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TRACE METAL LEVELS OF SOIL-GROWN AMARANTHS ON MUNICIPAL SOLID WASTE DRAINAGE OF WUKARI METROPOLIS

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ABSTRACT

Soil metal levels of municipal solid waste drainage and morphological traits of Amaranthus spp growing in the natural drainage of Wukari Metropolis was investigated as an ecological monitoring data survey and food chain contamination assessment. Selected morphological traits, physico-chemical parameters and the status of selected trace metal (Cr, Cu, Ni, Pb, Zn) levels of the municipal solid waste drainage used for the dry season cultivation of Amaranthus spp were determined according to standard analytical procedures. Results reveals a significant ($P<0.05$) soil Pb (48.96) and soil Cr (23.50) levels in the municipal solid waste drainage arising from automobile/vehicular mechanic sites runoffs along the natural MSW drainage and traffic density fallouts due to proximity of sampling sites to the highway. Only stem girth was significantly different ($P \leq 0.05$) among the leaf area, number of leaves and plant height of the Amaranths. A higher soil organic matter content, slightly acidic pH and Cations Exchange Capacity of the MSW drainage indicate the suitability of the composted wastes of the MSW drainage for Amaranths cultivation. Trace metal levels were below the Joint WHO/FAO Codex Alimentarius permissible limits (Pb = 2mg/kg; Cr = 1.30mg/kg; Cu = 10mg/kg; Zn = 5mg/kg) but higher for Cr and Pb revealing the close proximity of study area to high traffic density of the Katsina –Ala – Jalingo Highway. Therefore, the utilization of MSW Drainage for dry season irrigation farming of leafy vegetables near high traffic density reflects a tendency of potential food chain contamination.

Keywords: Amaranths, Drainage, Dumpsite, Municipal Solid Waste, Trace Metals, Wukari Metropolis

INTRODUCTION

Rapid population growth and urbanization in developing countries have led to the generation of enormous quantities of solid wastes and consequential environmental degradation (Nagendran et al., 2006). The consequences of inadequate collection and disposal of waste products have a negative impact on the ecosystem, which contribute to the degradation of the urban environment and pose health hazards to urban populations at large. Indeed, the nutrient content of wastes makes them attractive as fertilizers, but when untreated wastes are used in crop production, consumers risk to contact diseases like cholera and hepatitis,or to undergo heavy metal contamination (Drechsel et al., 1999). In addition to the potential beneficial nutrients, Chukwujindu et al. (2005) reported that some waste materials might also contain non-essential elements, persistent organic compounds and microorganisms that may be harmful to plants. For instance, the presence of toxic heavy metals in municipal solid waste composts (MSWC) raises serious concerns about the adverse environmental impact as a result of excessive application to agricultural lands (Ayari et al., 2008). Hamdi et al., (2003) noted that heavy metals originate mostly in non-source - separated municipal solid wastes from a variety of sources: batteries, electronic appliances, newspapers, paint chips, foils, motor oils, and plastics that can all introduce metal contaminant into the compostable organic fraction. High and excessive accumulation of heavy metals in soil and other media may eventually contaminate both human and animal food chain (Chukwujindu et al., 2005; Wei et al., 2022).

Heavy metals such as Zn, Ni, and Cr are primary concern because of their potential to harm soil organism like plant, animals and human beings. Nearly all human activities generate waste and the way in which these wastes are handled, stored, collected and disposed of can pose risk to the environment and also to the public health (Zhu *et al*., 2008). It is a common phenomenon to find people especially in urban areas using soil from refuse dumpsites for the purpose of vegetable garden farming. Often times, these soils are dark brown in color and are perceived to be rich in organic manure and other macro nutrient elements for plant cultivation. This perception or assumption may be right or wrong depending on the type and composition of the waste at such dumpsites and their impact on these useful elements in soils. Several researches have revealed that MSW is a rich source of soil nutrients and can be utilized for wealth creation in crop cultivation instead of being a waste. Municipal waste refuse dumps are important feeding site for microorganisms and pest species especially rat, birds and stray animals thereby contributing greatly to these substances and multiplication (Bellebaum *et al.*, 2005).

The use of municipal solid wastes (MSW) dumpsites as farmlands is a common practice in urban and sub-urban areas in Nigeria, due to the fact that decayed and composted MSW enhance soil fertility (Ogunyemi *et al*., 2003). Some of the MSW decompose and increase the fertility of the soil while others do not decompose (Ghaly and Alkoaik 2010). The concentrations of heavy metals in soil around waste dumps are influenced by types of wastes, topography, run-off and level of scavenging (Ideriah *et al*, 2007).

Various studies have shown that dumpsite soils in part of Nigeria support plants growth and biodiversity and as such they have been extensively used for cultivating varieties of edible vegetables and plant based foodstuff (Cobb *et al*., 2000; Benson and Ebong, 2005). In Nigeria, and other tropical countries of Africa where the daily diet is predominated by starchy staple foods, vegetables are the cheapest and most readily available sources of important proteins, vitamins, minerals and essential amino acids (Akubugwo *et al*., 2007). Since 1980, *Amaranthus* spp. have been rediscovered as a promising food crop mainly due to its resistance to heat, drought, diseases and pests, and the high nutritional value of both the seeds and leaves (Wu *et al*., 2000).

Amaranth is one of the oldest drought-tolerant food crop in the world necesating its adaptability to environmental conditions. Amaranth contribute to the nutritional well-being of rural people by providing the essential nutrients required for body growth and development and for prevention of diseases associated with nutritional disorders such as blindness due to vitamin A deficiency (Abolaji *et al.*,2017). Cultivation of this vegetable is a good source of income to women in most communities and serves as a means that could help fight poverty (Sustainet, 2006). Amaranths is one of the most consumed leafy vegetables in Wukari Metropolis since it needs little water for irrigation and has high yield potential and income generation during the dry season than the wet season. Regular monitoring of trace metals in leafy vegetables and other food crops is very essential which could help predict potential metal pollution arising from MSW. The aim of this research is to determine the status of trace metal levels of the drainages from the MSW dumpsites in a rapidly growing peri-urban population like Wukari, especially with the establishment of federal and private universities which had attracted many commercial activities.

MATERIALS AND METHODS

This work was carried out towards the late dry season or harmattan of January 2019 at Wukari Local Government Area of Taraba State situated at Latitude 7^{0}50’37”N, Longitude 9^{0}46’30”E and at an altitude of 189 km above the sea level. The map of the study area and the sampling site as inset is shown in Fig 1. The research was conducted at the Marmara pond, a major water body within Wukari metropolis which also serves as a municipal solid waste (MSW) drainage that carries and discharges all the wastes from the metropolis into other water bodies. The pond originates from River Ibi (a continuation of River Benue) from Wukari rice mill through the Great Leader Academy to the Crocodile pond behind FRSC Office and separates into two with one discharge flowing down to Angwan Mission Quarters where the dry season irrigation farming takes place on a yearly basis, while the other zigzagged down to Kasuwan Shanu adjoining to other water bodies. The water flowing through the drainage carries tonnes of MSW from different smaller drainages within Wukari Metropolis and later converged at the large major natural drainage at the the Angwan Mission Quarters. Three sampling points namely Up-Stream, Mid-Stream and Low Stream at distances of 72.3m, 51.6m and 63.4m respectively adjacent to the Marmara pond or MSW drainage was selected for this research. Up-Stream is plain and sloppy caused by erosion with fast flowing water; Mid-Stream is multi-undulated with steady flow of drainage while Low Stream is flat with steady flow of water. A pre-survey visit to site revealed that the drainage is highly polluted with solid waste such as; cow dung, plastic bottles, polythene bags, textiles, aluminum cans, farm wastes, papers, brken bottles, cans, tins among others. The plant community of the MSW drainage included mostly roselle, guinea corn, maize, tomato, mango and banana. The animal community included; butterflies, worms, ants and toads among others. The soil at the experiment area was clay loam with a pH range of 6.50 to 7.50.

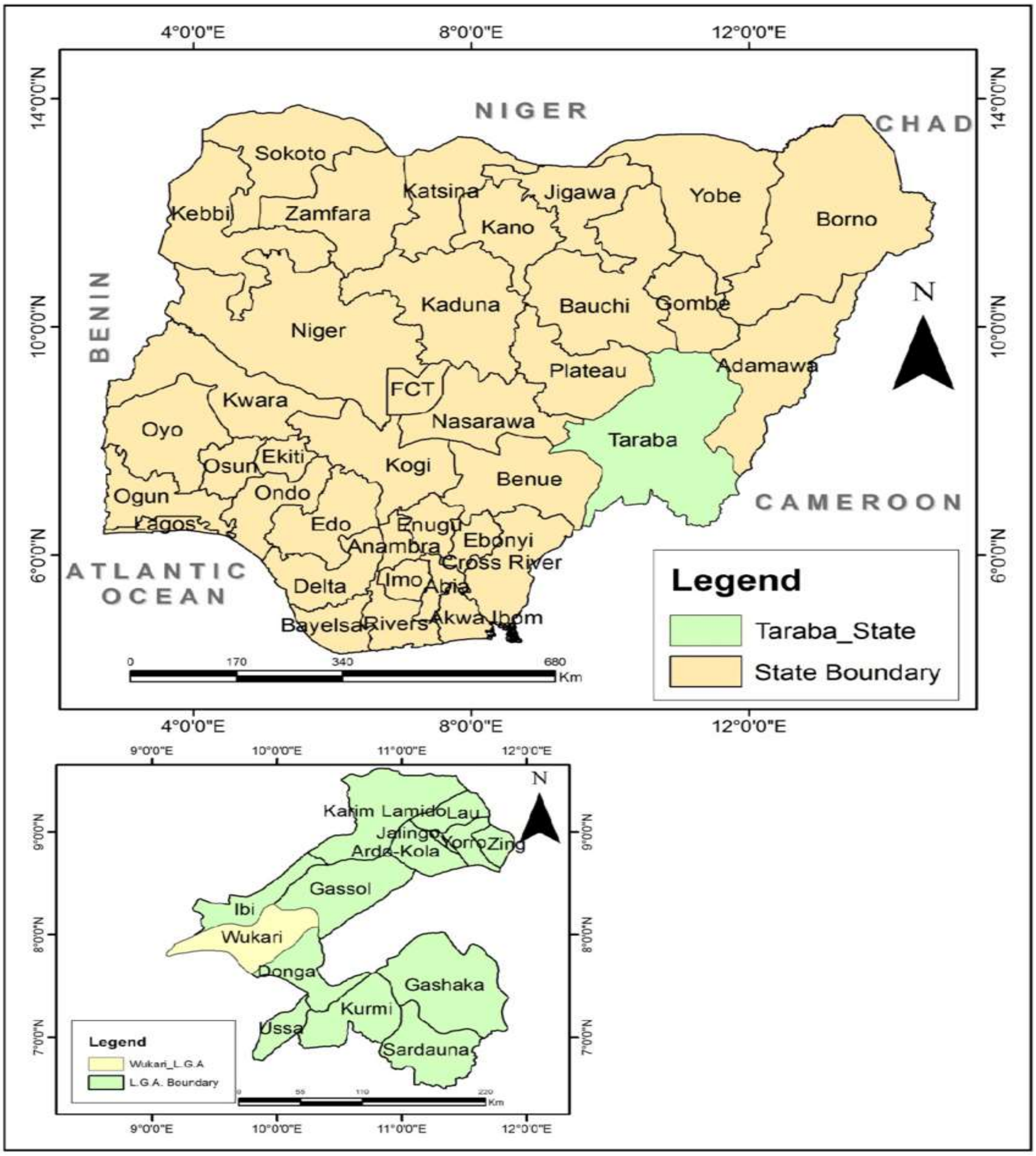

Figure 1: Map of Nigeria showing the study area (Wukari Local Government Area yellow insert).

A total of 24 Amaranthus species was randomly selected from the three sampling points. Morphological features of the sample.

Amaranthus was observed base on AVRDC - GRSU description (2008). Selected morphological characteristics (plant colour, plant height, number of leaves and plant girth) were observed, assessed and measured at their mature stage. Correspondence duplicate soil samples using a soil auger was collected at a depth of 0 – 15cm at the three sampling points and transferred into well labeled polythene bags. Both samples were taken to the Department of Soil Science laboratory Ahmadu Bello University Zaria for analysis**.** Plant height, leaf area, plant girth and number of leaves were the selected morphological traits with market value of Amaranthus species determined by visual observations according to standard procedures. Soil samples were air dried, ground, passed through a 2mm sieve and stored in labeled plastic bottles for Physico-chemical (soil pH in a ratio of 1:2 (Conyers and Davey 1988; organic carbon content by Walkey- Black and digestion method as described by Amoo *et al*., (2004) and heavy metal analyses.

The samples for trace metal analysis were digested according to the method described by Ademoroti (1996). The digested samples were analyzed for the metals (Cr, Cu, Ni, Pb, Zn) using Atomic Absorption Spectrophotometer equipped with an air- acetylene burner, Pye Unicam model sp-2900S. Total organic carbon (TOC) and Electrical conductivity were determined according to standard analytical procedures.

DATA AND STATISTICAL ANALYSIS

The statistical software packages used to analyze data from this study were the SPSS version 17.0 and MS-Excel version 2007. The descriptive statistics was used to compute the means, standard error and ranges of the data. Analysis of variance (ANOVA) was used to compare the levels of trace or heavy metals as well as the physicochemical properties of the soil across the three sampling points and significant means ($P < 0.05$) were separated using Student Newman Keuls Post Hoc test.

RESULTS AND DISCUSSIONS

From Table 1, the highest and lowest mean plant height of Amaranth was observed at Mid-Stream (104.4 cm) and low stream (94.7 cm) respectively. Leaf area was highest Up-stream (206 cm^3) and lowest (50.1 cm^3) at low stream. Also the number of leaves and plant girth was highest at Mid-stream (17.50; 3.78 cm) while low stream (13.16; 2.28 cm) recorded the lowest value. The high values could be related to the high concentration of the drainage nutrients further enriching the soil resulting to greater plant height, broader leaf area and plant girth as well as high number of leaves per plant. Results from this research showed a high range of variability of the selected morphological traits when compared with other works. Results of the field experiment by Kariithi *et al*., 2018 to evaluate the effect of organic and inorganic fertilizers application on growth parameters of two amaranth varieties as factorial combinations of three treatments in a randomized block design varied with the present research. The highest leaf area of 1415 cm^3 in the second season was observed in *A. cruentus* and 248 cm^3 in the first season, while *A. tricolor* recorded 700 cm^3 in the second season from 387cm^3 in season one at the same treatment of 16.9 t/h+500 kg/ha. In contrast to the present research, the Amaranths were grown in MSW drainage with mean leaf area ranging from 50.1 cm^3 at Low Stream to 206 cm^3 at Up-Stream (Table 1). Also the number of leaves obtained in this present study is similar to the works of Kariithi *et al.*, 2018. They remarked that the leaf number increased with increased NPK fertilizer application indicating a suitable concentration of nitrogen in the MSW drainage, though N content of the MSW drainage was not determined in this research (Table 1).

In contrast to the works of Gueco *et al*., 2016, the mean plant girth in this present research ranging from 3.78 cm at Mid-Stream to 2.28 cm (Low Stream) is higher than their stem diameter of 1.87 cm, ranging from 2.95 cm to 0.68 cm. Similarly, Gueco *et al*., 2016 reported a higher mean plant height of the *Amaranthus sp* of 136.27 cm ranging from 178.60 cm to 72.67cm than values obtained in this research revealing the efficacy of the inorganic fertilizer over the MSW drainage – a form of organic liquid manure. Municipal solid waste is mainly used as a source of nitrogen and organic matter, improving soil properties and microbial activity that are closely related to soil fertility. Bio-waste and food waste increase pH, nitrogen content, cation exchange capacity, water holding capacity, and microbial biomass in soil (Hossain *et al*., 2017).

Table 1: Morphological Characteristics of Amaranths Collected at Municipal Solid Waste Drainage in Wukari

Morphological Traits	Up-Stream	Mid-Stream	Low Stream
Plant Height(cm)	104.4±13.8a	117.7±12.2a	94.7±10.5a
Leaf area (cm)	206.0±433.8a	94.8±54.8a	50.1±18.9a
Plant Girth (cm^2)	3.41±0.81a	3.78±0.70b	2.28±0.18b
Number of Leaves	14.6±5.55a	17.50±3.46a	13.16±1.80a

Values sharing the same letter in each row are not significantly different from each other ($P \leq 0.05$)

The mean (±SE) of the trace metal levels of soils of the three sampling points from the MSW drainage are presented in Table 2. Data from the three sampling points were compared with the maximum permissible levels of heavy metals according to Codex Alimentarius Commission of the Joint FAO/WHO Food Standards (2006) (Pb = 2 mg/kg; Cr = 1.30 mg/kg; Cu = 10 mg/kg; Zn = 5 mg/kg). Pb and Cr are above the maximum while Cu and Zn were below the maximum permissible limits among the three sampling points (Table 2). However, there was significant difference ($P<0.05$) in Cu, Pb and Cr levels. This reveals that components of the MSW also contain a high level of Pb, Cu and Cr. The MSW drainage from where the wastes flows as described in matarials and methods has mechanic/automobile workshops and car wash sites scattered around the drainage due to easy access to water source. High level of Pb and Cr is also due to the location of the study area in close proximity to the Katsina-Ala – Jalingo road (a major and only highway present) at about 20metres perpendicular to the highway/traffic density. About 80% of Pb in petrol escapes through the exhaust pipe as particulate (Ogbuagu *et al*., 2001; Anongo *et al*., 2015). Cr has it most widespread application as corrosion inhibitors. Many metals used in household, traffic and industry are chrome-plated to extend durability (Anongo *et al*., 2015). High Cu levels may cause iron deficiency which is demonstrated as typical chlorosis features. However, the Amaranth plants did not exhibit chlorosis signs. Therefore the significant levels of Pb and Cr than the safety limits suggest a tendency of potential contamination and implies that these products are unsafe for consumption(Anongo *et al*., 2015)

Table 2: Mean (±SE) concentrations of Trace Metal Analysis in Soils obtained from Municipal Solid Waste Drainage in Wukari

Heavy Metals(mg/kg)	Up Stream	Mid Stream	Low Stream
Zn	2.35±0.80a	4.20±0.23a	1.34±0.06a
Cu	0.43±0.17a	0.45±0.12b	2.00±0.25a
Cr	0.00±0.00a	23.50±4.73b	9.51±0.24a
Pb	31.48±2.13a	48.96±1.25a	13.29±0.44b
Ni	3.68±0.05a	3.70±1.01a	3.03±0.83a

Similar letter in each row indicate no significant difference (P<0.05)

The mean concentration of trace metals (Cr, Cu, Ni, Pb, Zn) of the MSW drainage are shown in Table 3. Midstream reportedly had the highest trace metal (23.51 mg/kg = Cr, 48.96 mg/kg = Pb, 4.20 mg/kg = Zn) levels followed by highest Cu level (2.00 mg/kg) at Low Stream and Ni (3.68 mg/kg) at Up-Stream. This could be due to the high organic matter levels of the MSW drainage that attracts or binds metals to itself with respect to Cr, Pb and Zn. The decomposition of the MSW had reduced the harmful levels of Zn in the MSW drainage. According to the Joint FAO/WHO Codex Alimentarius (2006) acceptable or permissible limits in food crops, Cr and Pb have exceeded the permissible limits revealing the proximity of the study area to the high traffic density on the Katsina-Ala – Jalingo major highway and runoffs from automobile/mechanic workshops and car wash sites of vehicles due to utilization of chromium-plated car fixings and leaded gasoline thereby making them heavy metal pollutants, while Cu is below the limits.

Table 3: Mean Trace Metal (ppm) levels of the Municipal Solid Waste Drainage

Sampling Points	Ca	Cr	Cu	Ni	Pb	Zn
Up-Stream	0.16	0.00	0.43	3.68	31.48	2.40
Mid-Stream	0.14	23.51	0.46	3.70	48.96	4.20
Low Stream	0.10	9.52	2.00	3.03	13.29	1.34

The physic-chemical analysis of the soils of the MSW drainage is shown in Table 4. There was significant difference in the pH and magnesium levels only. The pH of the soils of the MSW drainage ranged from moderately acidic (6.07) at low stream to slightly acidic (6.37) at Up-Stream (Table 4). According to the FAO standards 1990, the concentration of ECEC among the three sampling points were low; organic matter was high at all the sampling points, and potassium ranged from medium (0.39) at Up-stream to high at both Mid-Stream (0.40) and Low-Stream(0.43). Soils containing high levels of exchangeable magnesium are often thought to be troubled with soil infiltration problems (Ayers and Westcot,1994). Magnesium acts on soils like calcium than sodium, and is preferentially adsorbed by the soil to a much greater degree than sodium but to a slightly less degree than calcium (Ayers and Westcot,1994).

Table 4: Physico-chemical Analysis of the Soils collected at MSW Drainage in Wukari

Physic-chemical Characteristics	Up Stream	Mid Stream	Low Stream
pH	6.37±0.04a	7.12±0.11a	6.07±0.17b
% Organic Carbon	2.12±3.02a	2.46±0.29a	2.62±0.08a
% Organic Matter	3.66±0.06a	4.24±0.49a	3.51±1.02a
% Moisture Content	0.58±0.02a	0.60±0.47a	0.65±0.28a
K (meq/100g)	0.39±0.02a	0.40±0.26a	0.43±0.02a
Na (meq/100g)	0.20±0.00a	0.25±0.05a	0.15±0.05a
Mg (meq/100g)	3.51±0.16a	4.36±0.03b	4.35±0.24b
Ca (meq/100g)	0.16±0.69a	0.13±0.04a	0.10±0.01a
Al+H (meq/100g)	0.20±0.00a	0.20±0.00a	0.17±0.03a
ECEC(meq/100g)	4.46±0.28a	5.34±0.13a	5.21±0.64a

Values sharing the same letter in each row are not significantly different from each other ($P \leq 0.05$)

However, the role of magnesium in causing or partly causing these problems is not well documented but researchers from several irrigated areas are investigating the problem (Ayers and Westcot,1994). Al+H is dependent on soil. At pH above 5.0, there is little Al in soluble form in most soils since Al is not a plant material. Deficiencies of Macronutrients like Ca, Mg are frequently encountered in very strongly acidic to ultra acidic soils (pH<5.0) reflecting sufficient concentration of Ca and Mg since the pH in this study is roughly slightly acidic. These characteristics reveal the quality of the MSW drainage arising from all the different wastes from Wukari Metropolis.

CONCLUSION

The utilization of different types of organic manures and inorganic fertilizers yields different results with respect to the morphological traits or growth parameters of Amaranths, physical and chemical properties of the soils, and landuse management practices. Values obtained from this study for plant height, plant girth or stem diameter and number of leaves agrees with the findings of other works with just slight variation. Similarly, the high variations in the leaf area between this research and other works revealed that the MSW drainage also promoted the vegetative growth of Amaranths suitable for market value. Though the Mid-Stream reportedly had the highest trace metal levels, only Cr and Pb exceeded the Joint FAO/WHO limits revealing the MSW drainage contains runoffs of vehicular wastes from automobile mechanic sites as well as proximity of the sampling sites to the Highway.

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