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A QUANTITATIVE ANALYSIS AND COMPARISON OF NITROGEN, PHOSPHORUS AND POTASSIUM IN SOIL AND WATER OF THE WUKARI MUNICIPAL SOLID WASTES NATURAL DRAINAGE

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ABSTRACT

Preliminary investigation of Municipal Solid Waste Natural (MSW) drainage for dry season irrigation farming of Amaranths at Angwan Mission Quarters – a densely populated locality known for cultivation of Amaranths due to availability of water and its accessibility to markets was conducted. Amaranths, soil and water samples from three drainage or sampling points was collected (December 2019 - March 2020) to ascertain suitability of drainage soils and water for irrigation of Amaranths. Visual observation and analysis of selected morphological traits (plant colour, plant height (cm), plant girth, leaf area (cm^2) and number of leaves) for market value was conducted. Physic-chemical analyses of pH, total organic carbon (C), total organic matter (OM), exchangeable bases (K, Na, Ca, Mg), cation exchange capacity (ECEC), moisture content, total nitrogen (N), phosphorus (P),potassium(K) concentrations of the MSW drainage soils and water were determined according to Standard laboratory procedures. Results reveal chlorosis of Amaranths at sampling point 1(Up-Stream) and sampling point 2(Mid-Stream) indicating specific mineral deficiency (such as Iron, magnesium, nitrogen) usually associated with MSW dumpsites. Significant difference ($p<0.05$) in whole plant height, leaf area, number of leaves and % nitrogen (Up-Stream - 0.11 ± 0.00^a; Mid-Stream - 0.14 ± 0.01^a : Low-Stream - 0.16 ± 0.15) reflects abundance water and inadequate nitrogen levels respectively. This study remarked that the drainage points are suitable for dry season vegetable farming and the transition from rural to peri-urban settlement has potentials for continuous utilization of drainage soil and water for large-scale vegetable farming and income generation by the rural farmers.

Keywords: Amaranths, Angwan Mission Quarters, Nitrogen, Phosphorus, Potassium, Soil, Water

INTRODUCTION

Municipal solid wastes (MSW) are dominated by food and non-food materials including paper and paper boards, metals, and plastics, all of which contain chemical elements (USEPA 2017; Abbey *et al*., 2021). Organic materials which constitute a greater portion of the waste in various dumpsites around the environment contain varying levels of both macro and micro nutrients needed by growing plant for sustainable growth and optimum yield (John and Effiong, 2008). However, both the organic and essential nutrients contained in this refuse are only released and become readily available to plants when they are decomposed. Though the level of plant nutrient in the refuse dumpsite is generally low, a study by John and Effiong (2008) revealed that the application of large amount of decomposed refuse (50% and above) could significantly improve the growth yield of maize. John *et al*., 2006) evaluated the physical composition of municipal waste and nutrient content of its organic component in Uyo municipality, Nigeria and observed that both the physical and macro nutrient contents of the waste differed from one location to another within the municipality. Oviasogie *et al*., 2007, investigated essential micronutrient (Fe, Mn, Zn, Cu) of refuse dumpsites in Akure, Nigeria where *Amarantus cruentus* was cultivated and remarked, that refuse at various dumpsites have contributed to the increase levels of the micronutrients in the soil. As pointed out by Drozd (2003), the use of composts from municipal solid wastes improves the restoration of degraded soils and allows an appropriate final disposition of such material, solving a major environmental and economic problem generated in the cities.

However, it is a common phenomenon to find people especially in peri-urban and urban areas using soils from refuse dumpsites for the purpose of vegetable farming (Ogunyemi *et al.,* 2003; Kufuor, 2016). Often times, these soils are dark brown in color and are perceived to be rich in organic manure and other macronutrients/elements for plant cultivation. This perception or assumption may be right or wrong depending on the type and composition of the waste at dumpsites and their impact of these useful elements in soils. MSW have been reported to be rich sources of soil nutrients and can be utilized for wealth creation in crop cultivation instead of being a waste (Abolaji *et al*., 2017). However, there are relatively insufficient reports on the levels and perhaps availability of these nutrients in the soil associated with refuse dumpsites (Oviasogie *et al.*, 2007). Population densities and low water table has forced rural farmers to utilized natural water channels which doubles as MSW waste disposal or discharge outlets for irrigation of dry season vegetable farming. Also, low soil fertility, non-availability of suitable lands for vegetable farming and lack of funds for purchase of suitable farmlands by the rural farmers as well as lack of capital to buy chemical fertilizers for optimum productivity are some of the problems faced by Amaranths growers in Nigeria. Cultivation of Amaranths is a good source of income to women and even men (in Northern Nigeria) in most communities in Nigeria and serves as a means of alleviating poverty (Sustainet, 2006). This research is significant because dry season irrigation farming involved the use of different categories of wastewater, sludge, cattle lot, industrial effluents etc as a form of bioremediative approach to prevent possible health risks from these environmental contaminants. It is also significant to investigate the suitability of the soil and water of the MSW natural drainage on the morphology of the Amaranths, which will create awareness for the populace on continuous utilization of MSW dumpsites for vegetable farming or not.

This study was limited to the Amaranth since is the commonest vegetable grown on a yearly basis at the Angwan

Mission Quarters MSW natural drainage during the dry season irrigation farming, and where tonnes of wastes washed along the drainage through Kasuwan Shanun channel to River Rici and are emptied into River Benue. The Amaranths is the most consumed leafy vegetables during the dry season period (October to April) by Wukari populace and as forage for livestock. The study aimed to ascertain the suitability of the drainage soils and water used for dry season irrigation farming of Amaranths mostly consumed by the people in Wukari Metropolis and to investigate the composition of Nitrogen, Phosphorus and Potassium of the waste soils and water as well as their impact on the Amaranths.

MATERIALS AND METHODS

This work was carried out at Wukari Local Government Area of Taraba State situated at latitude $7^0$50’37”N, longitude $9^0$46’30”E and at 189km high above the sea level.

Description of the Sampling Area

Marmara pond is the major water body within Wukari metropolis which originates from Ibi River (a continuation of River Benue) and flows through Wukari rice mill and Great Leader Academy to the Crocodile pond behind FRSC Office and divides into two with one discharge channel flowing down to Angwan Mission Quarters where the dry season irrigation farming takes place on a yearly basis, while the other discharge channel 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 discharged them at the large major natural drainage located at the Angwan Mission Quarters. The research was conducted between the months of November 2019 to March 2020 which is the period of dry season irrigation faming of the MSW drainage at Angwan Mission Quarters. The source of water for the dry season irrigation of Amaranths, Sesame and Sorrel vegetables comes from the MSW drainage water. The sampling site is a sloppy terrain where waters drains downward and is highly polluted with solid wastes arising from the wastes dumped by the community. The sloppy terrain in the study area is caused by erosion due to felling of trees for fuelwood. The drainage is also in close proximity to the Katsina-Ala – Jalingo Highway. The solid wastes are composed of cow dung, plastic bottles, polythene bags, textiles, farm waste, papers, cartons, cans, tins, demolition and construction wastes etc. The plant community of the MSW drainage include; *Ricinus communis* L., *Rosselle*, guinea corn, maize, Solanum, tomatoes, mango, banana etc. while the animal community include; butterfly, worm, ants, toads etc. The grasses include carpet grass (Axonopus compressus), Nut grass (*Cyperus rotundus*), Nuke-noh(*Tridax procumbens*), Bahama grass (*Cynodon dactylon*) among others. The soil at the experiment area is clay loam with a pH range of 6.50 to 7.50.

GPS was used to measure the coordinates of the three sampling sites are shown in Table 1. The distances of the sampling sites (Up-Stream, Mid-Stream and Low-Stream) where data was obtained from the drainage are 89.30m, 65.40m and 40.60m respectively.

Table 1: GPS Coordinates of the Three Sampling Points

Sampling Sites	GPS Coordinates	
Up-Stream	Latitude 7051’10’’N	Longitude 9046’50’’E
Mid-Stream	Latitude 7051’4’’N	Longitude 9046’53’’E
Low-Stream	Latitude 7051’11’’N	Longitude 9046’53’’E

Collection of Samples: Triplicate water samples and duplicate soil samples were collected at the three drainage points (Up-Stream, Mid-stream and Low-Stream) during the late dry season of December 2019 to March 2020 for determination of three major macro-elements namely nitrogen, phosphorus and potassium (NPK) and other physic-chemical parameters. Eight (8) Amaranths samples were collected at each drainage points during harvest for measurement of parameters.

A total of twenty-four (24) *Amaranthus species* cultivated at the municipal solid waste drainage were randomly selected. Eight (8) *Amaranthus* whole plant per sampling site cultivated on the MSW drainage soils were randomly uprooted from the three sampling sites, labeled and taken to the laboratory and eight (8) whole plants were uprooted each from the Up-Stream, Mid-Stream and Low-Stream, labeled and taken to the laboratory for visual observation and analysis of the selected morphological traits namely: plant color, plant height, number of leaves, leaf area and plant girth according to Standard laboratory procedures

The duplicate soils were collected with the aid of a stainless soil auger at 3 different drainage points or sampling sites selected using GPS. The soils were transferred into a well labeled polyethylene bags for storage and further analysis at Department of Soil Science Laboratory, Ahmadu Bello University Zaria, Kaduna State of Nigeria. The soils were dried at ambient temperature, crushed in a porcelain mortar and sieved through a 2mm (10 meshes) stainless sieve. Air dried 2mm soils were used for the determination of the physic-chemical properties namely total nitrogen (N), total organic carbon (C), total organic matter (OM), exchangeable bases (K, Na, Ca, Mg), pH, phosphorus (P), potassium (K), cation exchange capacity (ECEC), anions (Al^+, H,) and moisture content of the MSW drainage according to Standard laboratory procedures (AOAC, 1999).

Similarly, the triplicate water samples from the MSW drainage was collected in properly labeled clean plastic bottles rinsed with distilled water, from the three sampling or drainage points (Up-Stream, Mid-Stream and Low Steam). Nitrate oxide preservative was added onto the two sample plastic bottles designated as experimental A and B and control C containing no preservative was then taken to the Central Laboratory Federal University Wukari for determination of physic-chemical parameters (N, P, K, pH, Mg, Ca, Na, EC) and temperature using the X-ray fluorescence (XRF) spectroscopy and temperature according to standard laboratory procedures (AOAC, 1999) at the Central Laboratory Federal University Wukari, Taraba State.

Mean and standard error of the soil physicochemical parameters and NPK contents and mean and standard deviation of the water parameters were statistically analysed.

RESULT AND DISCUSSION

Soil NPK Levels of the MSW drainage

The mean soil nitrogen, phosphorus and potassium levels of the soils from the MSW drainage are shown in Table 2.

There was no significant difference in the drainage soil nitrogen, phosphorus and potassium as well as the drainage soil physico-chemical parameters levels at the three sampling sites in the study area (Table 2) indicating that the MSW has undergone adequate decomposition by microbial activities in the soils of the drainage.

Table 2: Mean ±S.E. of Nitrogen, Phosphorus and Potassium and other Physico-chemical Parameters of Soils of the Municipal Solid Waste (MSW) Drainage in Wukari

Parameters	Up-Stream	Mid-Stream	Low-Stream
pH	6.93 ± 0.28[a]	7.23 ± 0.58[a]	6.73 ± 0.28[a]
Organic Carbon (%)	1.92 ± 0.22[a]	2.38 ± 0.37[a]	2.17 ± 0.53[a]
Organic Matter (%)	3.33 ± 0.37[a]	4.17 ± 0.55[a]	3.73 ± 0.90[a]
Moisture Content (%)	0.60 ± 0.00[a]	0.48 ± 0.80[a]	0.71 ± 0.11[a]
% Nitrogen	0.11 ± 0.00[a]	0.14 ± 0.01[a]	0.16 ± 0.15
Phosphorus mg/kg	17.20 ± 0.60[a]	17.30 ± 0.90[a]	17.60 ± 0.99[a]
Potassium meq/100g	0.38 ± 0.01[a]	0.41 ± 0.02[a]	0.41 ± 0.01[a]
ECEC	4.45 ± 0.18[a]	5.32 ± 0.26[a]	5.20 ± 0.31[a]

a, b, c, implies that values in the same row with same superscript are not significantly different (P< 0.05)

Mean Phosphorus was the highest while nitrogen was the lowest then potassium indicating deficiencies in the ratio of NPK for leafy vegetables. Healthy levels of P in soil ranges from 25 to 50ppm (https://knowmoregrowmore.com) and sufficient phosphorus in the soil stimulates plant and root growth and accelerates maturity. This indicates that the relative levels of soil P in this study needs improvement. According to Barak 1999, the % mean ratio requirements for NPK is 1.5: 0.2: 1, this shows great deficiencies in the MSW drainage soil. Nitrogen is the most important to leafy vegetables which helps leafy vegetables produce chlorophyll to perform photosynthesis resulting to plant growth and development of quality leaves quickly for market value (https://www.gardeningnoob.com). Deficiencies of macronutrients (N, P, K, Ca, Mg) are frequently encountered in very strongly acidic to ultra-acidic (pH<5.0) soils. However, in this study, the Mid-Stream had the highest organic matter, organic carbon and ECEC levels than at the Up-Stream and Low-Stream reflecting a stable terrain with slower water flow and high assimilation of dissolved nutrients. The soil pH recorded in this study ranges from slightly alkaline to neutral from Low Stream and Up-Stream to Mid-Stream respectively. Carbon dioxide is the most common cause of acidity in water (Bialkowski, 2006). Photosynthesis, respiration and decomposition all contribute to pH fluctuations due to their influences on CO_2 levels (Radke, 2006).

Water NPK Levels of the MSW drainage

The water samples revealed differences in the selected water parameters of the MSW drainage as shown in Table 3. The water analysis revealed a very low (3.00; 2.83; 2.95) pH, which is an abnormally acidic water for dry season irrigation farming at the three sampling sites reflecting anthropogenic causes related to point source pollution (Utah State University, 2013; Lenntech, 2013) arising from agricultural runoff and wastewater discharge (food processing and domestic sources). In contrast to this study, the normal pH range for irrigation water is from 6.5 to 8.4(Ayers and Westcot, 1994). Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion (Ayers and Westcot, 1994). Water with low pH is problematic for several reasons (NCDA and CS, 2009); it can interfere with plant root growth by making the soil too acidic; it can increase or decrease the solubility and availability of micronutrients like dissolution of Aluminium which becomes toxic to plant growth. A lower pH value also allows certain plants to effectively absorb more nutrients from the soil so they can flourish. Low pH levels can encourage the solubility of heavy metals (USGS, 2013). As the level of hydrogen ions increases, metal cations such as aluminum, lead, copper and cadmium are released into the water instead of being absorbed into the sediment. This agrees with the findings of Anongo and Vincent 2022 where trace levels of Cu and Zn had low concentrations while Cr and Pb had high levels reflecting high solubility and low solubility respectively of the metals in the drainage soils in constant interaction with the drainage water. As the concentrations of heavy metals increase, their toxicity also increases (USGS, 2013). Furthermore, the acidity of the surrounding environment can also affect the pH of water which may occur naturally. Therefore, an abnormal value is a warning that the water needs further evaluation.

Table 3: Mean ± Standard deviation of selected water parameters of the MSW drainage

Parameters	Sample 1	Sample 2	Sample 3
Temperature	35.83±0.29abc	35.83± 0.29abc	35.33± 0.76abc
pH	3.00±3.65abc	2.83±3.44abc	2.95±3.67abc
Nitrogen(N)	0.67±1.15c	0.83±1.44c	0.90±1.56c
Phosphorus(P)	1.50±1.23ab	1.50±1.50ab	1.23±1.07ab
Potassium(K)	36.40±37.39ab	36.73±38.45ab	39.30±38.39ab
Calcium	9.40±8.71ab	8.40±7.76ab	8.00±6.93ab
Magnesium	1.03±0.89ab	0.92±0.79ab	1.03±0.89ab
ECEC	9.81±0.02abc	9.74±0.18abc	9.55±0.00abc
Sodium	23.40±25.88ab	22.53±23.67ab	38.17±33.81ab
SAR	4.4827	4.8354	8.4564

Mean ± Standard Deviation of group result obtained (n=3) with the mean having different superscript along the column are statistically significant (p<0.05)
KEY: SAR = Sodium Adsorption Ratio

Pollution can change the water's pH which in turn, can harm animals and plants (NCDA and CS, 2009). The concentration of nitrogen in most surface and groundwater is usually less than 5 mg/l NO_3 -N but some unusual groundwater may contain quantities in excess of 50 mg/l (Ayers and Westcot, 1994). Therefore, the nitrogen levels in this research are within the acceptable limits at the three sampling sites for soil and water of the MSW drainage (Tables 2 and 3).

The sodium adsorption ratio (SAR) ranges from 4.8564 to 4.8354 at Low Stream through Up-Stream to Mid-Stream (Table 3) indicates a low sodium hazard of the irrigation water used for dry season vegetable farming (Fipps 2021). The SAR is an irrigation water quality parameter used as an indicator of the suitability of water for use in agricultural irrigation. Although SAR is only one factor in determining the suitability of water for irrigation in general, the higher the sodium adsorption ratio, the less suitable the water is for irrigation.

Visual Observation and Analysis of selected Morphological Traits

The morphological observations of selected plants characters of Amaranth Species are presented in Table 4. Whole plant height (cm) and number of leaves of Amaranths harvested from the sampling sites was highest at Up-Stream (114cm and 25) and lowest (71cm and 17) at low stream respectively (Table 4). There was significant difference ($p<0.05$) in the observed morphological traits among the three sampling sites except for plant girth (Table 5).

Table 4: Morphological Observation of *Amaranthus species* cultivated on Soils of the MSW Drainage

Parameter	Up-Stream	MidStream	Low Stream
Plant Colour	Kelly-green	lime-green	forest-green
Whole Plant Height(cm)	114.00	100.00	71.00
Plant Girth(cm^2)	3.40	3.20	4.00
Leaf Area(m^2)	87.38	79.05	90.08
Number of Leaves	25	20	17

The Up-Stream drainage soil is enriched with higher concentrations of the decomposed MSW from the Marmara pond being the point of accumulation of MSW drainage from the various points of discharge around Wukari metropolis. This then result to reduction in the concentration of dissolved nutrients during flow from Up-Stream through Mid-Stream to the Low Stream. The high assimilation of dissolved nutrients by the Amaranths at the Up-Stream and Mid- Stream reduced the available nutrients at Low Stream. However, the leaf area ($90.08m^2$) and plant girth ($4cm^2$) was highest at Low Stream reflecting an abundant, slower and steady flow of the drainage water and higher water uptake by Amaranths producing wide broad leaves than at the Up-Stream ($87.38m^2$, $3.40cm^2$) then Midstream ($79.05m^2$, $3.20cm^2$) respectively. In contrast Musa *et al.*, 2019 revealed in their study that there is no significant variation in the leaf structures of *Luffa cylindrica* and *Amaranthus viridis* growing on dumpsite. They concluded that there was no remarkable variation in the morphology of Amaranths grown on MSW site.

The plant colour of the Amaranths varies with forest green at Low Stream indicating availability of nutrients due to the abundant, slower and steady flow of the drainage water. However the kelly green (strong yellowish green) and lime green of the Amaranths at Up-Stream and Mid-Stream respectively (Table 4) indicate early stages of chlorosis when leaves lack enough nutrients to synthesise all the chlorophyll they need and this is brought about by a combination of factors like a specific mineral deficiency in the soil such as iron (Koenig and Kuhns, 1996), magnesium or zinc (Capon, 2010); deficient nitrogen or proteins (Capon, 2010), a soil pH at which minerals become unavailable for absorption by the roots (Schuster,2008), pesticides and particularly herbicides may cause chlorosis, both to target weeds and occasionally to the crop being treated (Dreistadt and Clark, 2004). Another factor is the presence of any number of bacterial pathogens, for instance *Pseudomonas syringe pv. tagetis* that causes complete chlorosis on Asteraceae (Gerber *et al.*, 2011/2022). This agrees with the findings of Anongo and Ibrahim 2021 where Pseudomonas and Bacillus were the abundant bacteria community in the MSW dumpsite. However, the Up-Stream and Low-Stream sites may be lacking the specific nutrient resulting to chlorosis.

Table 5: Visual Observation and Mean ± S.E of the selected Morphological Traits of *Amaranthus species* Cultivated on Soils of the MSW Drainage

Parameter	Up stream	Midstream	Low-stream
Plant color	kelly-green	lime-green	Forest-Green
Whole plant height(cm)	114.03±3.97c	100.65±3.17b	71.00±1.85a
Plant Girth(m^2)	3.39±0.29a	3.21±0.30a	3.94±0.14a
Leaf Area(cm^2)	87.38±0.99b	79.05±0.62a	90.09±1.18b
Number of Leaves	25.00±0.76c	20.75±0.75b	17.25±0.37a

a, b and c implies that values in the same row with the same superscript are not significantly different ($P<0.05$)

CONCLUSION

The significant difference in the whole plant height (cm), leaf area(m^2) and number of leaves indicates availability of water required for the Amaranths. The very low value of the % nitrogen and the Kelly green to lime green colour of the Amaranth leaves reflects the non-availability of a significant amount of NPK in dissolved solution in the soil of the MSW Natural drainage required for dry season irrigation vegetable farming. The non-significant differences for all the soil physico-chemical parameters reveal that a larger percentage of the MSW from Wukari metropolis are mainly organic in nature indicating a lag phase growth of the rural settlement. Therefore, the use of the MSW dumpsites and drainages for vegetable and dry season irrigation farming reveals is suitable on the long run. The use of MSW is an important recycled opportunity in order to reduce environmental pollution. Prior to cultivation of Amaranths, the water and soil of the MSW natural drainage should be properly screened for the presence of adequate composition of the macro- and micronutrients as well as heavy metals. Continuous baseline data of the composition of MSW for other macro- and micronutrients, heavy metals as well as microbial community is significant as the Wukari metropolis continues to grow from rural through peri-urban and urban population with their attendant wastes generation and pollution impacts on the population.

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