concern because they not only pollute our biosphere but negatively impact food safety and security and ultimately resulting in various health issues (Chen *et al*., 2017; Imran *et al*., 2018). Excessive use of these pesticides causes various toxicity symptoms in plants, leading to reduced seed germination, shoot length, root length and biomass, chlorosis, necrosis, retarded growth and photosynthetic efficiency, and may persist in plant parts in the form of pesticide residues (Xia *et al*., 2009; Vidyasagar *et al*., 2013; Zhou *et al*., 2015; Sharma *et al*., 2016; Sharma *et al*., 2018). The highest and most intensive pesticide usage in agricultural activities is vegetable and secondary crop cultivation.

Food contamination by human activities (Ogbonna *et al*., 2012; 2013) is becoming very alarming due to the quest to cope with a high rate of food insecurity caused by pest infestation, nutrient depletion in soil as well as other myriads of human needs in Nigeria (Ogbonna *et al*., 2020). Thus, human health challenges in recent times have been attributed to the consumption of food contaminated with heavy metals (Ogbonna *et al*., 2018a). For instance, the prevalence of upper gastrointestinal cancer in the region of Turkey has been linked to metal pollution in soil, fruits, and vegetables (Turkdogan *et al*., 2003). Lead (Pb) poisoning causes inhibitions of the synthesis of hemoglobin and poor development of grey matter in the brain of children (Ogwuegbu and Muhanga, 2005; Udedi, 2003). The inhalation of cadmium (cd) causes bronchitis, pneumonitis, and inflammation of the liver (Mac farland, 1979) while argon (Ar) exerts a deleterious effect on the skin and hyperkeratosis on soles and feet, and palms and skin cancer (Berman, 1980). Consequently, heavy metal pollution is a worldwide phenomenon that poses a serious health hazard to aquatic and terrestrial ecosystems (Ogbonna *et al*., 2018a).

Chemical pollution of the environment attributable to economic, industrial, technological, and agricultural activities of humans, results in various deformations of the natural circulation of trace elements in the environment (Gorlach and Gambuś 1991). Pollution of soils with heavy metals is particularly dangerous to living organisms (Laskowski *et al*. 1995, Skwaryło-Bednarz 2006). Heavy metal-contaminated soil may transfer pollutants to further levels of the trophic chain, that is, plants, animals, and humans, or it may constitute a source of secondary pollution of air and water, therefore, impacting humans directly, without passing through the trophic chain. As opposed to air or water, the soil cleaning process is very slow. Correct assessment of soil pollution with heavy metals is very important to man since excessive quantities of heavy metals pose a significant threat to plants and humans as well as soil fauna.

The four crops sampled in this study (*Zea mays* L., *Colocasia esculenta* L. (Schott), *Manihot esculenta* Crantz and *Telfairia occidentalis* Hook f. are very crucial to the nutritional and health benefits of man. For instance, *Zea mays* L. grain is a good source of carbohydrates, minerals, vitamins, carotenoids, fiber and its oil is used for cooking, and soap making but the starch is used as diluents in pharmaceutical industries, and the seeds are used to make alcohol while the stem is for paper manufacturing (Huma *et al*., 2019). It has a wide range of vitamins (A, B, E, and K), minerals (Mg, P, and K), phenolic acids (ferulic acid, coumaric acid, and syringic acid), carotenoids and flavonoids (anthocyanins), and dietary fiber exhibiting health-promoting effects and lowering the risk of chronic diseases (Siyuan *et al*., 2018). *Colocasia esculenta* L. (Schott) ranks third in importance of staple root and tuber crops, after cassava and yam, among the class of root and tuber crops cultivated and consumed in most African countries (Onyeka, 2014). It has nutraceutical ingredients that act against chronic diseases and help maintain good health (Otekunrin *et al*., 2021). *Manihot esculenta* Crantz is the cheapest source of industrial starch the world over (Zainuddin *et al*., 2019; Oyeyinka *et al*., 2019), alternative feedstock in many industrial applications like industrial baking flour, drug manufacturing, and ethanol production among others due to its availability and low comparative cost (Anyanwu *et al*., 2015; Lawal *et al*., 2019; Ogbonna *et al*., 2020). *Telfairia occidentalis* Hook f. has haematinic properties with high levels of protein and iron, phosphorus, oleic acid, vitamin A, alkaloids, tannins, flavonoids, resins, hydrocyanic acid, linoleic acid, dietary fiber and it is effective in the prevention of cancer and other associated health conditions like ulcer, kidney stone, infertility issues in both men and women (Akoroda, 1990; Asoegwu, 2000; Balogun *et al*., 2002; Akanbi *et al*., 2007; Ibironke and Owutomo, 2019).

Literature search showed that no work has been carried out on soil chemical characteristics and metal accumulation in important food crops like *Zea mays*, *Colocasia esculenta*, *Manihot esculenta*, and *Telfairia occidentalis* in any pesticide-contaminated soil in Nigeria. The objective of this study, therefore, is to investigate the soil status and metal contamination of food crops at pesticide-contaminated sites and compare the results with permissible limits of FAO/WHO, Dutch criteria, and National Environmental Standards and Regulations Enforcement Agency (NESREA) of Nigeria. The results of this research will provide background information on the values of soil parameters tested in the study and metal contamination in food crops and serve the purpose of awareness creation to farmers on the possible health risk associated with pesticide usage.

Methodology

Study area

The study was carried out National Root Crops Research Institute, Umudike which belongs to the tropical rainforest zone (Keay, 1959) of Southeast Nigeria. Umudike is located at latitude 05°29′N and longitude 7°33′E, and altitude of 122m above sea level. The annual rainfall total is about 2200mm. Averagely, September is the month with the highest amount of rainfall while the month with the lowest amount is December (Okoye *et al*., 2020). The air temperature ranges between 21.2°C and 33.6°C, and the relative humidity of 60% to 83% (NRCRI, 2016).

Sample collection

Soil and food crops were collected from the experimental plot of the National Root Crops Research Institute (NRCRI) Umudike. Field collection of soil and plant samples was conducted in June 2021. Soil samples were collected separately at each particular depth of 0-10 cm, 11-20 cm 21-30 cm with the aid of a thoroughly cleaned soil auger at eighteen different sampling points. Thus, eighteen soil samples from each particular depth (e.g. 0-10 cm) were bulked together to form a composite sample, placed in a large polyethylene bag (about 100 g), well-sealed, carefully labeled, placed in a wooden box and covered to avoid contamination from external sources and transferred to the laboratory for pre-treatment and analysis. Each bulked sample was freed from impurities and air-dried to constant weight. The samples were pulverized, homogenized, and sieved through a 2.0 mm sieve pore. Sub-samples from each depth were subjected to analysis for the physicochemical properties of the experimental site. The reference site, located about 2 km away (upland) from the farmland, is a pristine agricultural land.

Zea mays L. (maize, Poaceae), *Colocasia esculenta* L. (cocoyam, Araceae), *Manihot esculenta* Crantz (cassava or manioc, Euphorbiaceae), and *Telfairia occidentalis* Hook f. (fluted pumpkin, Cucurbitaceae) were the food crops in the farmland. Due to the humid nature of the area, crops are protected from weed invasion, and pest attack via the application of pesticides once in a while. Food crops were sampled within the points where soil samples were collected from the experimental plot. Plant samples were collected randomly from different parts of each plant species. Samples from each plant species, for instance, *Zea mays* L. were placed separately in a large envelope, carefully sealed, labeled properly, placed in a wooden box, and covered to avoid contamination from external sources, and transferred to the laboratory. Samples were cleaned thoroughly with deionized water, and oven-dried at 60°C for 72 hr. Dried samples from each food crop were crushed and homogenized using thoroughly cleaned porcelain pestle and mortar, sieved and poured into plastic bottles, weighed accurately, and stored in the refrigerator at 4°C.

Statistical analysis and experimental design

A simple factorial experiment was conducted in a randomized complete block design with three replications in soil and four replications for food crops. Data generated from the laboratory analysis of samples were subjected to one-way analysis of variance (ANOVA) using statistical package for social sciences (SPSS) v. 20 and means were separated (Steel and Torrie, 1980) at $P<0.05$ using Duncan Multiple Range Test (DMRT) while Correlation analysis was used to determine the relationship between the means of the parameters analyzed in soil and food crops.

Results and Discussion

Heavy metals concentrations (mg/kg) in soil

The result of the statistical analysis of data from the laboratory on the concentration of heavy metals in soil is presented in Table 1. The result indicates that the highest and lowest concentrations of heavy metals were observed at the pesticide-contaminated site and control site, respectively. The high concentrations of heavy metals at the study site is attributed to pesticides used for the control of insect pests and weed. Pesticides are usually used by farmers and Research Institutes to eliminate weeds, pests, and diseases to boost crop quality and yield (Ogbonna *et al*., 2013; Lei *et al*., 2020). The result also showed that the concentrations of heavy metals at the study site varied significantly ($p<0.05$) across depths in soil but the highest levels of metals (Cu, Cr, As, Ni, and Zn) were obtained at 0-10 cm depth while the lowest values were recorded at 21-30 cm depth. It was observed that the values of metals decreased with an increase in depth. The high levels of heavy metals at 0-10 cm depth at the study site may be attributed to high organic matter content at 0-10 cm depth (0.12±0.00 %) unlike the 21-30 cm depth (0.01±0.00 %) (Table 2). Metals are bound to surface soil (Sukkariyah *et al*., 2005) because they (metals) are complex by organic matter, thus, reducing the leaching of metals into the lower depths of 11-20 and 21-30 cm (Ogbonna *et al*., 2018a). These could explain the low values of heavy metals in sub-soils (11-20 and 21-30 cm). However, the pH of soils across the depths of the study site encouraged the migration of metals from surface soil (0-10 cm) to sub-soils (11-20 and 21-30 cm) since the pH values were below 6.0. Generally, most metals do not exist in free form in the pH range of 6.0 to 9.0 (Adie and Etim, 2012; Ogbonna *et al*., 2021).

In this study, the values of Cu (3.97±0.04 mg/kg) at 0-10 cm soil depth was 4.73 and 44.11 times higher than its values at 11-20 and 21-30 cm depths while the value of Cr (1.01 mg/kg) at 0-10 cm soil depth was 4.81 and 1010 times higher than its values at 11-20 and 21-30 cm depths. Similarly, the value of As (1.68 mg/kg) at 0-10 cm soil depth was 2.05 and 84 times higher than its values at 11-20 and 21-30 cm soil depths while the value of Ni (0.89 mg/kg) at 0-10 cm soil depth was 12.71 and 890 times higher than its values at 11-20 and 21-30 cm depths. The value of Zn (9.66 mg/kg) at 0-10 cm soil depth was 2.46 and 11.23 times higher than its values at 11-20 and 21-30 cm depths. Comparing the values of heavy metals in soils at the study site with the values obtained at the control plot, the value of Cu, Cr, As, Ni, and Zn were 3970, 1010, 1680, 890, and 50.84 times higher than their values at the control site, respectively.

The values of Cu in soil increased from 0.09 to 3.97 mg/kg, which is well below the target value of 36 mg/kg (Cu) set by Dutch criteria for soil (Ogbonna *et al*., 2018b) and 100 mg/kg (Cu) by National Environmental Standards and Regulation Enforcement Agency (NESREA, 2011). The values of Cr in soil increased from 0.00 to 1.01 mg/kg, which is well below the permissible limit of 100 mg/kg (Cr) set by the Codex Alimentarius Commission (FAO/WHO, 2001 and 100 mg/kg by the National Environmental Standards and Regulation Enforcement Agency (NESREA, 2011). The values of As in soil increased from 0.02 to 1.68 mg/kg, which is well below the target value of 29 mg/kg (As) set by Dutch criteria for soil (Ogbonna *et al*., 2018a). The values of Ni increased from 0.00 to 0.89 mg/kg, which is well below the target value of 35 mg/kg (Ni) by Dutch criteria for soil (Ogbonna *et al*., 2018a). The values of Zn in soil increased from 0.86 to 9.66 mg/kg, which is well below the permissible limit of 60 mg/kg (Zn) by the Codex Alimentarius Commission (FAO/WHO, 2001) and 421 mg/kg (Zn) by National Environmental Standards and Regulation Enforcement Agency (NESREA, 2011). Generally, the values of heavy metals in soil followed an increasing order:

Ni<Cr<As<Cu<Zn.

Chemical properties of soil

The values of pH, organic matter, and electrical conductivity in the soil of the pesticide-contaminated site and control site are presented in Table 2. The highest and lowest pH and organic matter values in soils were obtained at the control site and pesticide-contaminated site, respectively. The soil pH of the study site increased from 4.93 to 5.90 which is lower than 6.29 recorded at the control site. The high acidity of soil at the study site may be attributed to low organic matter content (Table 2) vis-à-vis the impact of pesticide residues on the soil.

The highest and lowest organic matter values in soils were recorded at the control site and pesticide-contaminated site, respectively. The level of organic matter in the soil of pesticide-contaminated sites increased from 0.01 to 0.12 % which is lower than the 0.38 % observed at the control site. The high organic matter at the control site may be attributed to the release of litter falls (i.e. flowers, leaves, pollens, twigs, seeds, fruits, etc.) by plant species at the control site coupled with the absence of pesticide residues in soil, unlike the pesticide-contaminated site where pesticide residues might have resulted to low species diversity (i.e. destroyed weeds) as well as negated the activities of soil fauna (e.g. earthworms) that aid in breaking down and decomposition of organic materials. Soil microorganisms play essential roles in soil ecosystem processes such as organic matter decomposition**,** which ultimately affect soil function but soil microbial communities are influenced by soil pH (Lauber *et al*., 2009; Rousk *et al*., 2010). The values of pH and organic matter in the soil decreased as the soil depth increased. Similarly, the high acidity of the pesticide-contaminated site (unlike the control site) might have affected microbial activities in the soil. The result is in agreement with the findings of Ogbonna *et al*. (2021) in a related study.

The highest and lowest values of electrical conductivity (EC) in soils were observed at the pesticide-contaminated and control site, respectively. The values of EC in the soil at the pesticide-contaminated site increased from 1.08 to 2.05 µS/cm which is higher than 0.52 µS/cm obtained at the control site. The high EC at the pesticide-contaminated site may be associated with low pH (4.93 to 5.90) in soil, unlike the control site with a high pH value of 6.29. Salinity usually refers to the presence of soluble salt in the soil and pH affect the solubility of salts (Mohd-Aizat *et al*., 2014).

Heavy metals concentration (mg/kg) in plants

The values of the heavy metals in different plant species are presented in Table 3. The results indicate that the highest and lowest values of heavy metals in plants were recorded in the pesticide-contaminated site and control sites, respectively. The result also showed that the assimilation of heavy metals by plant species (*Zea mays*, *Colocasia esculenta*, *Manihot esculenta*, and *Telfairia occidentalis*) varied considerably. *Zea mays* (maize) assimilated the highest values of Cu (1.82 mg/kg) and Cr (0.98 mg/kg) and this may be attributed to the inherent ability of the plant (Z. mays) to absorb and translocate more Cu and Cr from soil solution to the aerial plant parts (leaves) than other plants. Its (Z. mays) fibrous root system might have facilitated the absorption of the metals from 0-20 cm depth where a significant level of these metals occurred in soil solution (Table 1) and translocated it (Cu and Cr) to the aerial part of the plant. Inherent ability is an important plant potential to absorb and translocate metals from soil solution to aerial plant parts (Ogbonna *et al*., 2018b). The values of Cu increased from 0.92 to 1.82 mg/kg, which is well below the permissible limit of 40 mg/kg (Cu) by Codex Alimentarius Commission (FAO/WHO, 2006) for crops. The values of Cr increased from 0.10 to 0.98 mg/kg, which is lower than the permissible limit of 2.3 mg/kg (Cr) by FAO/WHO (2006) for crops. Chromium (III) is an essential element for plant growth and development but its accumulation in the food chain can pose a health risk to man. For instance, health problems like irritation to the lining of the nose, stomach tumors and respiratory diseases have been associated with chromium exposure (Arhin *et al*., 2017).

Colocasia esculenta (cocoyam) accumulated the highest values of As (0.91 mg/kg) and Ni (0.42 mg/kg). Metal accumulation in plants is dependent on type of metal and plant species involved (Juste and Mench, 1992; Ogbonna and Okezie, 2011; Ogbonna *et al*., 2018a). The high accumulation of As and Ni in *C. esculenta* may be attributed to its fibrous root system that grows deeper beyond the surface soil (0-10 cm) and sub-soils (11-30 cm). For instance, the root system of *Colocasia esculenta* is fibrous and lies mainly at a depth of up to one meter of soil (Onwueme, 1994; Onyeka, 2014; Otekunrin *et al*., 2021). The values of As increased from 0.08 to 0.91 mg/kg, which is higher than the permissible limit of 0.2 mg/kg (As) by Codex Alimentarius Commission (FAO/WHO, 2006) for crops. Cocoyam leaves are eaten in sauces, soups or stews due to the high content of vitamins (vitamin C, thiamin, riboflavin, and niacin), minerals (calcium, phosphorus, iron), secondary metabolites, and fiber (Lebot, 1999; Lebot *et al*., 2004; Bhagyashree and Hussein, 2011; Lebot and Legendre, 2015; Ahmed *et al*., 2020; Otekunrin *et al*., 2021). Additionally, its leaves are a veritable wrapping material for sliced seeds of *Pentaclethra macrophylla*, kola nuts, “moi-moi”, and fermented “fufu” among others in Southeast Nigeria. Ingestion and dermal contact are one of the main routes of entry of heavy metals, thus, wrapping such food items with arsenic-contaminated cocoyam leaves could be a route of entry of arsenic (As) in the human alimentary system vis-à-vis accumulation in human organs and tissues. For instance, arsenic toxicity by food occurred in western areas of Japan when arsenic compounds were accidentally mixed into Morinaga's dried milk made by the Tokushima plant of the Morinaga Milk Company. Indubitably, out of 13,389 newborns that ate the contaminated milk, 600 died, whereas 6093 suffered health difficulties, and 624 were mentally handicapped, had biological process difficulties, and had brain-damage-related paralysis (Dakeish *et al*., 2006). Long-term exposure to arsenic from food consumption can cause cancer, bladder, kidney, and skin lesions (WHO, 2016), dehydration, weakness and lethargy (Gupta and Gupta, 2013), cardiovascular, gastrointestinal, hepatic, and renal disease (Vamerali *et al*., 2010). Arsenic does not have any essential function to plants or humans and it has a very long soil residence time from 1,000 to 3,000 years (Bowen, 1979; Gonzalez-Chavez *et al*., 2015). The translocation of arsenic to the shoot inhibits plant growth by slowing biomass accumulation and compromising plant reproductive capacity through losses in fertility, yield, and fruit production (Garg and Singla, 2011). The values of Ni increased from 0.01 to 0.42 mg/kg, which is lower than the permissible limit of 1.68 mg/kg (Ni) set by FAO/WHO (2001). 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-Chodak and Blaszczyk, 2008).

The highest value of Zn (6.17 mg/kg) was recorded in *Telfairia occidentalis* (fluted pumpkin). The values of Zn increased from 0.22 to 6.17 mg/kg, which is well below the permissible limit of 50 mg/kg (Zn) by FAO/WHO (2006). The value of Zn in *T. occidentalis* makes the plant an important source of Zn to man including animals. Fluted pumpkin is a good source of Zn which is relevant for immune function, wound healing, blood clotting, and thyroid function (Debjit and Kumar, 2010). Generally, the values of heavy metals in soil followed an increasing order: Ni<As<Cr<Cu<Zn.

Pearson correlation analysis between heavy metals in soil and chemical properties of soil

The Pearson correlation between heavy metals concentration in soil and chemical properties of soil is presented in Table 4. The results indicate a positive relationship between heavy metals and chemical properties in soil. For instance, a positive relationship exists between soil pH and Cu (r = 0.250), soil pH and Cr (r = 0.262), soil pH and As (r = 0.143), soil pH and Ni (r = 0.304), soil pH and Zn (r = 0.139). However, a negative relationship exists between organic matter and Cu in soil (r= -0.198), organic matter and Cr in soil (r = -0.182), organic matter and As in soil (r = -0.267), organic matter and Ni in soil (r = -0.141), organic matter and Zn in soil (r = -0.288) while very strong negative relationship exists between electrical conductivity and soil pH (r = -0.988, p<0.01) as well as electrical conductivity and organic matter in the soil (r = -0.916, p<0.01). Indeed, a very strong positive relationship exists between organic matter and soil pH (r = 0.876, p<0.01). More so, very strong positive relationship exists between Cr and Cu in soil (r = 0.999, p<0.01), As and Cu in soil (r = 0.956, p<0.01), As and Cr in soil (r = 0.958, p<0.01), Ni and Cu in soil (r = 0.987, p<0.01), Ni and Cr in soil (r = 0.989, p<0.01), Ni and As in soil (r = 0.909, p<0.01). Furthermore, a very strong positive relationship exists between Zn and Cu in soil (r = 0.981, p<0.01), Zn and Cr in soil (r = 0.982, p<0.01), Zn and As in soil (r = 0.990, p<0.01), and Zn and Ni in soil (r = 0.945, p<0.01).

Pearson correlation analysis between heavy metals in plants and chemical properties of soil

The Pearson correlation relationship between heavy metals concentration in plants and chemical properties in the soil is presented in Table 5. The results indicate a very strong positive relationship between heavy metals in plants and chemical properties in soil. For instance, a very strong positive relationship exists between soil pH and Zn in plants (r = 0.616, p<0.01), organic matter in soil and Zn in plants (r = 0.893, p<0.01), organic matter in soil and soil pH (r = 0.876, p<0.01) while very strong relationship exists between electrical conductivity in soil and Cu in plants (r = 0.769, p<0.01), electrical conductivity and Cr in plants (r = 0.784, p<0.01), electrical conductivity and As in plants (r = 0.937, p<0.01) as well as electrical conductivity and Ni in plants (r = 0.796, p<0.01). Furthermore, a very strong positive relationship exists between Cr and Cu in plants (r = 0.919, p<0.01), As and Cu in plants (r = 0.788, p<0.01), As and Cr in plants (r = 0.815, p<0.01). Similarly, a very strong positive relationship exists between Ni and Cu in plants (r = 0.563, p<0.01), Ni and Cr in plants (r = 0.548, p<0.01), Ni and As in plants (r = 0.929, p<0.01).

Pearson correlation analysis between heavy metals in soil and plants

The Pearson correlation relationship between heavy metals concentration in soil and plants is presented in Table 6. The results indicate that a negative relationship exists between Cu in plants and Cu in soil (r = -0.265), Cu in plants and Cr in soil (r = -0.265), Cu in plants and As in soil (r = -0.007), Cu in plant and Ni in soil (r = -0.375), and Cu in plant and Zn in soil (r = -0.085). Similarly, a negative relationship exists between Cr in plant and Cu in soil (r = -0.178), Cr in plant and Cr in soil (r = -0.183), Cr in plant and As in soil (r = -0.071), Cr in plant and Ni in soil (r = -0.295), and Cr in plant and Zn in soil (r = -0.001). A very strong positive relationship exists between Cr and Cu in soil (r = 0.999, p<0.01), As and Cu in soil (r = 0.956, p<0.01), As and Cr in soil (r = 0.958, p<0.01), Ni and Cu in soil (r =0.987, p<0.01), Ni and Cr in soil (r = 0.989, p<0.01), and Ni and As in soil (r = 0.909, p<0.01). Similarly, a very strong positive relationship exists between Cr and Cu in the plant (r = 0.919, p<0.01), As and Cu in the plant (r = 0.788, p<0.01), and As and Cr in the plant (r = 0.815, p<0.01).

Conclusion

The study show that heavy metals such as Cu, Cr, As, Ni, and Zn were present at various levels in the soil studied and accumulated in plants growing at the pesticide contaminated site. The result shows that values of heavy metals in soil were below the Dutch criteria, FAO/WHO and NESREA permissible limits. It also shows that concentrations of heavy metals decreased with increase in soil depths. Of all the heavy metals tested in this study, the value of As (0.08 to 0.91 mg/kg) in *Colocasia* *esculenta* exceeded the permissible limit of FAO/WHO, which could be a threat to the health of people inhabiting the area since it (*Colocasia esculenta*) is a wrapping material for food products in the area. Therefore, it is recommended that effective monitoring of the pesticide contaminated site should be carried out on regular basis by the National Root Crops Research Institute, Umudike and the results be communicated to inhabitants of the area. In addition, bio-pesticides should be used for control of weed and insect pests in the study area.

Acknowledgement

We wish to acknowledge the staff of National Root Crops Research Institute, Umudike that granted us access to the study site.

Conflict of interest

There authors declare no conflict of interest.

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Table 1: Heavy metals concentrations (mg/kg) in soil

Depth (cm)	Cu	Cr	As	Ni	Zn
0-10	$3.97^a \pm 0.04$	$1.01^a \pm 0.04$	$1.68^a \pm 0.04$	$0.89^a \pm 0.08$	$9.66^a \pm 0.56$
11-20	$0.84^b \pm 0.02$	$0.21^b \pm 0.00$	$0.82^b \pm 0.01$	$0.07^b \pm 0.02$	$3.93^b \pm 0.08$
21-30	$0.09^c \pm 0.02$	$0.00^c \pm 0.00$	$0.02^c \pm 0.00$	$0.00^b \pm 0.00$	$0.86^c \pm 0.05$
Control	$0.001^d \pm 0.000$	$0.00^c \pm 0.00$	$0.00^c \pm 0.00$	$0.00^b \pm 0.00$	$0.19^d \pm 0.02$

Values are mean ± standard deviation of 3 replicates
[abcd] Means in a column with different superscripts are significantly different (P<0.05)

Table 2: Chemical properties in soil

Depth (cm)	**pH**	**OM (%)**	**EC (µS/cm)**
0-10	$5.90^b \pm 0.10$	$0.12^b \pm 0.00$	$1.08^c \pm 0.00$
11-20	$5.23^c \pm 0.08$	$0.08^b \pm 0.01$	$1.73^b \pm 0.04$
21-30	$4.93^d \pm 0.12$	$0.01^c \pm 0.00$	$2.05^a \pm 0.05$
Control	$6.29^a \pm 0.03$	$0.38^a \pm 0.05$	$0.52^d \pm 0.00$

Values are mean ± standard deviation of 3 replicates
[abcd] Means in a column with different superscripts are significantly different (P<0.05)

Table 3: Heavy metals concentration (mg/kg) in plants

Depth (cm)	Cu	Cr	As	Ni	Zn
M. esculenta	$1.02^c \pm 0.00$	$0.28^c \pm 0.02$	$0.11^c \pm 0.02$	$0.02^{cd} \pm 0.01$	$0.22^d \pm 0.02$
Zea mays	$1.82^a \pm 0.00$	$0.98^a \pm 0.01$	$0.55^b \pm 0.05$	$0.09^b \pm 0.03$	$2.06^b \pm 0.05$
C. esculenta	$1.38^b \pm 0.00$	$0.57^b \pm 0.04$	$0.91^a \pm 0.02$	$0.42^a \pm 0.00$	$0.90^c \pm 0.10$
T. occidentalis	$0.92^d \pm 0.00$	$0.10^d \pm 0.02$	$0.08^d \pm 0.02$	$0.01^d \pm 0.00$	$6.17^a \pm 0.03$
Manihot control	$0.00^e \pm 0.00$	$0.00^e \pm 0.00$	$0.00^e \pm 0.00$	$0.00^d \pm 0.00$	$0.01^f \pm 0.01$
Zea mays control	$0.00^e \pm 0.00$	$0.00^e \pm 0.00$	$0.00^e \pm 0.00$	$0.00^d \pm 0.00$	$0.07^{ef} \pm 0.01$
Colocasia control	$0.00^e \pm 0.00$	$0.00^e \pm 0.00$	$0.00^e \pm 0.00$	$0.00^d \pm 0.00$	$0.02^f \pm 0.01$
Telfairia control	$0.00^e \pm 0.00$	$0.00^e \pm 0.00$	$0.00^e \pm 0.00$	$0.00^d \pm 0.00$	$0.10^e \pm 0.02$

Values are mean ± standard deviation of 3 replicates
[abcdefg] Means in a column with different superscripts are significantly different (P<0.05)

Table 4: Correlation between heavy metal in soil and some chemical properties of soil

	Cu (soil)	Cr (soil)	As (soil)	Ni (soil)	Zn (soil)	pH	OM	EC
Cu (soil)	1							
Cr (soil)	0.999**	1						
As (soil)	0.956**	0.958**	1					
Ni (soil)	0.987**	0.989**	0.909**	1				
Zn (soil)	0.981**	0.982**	0.990**	0.945**	1			
pH	0.250	0.262	0.143	0.304	0.139	1		
OM	-0.198	-0.182	-0.267	-0.141	-0.288	0.876**	1	
EC	-0.175	-0.190	-0.073	-0.234	-0.069	-0.988**	-0.916**	1

*****. Correlation is significant at the 0.01 level (P<0.01). *. Correlation is significant at the 0.05 level (P<0.05)***

Table 5: Correlation between heavy metal in plants and chemical properties of soil

	Cu (plant)	Cr (plant)	As (plant)	Ni (plant)	Zn (plant)	pH	OM	EC
Cu (plant)	1							
Cr (plant)	0.919**	1						
As (plant)	0.788**	0.815**	1					
Ni (plant)	0.563**	0.548**	0.929**	1				
Zn (plant)	0.433*	0.173	0.096	-0.009	1			
pH	-0.777**	-0.786**	-0.952**	-0.810**	0.616*	1		
OM	-0.626*	-0.673*	-0.758**	-0.655*	0.893**	0.876**	1	
EC	0.769**	0.784**	0.937**	0.796**	-0.682*	-0.988**	-0.916**	1

*****. Correlation is significant at the 0.01 level (P<0.01). *. Correlation is significant at the 0.05 level (P<0.05)***

Table 6: Correlation between heavy metal in soil (s) and heavy metal in plant (p)

	Cu (s)	Cr (s)	As (s)	Ni (s)	Zn (s)	Cu (p)	Cr (p)	As (p)	Ni (p)	Zn (p)
Cu (s)	1									
Cr (s)	.999**	1								
As (s)	.956**	.958**	1							
Ni (s)	.987**	.989**	.909**	1						
Zn (s)	.981**	.982**	.990**	.945**	1					
Cu (p)	-.260	-.265	-.007	-.375	-.085	1				
Cr (p)	-.178	-.183	.071	-.295	-.001	.919**	1			
As (p)	-.463	-.479	-.401	-.496	-.385	.788**	.815**	1		
Ni (p)	-.424	-.440	-.478	-.402	-.417	.563**	.548**	.929**	1	
Zn (p)	-.587*	-.572	-.598*	-.546	-.637*	.433*	.173	.096	-.009	1

*****. Correlation is significant at the 0.01 level (P<0.01). *. Correlation is significant at the 0.05 level (P<0.05)***