SOIL SCIENCE SOCIETY OF NIGERIA (SSSN)

PROCEEDINGS

OF THE

43RD ANNUAL CONFERENCE, SOIL SCIENCE SOCIETY OF NIGERIA (SSSN)

FOOD BASKET 2019

Date: 15th - 19th July, 2019

Theme:

UNDERSTANDING NIGERIAN SOILS FOR SUSTAINABLE FOOD AND NUTRITION SECURITY AND HEALTHY ENVIRONMENT

Host:
Department of Soil Science
University of Agriculture, Makurdi

EDITED BY:
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DEPARTMENT OF SOIL SCIENCE, COLLEGE OF AGRONOMY, FEDERAL UNIVERSITY OF AGRICULTURE, MAKURDI, BENUE STATE – NIGERIA

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FOREWORD

The 43rd Annual Conference of the Soil Science Society of Nigeria held on the 15th to 19th July, 2019 at the College of Agronomy Complex, Federal University of Agriculture, Makurdi with the theme: "Understanding Nigerian Soils for Sustainable Food and Nutrition Security and Healthy Environment". The choice of the theme was premised on the fact that Soil is a non-renewable resource and thus a sustained production of crops that would guarantee food and nutrition security while preserving and protecting the environment in Nigeria would require a clear understanding of the nature, dynamics and properties of these soils.

Papers were presented in the areas of Pedology, Soil survey and Climatology, Land use and Land Use Planning, Soil fertility and Plant nutrition, Fertilizer use and Management, Soil chemistry and Microbiology, Soil biology and Biochemistry, Biotechnology and Bioremediation studies, Soil physics, Soil and water management, Land degradation and Soil conservation.

The modern environmental movement that has evolved from a traditional emphasis on chemical reactions affecting plant growth to a focus on soil contaminant reactions was clearly demonstrated at this conference in terms of the number and quality of papers presented in this area. It was evident that the sources of these contaminants include fertilizers, pesticides, acid deposition, agricultural and industrial waste materials as well as oil spillage in the delta areas of Nigeria. Discussions on these contaminants and the soil chemical reactions that these contaminants undergo and how a knowledge of these reactions is critical in predicting their effect on the environment and quality of produce is well reported in this book of proceedings.

There were no field trips as a result of the prevailing security situation in the state. However, a presentation of the school laboratory project by the OCP Africa fertilizer company came in handy. This is a modern mobile Laboratory that conducts on site analysis of soil samples, instantly calibrates and provides field specific fertilizer recommendations. This ensures that fertilizers are applied at rates required by crop plants thus avoiding excesses that are bound to be applied when blanket recommendations are made with its attendant effect on the environment.

The papers presented at the conference which are published in this book of proceedings were painstakingly subjected to a peer review process. It is our hope that the information contained herein will be found helpful to environmentalists, Agriculturalists, policy makers, the academia and indeed a wide range of professionals.

Bemgba Anjembe Ph.D.
Chairman, Local Organizing Committee.
14th February, 2020.

ACKNOWLEDGEMENTS

The Local Organizing Committee (LOC) of the 43rd Annual Conference of Soil Science Society of Nigeria (SSSN) wishes to express her profound appreciation to the Vice Chancellor, Federal University of Agriculture, Makurdi for providing venues and an enabling environment for the successful hosting of the conference. Apart from providing seed money as loan, his contributions towards provision of accommodation for the Leadership of our society is deeply appreciated.

His excellency, the executive Governor of Benue State Dr. Samuel Ioraer Ortom apart from supporting the LOC financially, was represented at the opening ceremony by his deputy. He graciously granted the Society a state banquet, personally decorated our President and presented him with an honorary citizenship of the state.
The notable contributions of OCP Africa, Indorama, IFDC, Value Seeds Nigeria Limited, Teryima Nigeria Limited and other bodies significantly contributed to the success of the conference.

The chairmen of technical sessions and rapporteurs contributed greatly to the success of the conference. We sincerely appreciate all reviewers of manuscripts presented at the conference. We are also thankful to the Management and Staff of ASOFAD Pinting Ltd. who worked tirelessly to ensure that our book of abstracts, programme of events, customized tags and certificates of attendance as well as the conference proceedings were delivered on time.

We are very highly indebted to the National Executive Committee of SSSN for their support and encouragement through this tasking period. The long conversations, arguments and constructive criticisms from the National President Prof. B. A. Raji largely improved the quality of our decisions and have tremendously contributed to our successful hosting of the 43rd Annual Conference.

Bemgba Anjembe Ph.D
Chairman, LOC
January, 2020

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EFFECTS OF IRRIGATION WATER QUALITY ON SOIL MICROBIAL ENZYME ACTIVITIES AND CROP QUALITY IN MINNA, NIGER STATE.

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ABSTRACT

The quality of irrigation water is of paramount importance in the knowledge of the end products of cultivation, as well as the subsequent health of the soil. To this effect, soil samples were collected from five locations under urban and peri-urban agriculture in Minna metropolis and its environments, which are principally irrigated from canals running through the city. Across the locations, soil samples collected at a depth of 0-15cm, were analysed for physical and chemical properties. Soil pH, Electrical Conductivity, Total Nitrogen, Available Phosphorus, and Organic Carbon contents were 8.23, 193μ^2/cm, 0.16mg/kg, 4.32mg/kg, and 1.14%, averagely, across sites. So also, water samples were collected at a depth of 0-15cm, yielding ranges of pH, Electrical Conductivity, Organic Carbon, Lead, and Zinc, of 6.56-7.98, 0.14-1.04ds/m, 0.53-0.72mg/l, 0.00-0.02mg/l, and 0.02-0.44mg/l, respectively. The results of analysis and evaluation of water samples across treatment locations revealed that the water is suitable for irrigation based on results of EC, SAR, Specific ion toxicities, and Heavy metal analysis. Their suitability/quality for irrigation purposes occurred in the following order: Kanfanin Kutare >Gidan Mangoro> Morris > Opposite Federal Secretariat >Ketaren Gwari. Water sampled from Ketaren Gwari is noted to be in the zone of increasing problems. The results of the analysis of plants in these locations showed that Vegetables in Gidan Mangoro, Kanfanin Kutare, Opp. Fed. Secretariat showed no traces of lead contamination. there was no trace of copper across three sites namely; Kanfanin Kutare, Opp. Fed. Secretariat, and Morris. Cadmium content of the plants in Gidan Mangoro, Morris and Ketaren Gwari exceeded the permissible limits set by FAO (2015). Further analysis of enzymatic activities showed that Dehydrogenase, Urease and Alkaline phosphatase activities were positively correlated with most of the water quality parameters which indicates that an increase in the concentration of the chemical properties of irrigation water will lead to a significant increase in the activities of Dehydrogenase, Urease and Alkaline Phosphatase.

***Keywords:** Heavy metal, Water Quality, Irrigation, Enzyme Activities.*

INTRODUCTION.

The quality of irrigation water directly influences the quality of soil and crops grown on a given irrigated soil. Salinity is the most common problem and about 10 million hectares of land is lost annually due to salinity (Tanji, 1990). As a consequence, the effective use of both the agricultural land and the irrigation water has become an indispensable component. The quality of irrigation water is as important as the nature of a soil. If the quality of water supplied for irrigation is not good, the soil deteriorates and ultimately decreases the crop yield. The irrigation water quality criteria depend on salinity, permeability, specific ion toxicity like sodium in terms of Sodium Adsorption Ratio (SAR), chloride, boron and miscellaneous effects like nitrates, bicarbonates and pH of water (Ayers and Westcott, 1985).

Following additions to the soil, organic loading of waste water undergoes decomposition to CO_2, low molecular weight soluble organic acids, residual organic matter and inorganic constituents (Boyd *et al.*, 1980).

Soil microorganisms as one part, can be sensitive biological markers and can be used to assess soil quality or degradation. Enzymes require a certain level of water in their structures in order to maintain their natural conformation, allowing them to deliver their full functionality. Furthermore, as a modifier of the solvent, up to a certain level, water can modify the solvent properties such as polarity/polarizability as well as the solubility of the reactants and the products. In addition, depending on the type of the reaction, water can be a substrate (e.g., in hydrolysis) or a product (e.g., in esterolysis) of the enzymatic reaction, influencing the enzyme turnover in different ways. It is found that regardless of the type of reaction, the functionality of enzyme itself is maximum at an optimum level of water, beyond which the enzyme performance decline due to the loss in enzyme stability.

Some problems associated with these irrigated soils include; heavy metal contamination, nutrient immobilization, organic matter accumulation, and pH extremes depending on the source of inputs. In this study, an attempt was made to study the effect of the quality of irrigation water on soil microbial enzyme activities in irrigated soils under agriculture, as well as the heavy metal loading in plants. For this, the urban and peri-urban areas in Minna, Niger state, were considered.

The major source of irrigation water is the wastewater that drains into the water canals that criss-cross the city. The wastewater is derived from discharge from domestic waters as well as effluents from industrial and other economic activities which ultimately affect the quality of the water used for irrigation. Industrial effluents and discharges from activities from motor mechanics workshops as well as chemicals from everyday domestic use, may build up in the soil and get into the food chain. Finding out the effect of this irrigation water and the heavy metal load (if any) on human health and soil health, is of paramount importance.

The aim of this research is to determine the effects of irrigation water quality on microbial enzyme activities in soils under irrigated agriculture in Minna, Niger state. The objectives also are to determine the quality of the irrigation water used for cultivation, examining the health of irrigated soils using microbial enzyme activities as biological indicators, assessing the heavy metal loading in plants, and soils irrigated with water running through specific canals, and correlate the properties of the soil with microbial enzyme activity.

MATERIALS AND METHOD.

Site Description.

The study took place in Minna (9°14'N, 6°30'E), which lies in the Southern Guinea Savanna of Nigeria. The climate is sub-humid tropical with mean annual rainfall of about 1200mm (90% of the rainfall is between June and August). The mean daily temperature rarely falls below 22°C with peaks of 40°C and 36°C from February to March and November to December respectively. The soils of Minna are predominantly Alfisols (USDA) developed from basement complex rocks ranging from shallow to very deep soils, overlying deeply weathered gneiss and magnetite with some underlain by iron pan to varying depths (FDLAR, 1990). Soil, Water and Plant samples were taken at three sampling points from five treatment locations which are as follows:

i. Kanfanin Kutare - N 09°31' 54.7'' E 006°35' 16.3'' Elevation (m) 214m.
ii. Morris - N 09°35' 44.4'' E 006°32' 14.4'' Elevation (m) 225m.
iii. Ketaren Gwari - N 09°36' 14.9'' E 006°32' 16.1'' Elevation (m) 233m.
iv. Federal Secretariat - N 09°37' 31.9'' E 006°31' 34.0'' Elevation (m) 253m.
v. Gidan Mangoro. - N 09°33' 40.3'' E 006°30' 29.0 Elevation (m) 260m.

Water Sampling Procedure and Analysis.

Water samples were collected using sterilized containers at a depth of 0-20cm, early in the morning (6 am). The water sample containers, which were polyvinyl chloride (PVC) bottles were properly washed and labelled prior to sample collection. The water samples were taken at three intervals during the year in order to better monitor the accumulation of heavy metals over time. Collected samples were kept in dry, and shaded place prior to analysis (Pennstate, 2018). Samples were then immediately taken to the laboratory for analysis.

Organic Carbon was determine using Walkey and Black wet oxidation method, as narrated by Rodajevic and Bashkin (1999), pH was determined using glass electrode pH meter as described by Rodajevic and Bashkin (1999), Electrical Conductivity was determined with a digital conductivity meter as described by Rodajevic and Bashkin, (1999), Exchangeable bases (sodium and potassium) in the digest were determined with flame - photometer filter, and was set for reading at 589nm, For Potassium, the flame photometer filter was set for reading at 769 nm, While magnesium and calcium were determined by complex metric titration method with ethylene diamine tetra acetic acid, described by Rodajevic and Bashkin (1999), Titre value (ml) was multiplied with 1000 and divided by the volume of sample (ml) to obtain the total hardness, The following formula was employed to get value of calcium in (mg/l). T*400.5*1.05/V. Where T= volume of titrant (ml) and V= volume of sample used (ml), Magnesium values were calculated from the values of total hardness and calcium hardness determined earlier using the formula : Magnesium (mg/l) = (T-C)* 0.244. Where, T= total hardness (mg/l, as $CaCO_3$). and C= calcium hardness (mg/l, as $CaCO_3$).

Free chlorine was determined using ion chromatography method as described by Rodajevic and Bashkin (1999), Nitrate (NO_3^-) was determined by phenol di-sulphonic method described by Rodajevic and Bashkin (1999), Heavy metal pollutants in water (cadmium, chromium, lead, copper and zinc) were determined using atomic absorption spectrophotometer after digesting with concentrated nitric acid, as described by Rodajevic and Bashkin (1999).

Soil Sampling Procedure and Analysis

Using simple random sampling method, fifteen soil samples were collected from three (3) plots at the five treatment locations for analysis. The soil samples were collected at a uniform depth of 0-15cm. All samples were taken early in the morning before 10am and were collected using sterilized containers and equipment. Following sample collection, the samples were properly labelled, before being taken to the laboratory for sample preparation and analysis. The composite soil samples were air dried, disaggregated by hand and some quantity passed through 0.5mm mesh sieve while the remaining via 2mm sieve for physical and chemical properties determination according to standard methods.

The soils at all the five sites are subjected to continuous cultivation under unified conditions during rainy season and under irrigation during the dry season. Except for Kanfanin Kutare site which is irrigated using water from a river, the sources of water for irrigation at the other four sites are drainage channels which drain waste water from domestic and commercial activities. Hence, the Kanfanin Kutare site is used as a control for this study.

Particle size distribution was determined by pipette method as described by Rodajevic and Bashkin (1999), Soil pH (soil-solution ratio 1:1) was determined using glass electrode pH meter in distilled water according to the procedure described by Ibitoye (2008), Electrical conductivity was determined electrometrically using digital conductivity meter (soil- distilled water ratio 1:1) (Gosh *et al.*, 1983). Total nitrogen was determined using the Kjeldahl procedure as narrated by Ibitoye (2008). Available phosphorus was extracted by BrayP-1 method (Bray and Kurtz, 1945), Organic carbon was determined using Walkey and Black wet oxidation method as described by Rodajevic and Bashkin (1999). Exchangeable bases were determined by extraction with neutral 1N sodium acetate solution (NH_4OAc), as described by Ibitoye (2008), Values of exchangeable acidity were calculated using this formula. <u>T_1-T_2*N*50</u> (cmol kg^{-1}). T_1=Sample titre value, T_2=Blank titre value, W= Weight of sample, N=Normality of NaOH and Heavy metals were determined using atomic absorption spectrophotometer after digesting the soil samples using aqua regia digest method (Baker and Amacher, 1982).

Microbial Enzyme Activity Analytical Methods.
Alkaline Phosphatase activity, Acid Phosphatase activity, and Urease activity were determined using Tabatabai Method (1994), Dehydrogenase activity was determined using Thalmann (1968) method, while Phosphotriesterase activity was determined using Tabatabai and Bremner (1969) Method.

Plant Sampling Procedure and Analysis
Whole plant parts, were taken for analysis, prior to fruiting stage. The plant samples (*Amaranthus viridis*) were collected using simple random sampling method. They were stored in a clean, air tight container, properly labelled, and taken to the laboratory for analysis, where the plant samples were thoroughly rinsed to remove foreign particles and oven dried at 65°C. This sample preparation preceded the actual plant analysis.
Heavy metals (Cadmium, Chromium, Lead, Copper and Zinc) in the plant tissue were determined by atomic absorption spectrophotometer, after digestion by wet oxidation with nitrate acid (HNO_3) as narrated by Ibitoye (2005).

Statistical Analysis
The result of this work was subjected to Analysis of Variance (ANOVA) using the SAS 9.1 program. Duncans Multiple Range Test was used for means separation. Correlation matrix was used to correlate microbial enzyme activities with soil physical and chemical properties, as well as with water chemical properties.

RESULTS AND DISCUSSION
Water Sampling Analytical Results.
Table i: Selected Chemical Properties of Irrigation Water of the Study Area.

Property	Gidan Mangoro	Kanfanin Kutare	Ketaren Gwari	Morris	Opp. Fed. Secretariat
pH	7.34^{a}	6.56^{a}	7.61^{a}	7.46^{a}	7.98^{a}
E.C (ds/m)	0.48^{bc}	0.14^{c}	1.04^{a}	0.63^{b}	0.48^{bc}
Cl (mg/l)	43.22^{b}	8.24^{b}	106.09^{a}	43.27^{b}	37.00^{b}
Ca (mg/l)	27.12^{a}	9.67^{b}	39.11^{a}	31.33^{a}	26.35^{ab}
Mg (mg/l)	16.43^{a}	8.25^{a}	12.09^{a}	9.12^{a}	8.54^{a}
Na (mg/l)	22.62^{a}	21.59^{a}	63.99^{a}	17.88^{a}	39.58^{a}
K (mg/l)	9.13^{a}	9.98^{a}	21.76^{a}	8.42^{a}	47.40^{a}
O.C (mg/l)	0.69^{a}	0.72^{a}	0.53^{a}	0.72^{a}	0.65^{a}
HCO_3 (mg/l)	48.89^{b}	13.92^{b}	102.41^{a}	53.18^{b}	33.08^{b}
SAR	0.80^{a}	1.21^{a}	2.57^{a}	0.82^{a}	1.97^{a}
NO_3-N (mg/l)	0.29^{a}	0.19^{a}	0.79^{a}	0.52^{a}	0.41^{a}
Pb (mg/l)	0.01^{a}	0.00^{a}	0.02^{a}	0.00^{a}	0.00^{a}
Cd (mg/l)	0.00^{a}	0.00^{a}	0.02^{a}	0.00^{a}	0.01^{a}
Cr (mg/l)	0.06^{a}	0.00^{b}	0.06^{a}	0.02^{b}	0.00^{b}
Zn (mg/l)	0.12^{bc}	0.02^{c}	0.44^{a}	0.23^{b}	0.20^{b}
Cu (mg/l)	0.08^{a}	0.07^{a}	0.06^{a}	0.05^{a}	0.04^{a}

Means on the same row with different superscripts are significantly different ($p \leq 0.05$).

Acidity/Alkalinity - The pH values ranged from 6.56 – 7.98. With the highest pH recorded at Opposite Federal Secretariat Location and the lowest value recorded at Kanfanin Kutare location. These analytical results of water samples indicate that they were slightly acidic to slightly alkaline in nature and their pH ranges were found to be within the standard recommended limit of 6.5 – 8.5 (Ayers and Westcott, 1976). The lower pH value of sample from Kanfanin Kutare may be partly due to high content of humic acids in the sediments.

Salinity - The EC of water ranged from 0.14 ds/m - 1.04 ds/m, indicating that they are highly suitable for irrigation purposes in their respective locations as reported by Tsado *et al.*, (2016). The relatively higher value of EC of water sampled in Ketren Gwari, could be attributed to the discharge of waste waters and suspended inorganic matter present in the canal through which the water flows.

Water Infiltration Rate - The results of the analyzed water samples indicate that samples from Gidan Mangoro had the least value of 0.80, with the highest recorded at Ketaren Gwari which had a value of 2.57. The highest value of SAR here, is considered a moderate level of SAR as stated by Tsado, *et al.*, (2016). All water sampled across treatment locations, were considered s excellent seeing as all SAR values were < 10.

Specific Ion Toxicities (Ca, Mg, Na, Cl, HCO_3, K, NO_3-N) - Calcium Content of water samples varied from 9.67 mg/l – 39.11 mg/l in Kanfanin Kutare and Ketaren Gwari respectively as well as Magnesium content of water samples which varied from 8.25 – 16.43 mg/l in Kanfanin Kutare and Gidan Mangoro respectively. The concentrations of Calcium and Magnesium content of water samples across the treatment locations are considered suitable for irrigation (Hossain and Ahmed, 1999). Sodium content in all the sites ranged from 17.88 mg/l – 63.99 mg/l. with the lowest rate recorded in Morris and the highest rate occurring in Ketaren Gwari. Chloride levels across the sites ranged from 8.24 mg/l – 106.09 mg/l with the lowest rate occurring in Kanfanin Kutare. The values are within the usual range expected from irrigation water (0-30 meq/l) (Dewis and Freitas, 1970). Sodium, Chloride and Potassium content in all the locations were within the safe limit for irrigation (Ayers and Westcott, 1985). NO_3-N content in water samples across sites was highest in Ketaren Gwari at 0.79 mg/l and was lowest in Kanfanin Kutare at 0.19 mg/l. The specific toxicities of ions such as Ca, Mg, Na, Cl, HCO_3, K, NO_3-N were lowest in Kanfanin Kutare which served as the control in this experiment. According to water quality classification after Wilcox (1945), All water samples were within the safe limit (B < 0.75 mg/l), and are excellent for irrigation.

Organic Carbon Content - Levels of organic carbon content ranged from 0.53 mg/l – 0.72 mg/l. the lowest level occurred in Ketaren Gwari while the highest level occurred in two locations namely, Kanfanin Kutare and Morris.

Heavy Metal Concentrations - Across all the sites, the heavy metal concentrations were very low to non-detectible, thus suggesting that the irrigation water across sites is low in heavy metal contents and suitable for agriculture on the basis of heavy metal concentration according to FAO (2013).

Table ii: Expected annual loading rates (ALR) in kg/ha/year of heavy metals at the study sites.

Metal	Sites					ALR Limit in Kg/ha/yr
	A	B	C	D	E	
Pb	0.37	0	0	0	0.56	15
Cd	0.19	0.19	0.56	0	0.75	0.15
Cr	1.12	0	0	0.37	1.12	15
Zn	2.25	0.37	0.94	4.31	8.24	15
Cu	1.5	1.31	0.75	2.62	1.12	7.5

A= Gidan Mangoro, B= Kanfanin Kutare C= Opposite Federal Secretariat, D= Morris, E= ketaren Gwari

This represents the rates at which heavy metals are expected to load the soil at the study sites, annually. The table shows that except for Cd, the other heavy metals such as Pb, Cr, Zn and Cu concentrations will increase significantly annually.

Soil Sampling Analytical Results.

Table iii: Selected Physical Properties of the Soils of the Study Area.

Parameters	Gidan Mangoro	Kanfanin Kutare	Opp. Fed. Secretariat	Morris	Ketaren Gwari
Sand (g/kg)	801^{ab}	725^{b}	855^{a}	804^{ab}	887^{a}
Silt (g/kg)	139^{ab}	208^{a}	89^{b}	153^{ab}	71^{b}
Clay (g/kg)	61^{a}	67^{a}	56^{ab}	44^{bc}	43^{c}
Textural Class	Sandy Loam	Sandy Loam	Loamy Sand	Loamy Sand	Loamy Sand

Means on the same row with different superscripts are significantly different ($p \leq 0.05$).

Soil Texture.

Soils samples which were taken from 0-15cm of the top soil, ranged from sandy loam soils to loamy sand soils. Sandy soils were also inclusive. But the bulk of the samples were predominantly loamy sand soils. The highest concentration of sand occurred in Ketaren Gwari at 887 g/kg, while the lowest concentration occurred in Kanfanin Kutare which served as the control for this experiment at 725 g/kg. Ketaren Gwari which showed the highest concentration of sand, was regarded as a sandy soil, unlike other locations which were predominantly loamy sand soils.

All soils are not created equal. A basic and important difference between soils is texture. This refers to the mixture of size particles in a soil. Soils of different texture pose different risks for the movement of contaminants from agricultural land. Knowing what soil textures make up the fields on a farm, is an important step toward using management practices that maximize productivity and minimize environmental harm (Hilliard and Reedyk, 2014).

Table iv: Selected Chemical Properties of the Soils of the Study Area.

Parameters	Gidan Mangoro	Kanfanin Kutare	Opp. Fed. Secretariat	Morris	Ketaren Gwari
pH (H_2O)	7.53^{b}	7.34^{b}	8.23^{a}	6.90^{c}	6.68^{c}
E.C (ds/m)	0.17^{abc}	0.12^{c}	0.26^{ab}	0.27^{a}	0.15^{bc}
Total N (g/kg)	1.40^{b}	1.50^{ab}	1.30^{b}	2.03^{a}	1.87^{ab}
Available P (mg/kg)	2.85^{c}	3.52^{c}	2.80^{c}	4.94^{b}	7.51^{a}
O.C (g/kg)	8.40^{b}	11.73 ab	10.83^{b}	14.77^{a}	11.23^{b}
Ca (cmol/kg)	2.00^{b}	2.60^{b}	4.03^{ab}	5.83^{a}	2.70^{b}
Mg (cmol/kg)	0.37^{c}	0.60^{bc}	0.73^{bc}	1.23^{a}	0.97^{ab}
K (cmol/kg)	0.12^{ab}	0.07^{b}	0.41^{ab}	0.80^{a}	0.39^{ab}
Na (cmol/kg)	0.28^{ac}	0.03^{c}	1.04^{a}	1.07^{a}	0.91^{ab}
Al (cmol/kg)	0.17^{a}	0.27^{a}	0.20^{a}	0.25^{a}	0.31^{a}
H (cmol/kg)	0.12^{a}	0.11^{a}	0.07^{a}	0.07^{a}	0.08^{a}

Means on the same row with different superscripts are significantly different ($p \leq 0.05$)

Acidity/Alkalinity (Soil pH) - Soil pH, ranged from 6.68 to 8.32 across treatment locations. With the highest rate recorded occurring in Opposite Federal Secretariat and the lowest rate occurring in Ketaren Gwari. The analytical results of the soil samples indicate that the soils are slightly acidic to slightly alkaline in nature. These pH values were found to be within the standard recommended limit of 6.5-8.5 (Ayers and Westcott, 1976).

Soil Electrical Conductivity - Means across all treatment locations were significantly different from each other. With EC ranging from 0.27 ds/m – 0.12 ds/m, with the highest rate occurring in Morris and the lowest rate occurred in Kanfanin Kutare.

Total Nitrogen - Total Nitrogen content varied across treatment locations, ranging from low to medium with the highest Total Nitrogen content recorded (2.03 g/kg), occurring in Morris and the lowest rate (1.30 g/kg) occurring in Opposite Federal Secretariat location.

Available Phosphorous - Available Phosphorous ranged from 2.80 mg/kg - 7.51 mg/kg across treatment locations. With the lowest range occurring in Opposite Federal Secretariat location and the highest range occurring in Ketaren Gwari.

Exchangeable Bases (Ca, K, Mg) - Potassium content ranged from 0.07 cmol/kg – 0.80 cmol/kg in Kanfanin Kutare (Control) and Morris respectively, Calcium content ranged from 2.0 cmol/kg in Gidan Mangoro to 5.83 cmol/kg in Morris. 0.37 cmol/kg was recorded in Gidan Mangoro as having the lowest magnesium content. While the highest occurrence was recorded in Morris as 1.23 cmol/kg. The high magnesium content at Morris can largely be attributed to the presence of a fully functioning fertilizer plant in the area which discharges effluents into the canal.

Exchangeable Acids (Al, H) - The highest concentration of Aluminum occurred in Ketaren Gwari, at 0.31 cmol/kg, while the lowest occurred in Gidan Mangoro at 0.17 cmol/kg. Gidan Mangoro recorded the highest concentration of exchangeable hydrogen which occurred at 0.12 cmol/kg, and Opposite Federal Secretariat recorded the lowest concentration at 0.07 cmol/kg. These values were low, indicating that the study area, had relatively low acidity.

Table v: Selected Heavy Metal Concentrations of Soils in the Study Area.

Parameters	Gidan Mangoro	Kanfanin Kutare	Opp. Fed. Secretariat	Morris	Ketaren Gwari
Lead (Pb) (mg/g)	0.19^b	0.00^c	0.00^c	0.12^c	0.41^a
Cadmium(Cd) (mg/g)	0.20^b	0.13^b	0.11^b	0.21^b	0.68^a
Chromium(Cr) (mg/g)	2.48^b	0.00^c	0.17^c	4.91^a	4.18^a
Zinc (zn) (mg/g)	8.15^b	4.63^c	3.09^d	8.47^b	13.04^a
Copper (Cu) (mg/g)	18.77^b	9.62^c	3.50^d	4.63^d	24.82^a

Means on the same row with different superscripts are significantly different ($p \leq 0.05$)

Heavy Metals in Soils.

There were no traces of lead in Kanfanin Kutare and Opposite Federal Secretariat. Whereas, Ketaren Gwari recorded the highest lead concentration at 0.41 mg/g. Cadmium concentrations ranged from 0.11 mg/g to 0.68 mg/g. Which were the lowest and highest occurrences across sites at Opposite Federal Secretariat and Ketaren Gwari respectively. There were no traces of Chromium at Kanfanin Kutare treatment location, while the highest concentration of Chromium, occurred at Morris treatment location at 4.91mg/g. Zinc had the highest concentration occurring in Ketaren Gwari at 13.04 mg/g and the lowest concentration occurring in Opposite Federal Secretariat location at 3.09mg/g. The highest concentration of Copper occurred in Ketaren Gwari at 24.82mg/g, while the lowest concentration occurred Opposite Federal Secretariat at 3.50mg/g with treatment means, differing across treatment locations. Across sites, the highest levels of all heavy metals were recorded at Ketaren Gwari which can largely be attributed to the presence of a mechanic village in the area

Table vi: Selected Soil Microbial Enzyme Activities of Soils in the Study Area.

Parameter	Gidan Mangoro	Kanfanin Kutare	Opp. Fed. Secretariat	Morris	Ketaren Gwari
Alkaline Phosphatase (g/g)	0.012[a]	0.014[a]	0.025[a]	0.023[a]	0.016[a]
Acid Phosphatase (g/g)	0.009[a]	0.015[a]	0.019[a]	0.011[a]	0.012[a]
Urease (ugN/g dry soil)	9.227[d]	21.020[c]	26.09[b]	33.127[a]	24.653[b]
Dehydrogenase (mg TPF/kg dry soil)	69.253[c]	67.173[c]	82.100[a]	78.427[b]	68.293[c]
Phospho-triestease (ugPNP/g dry soil)	15.643[b]	31.930[a]	16.29[b]	17.46[b]	10.470[c]

Means on the same row with different superscripts are significantly different ($p \leq 0.05$).

In Opposite Federal Secretariat, the highest level of alkaline phosphatase activity was recorded at 0.025 g/g, indicating that Phosphorus is most limited here, while the least level was recorded in Gidan Mangoro at 0.012 g/g indicating that Phosphorus is most sufficient here. These values indicate a relatively low activity of alkaline phosphatase in the soils across treatment locations as supported by Nannipieri *et al.*, (2011). There was no significant difference in acid phosphatase activity across the treatment locations. Although the highest rate was recorded in Opposite Federal Secretariat Location which invariably means that the soils of the area are limited in Phosphorus while the lowest was recorded in Gidan Mangoro which also means that Phosphorus is most sufficient in this area at 0.019 g/g and 0.009 g/g respectively, while 0.015g/g was recorded at Kanfanin Kutare. Urease activity in soils of the study area ranged from 9.22 ugN/g dry soil to 26.09 ugN/g dry soil across treatment locations. With the highest rate occurring in Opposite Federal Secretariat location and the lowest rate occurring at Gidan Mangoro site. Also, Kanfanin Kutare recorded 21.020 ugN/g dry soil. Urease activity which is considerably high here, is directly related to the vegetation of the soil. Higher values of urease activity in Opposite Federal Secretariat location suggests that there is higher vegetation there than in other locations The highest rate of dehydrogenase activity recorded, occurred in Opposite Federal Secretariat treatment location at 82.1

mg TPF/kg dry soil indicating that the site is most dehydrated and most oxidized, while the lowest rate of dehydrogenase activity recorded occurred in Kanfanin Kutare at 67.173 mg TPF/kg dry soil, indicating the site as the least hydrated and least oxidized. These rates of activity are appreciably high as reported by Jarvan *et al.*, (2014). The highest rate of phosphotriesterase activity occurring in Kanfanin Kutare at 31.93 ugPNP/g dry soil and the lowest rate occurring in Ketaren Gwari at 10.47 ugPNP/g dry soil. The values of the enzyme activity suggest that there was an appreciable activity of phospotriesterase in the soils of the study area as suggested by Nannipieri, (2011).

Table vii: Selected Heavy Metal Concentrations of *Amaranthus viridis* in the Study Area.

Sites	Pb (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
Gidan Mangoro	0.00	0.16	0.00	3.55	0.12
Kanfanin Kutare	0.00	0.05	0.00	2.73	0.00
Opp. Fed. Secretariat	0.00	0.00	0.00	0.89	0.00
Morris	0.1	0.15	0.00	3.25	0.00
Ketaren Gwari	0.14	0.13	0.05	6.36	0.01

Vegetables in Gidan Mangoro, Kanfanin Kutare, Opp. Fed. Secretariat showed no traces of lead contamination whereas, vegetables analyzed in Morris showed a lead concentration of 0.1 mg/kg, while Kataren Gwari showed lead concentrations of 0.14 mg/kg. These levels are relatively low and quite safe for human and animal consumption. This is supported by a publication by Yusuf and Oluwole, (2009). Cadmium concentrations ranged from 0.05 mg/kg to 0.16 mg/kg with the highest occurring in Gidan Mangoro site and the lowest in Kanfanin Kutare. There was no trace of cadmium in Opposite Federal Secretariat site. The rates of cadmium concentration in the vegetables were low and did not exceed the safe limits as stated by FAO/WHO. Except for Ketaren Gwari which showed chromium concentration of 0.05 mg/kg, all other sites showed no traces of chromium. The heavy metal at 0.05 mg/kg concentration, was low and pose little to no risk to the consumers. Zinc concentrations ranged from 0.89mg/kg to 6.36 mg/kg with the lowest concentration occurring in Opposite Federal Secretariat location and the highest occurring in Ketaren Gwari. These levels of zinc are relatively low and will have no adverse effects on the health of animals and humans. This assertion is supported by Yusuf and Oluwole, (2009). Who stated that the safe levels for zinc concentration in vegetables is 40.0 - 60 $\mu g\ g^{-1}$dryweight. There were no traces of copper across three sites namely; Kanfanin Kutare, Opp. Fed. Secretariat, and Morris. Ketaren Gwari recorded copper concentration of 0.01 mg/kg while Gidan Mangoro recorded a rate of 0.12 mg/kg. These levels of copper concentrations were relatively low and pose little to no risk to human and animal health.

Table viii: Correlation of Microbial Enzyme Activities with Chemical Properties of Irrigation Water.

	ALKALINE PHOSPHATASE ACTIVITY (g/g)	ACID PHOSPHATASE ACTIVITY (g/g)	UREASE (ugN/g dry soil)	DEHYDROGENASE ACTIVITY (mg TPF/kg dry soil)	PHOSPHOTRIESTERASE ACTIVITY (ugPNP/g dry soil)
pH	0.511	-0.150	0.244	-0.017	-0.477
EC μ^{2}□ cm	0.280	-0.306	0.197	-0.077	-0.462
Cl mg/l	0.061	-0.081	0.110	-0.206	-0.337
Ca mg/l	0.377	-0.282	0.256	-0.054	-0.368
Mg mg/l	-0.291	-0.041	0.152	-0.105	-0.221
Na mg/l	-0.158	0.072	0.414	0.212	-0.320
K mg/l	-0.237	0.353	0.219	0.341	-0.238
O.C mg/l	0.495	-0.030	-0.499	-0.281	0.406
HCO^-_3 mg/l	0.068	-0.138	0.128	-0.130	-0.331
SAR	-0.177	0.152	0.382	0.238	-0.310
Pb mg/l	-0.087	-0.245	0.108	-0.194	-0.160
Cd mg/l	-0.179	0.166	-0.103	0.021	-0.192
Cr mg/l	-0.256	-.538*	-0.229	-0.288	-0.381
Zn mg/l	0.153	-0.138	-0.004	-0.062	-0.444
Cu mg/l	0.237	-0.245	-0.447	-0.321	0.098
NO^-_3 mg/l	0.365	-0.179	-0.103	-0.336	-0.320

Correlation of Microbial Enzyme Activities with Chemical Properties of Irrigation Water.

Soil acid phosphatase activity was negatively correlated to most of the water quality parameters, but showed close and positive correlation to Na, K, SAR and Cd. Soil urease activity was negatively correlated to water organic carbon and all heavy metals excluding lead. Soil urease activity was closely and positively correlated to pH, Cl, Ca, Mg, Na, K, HCO^-_3, and SAR of water samples. Alkaline phosphatase activity showed positive correlation to pH, EC, Cl, Ca, O.C, HCO^-_3, Zn, Cu, and NO^-_3. while on the other hand, it showed a negative correlation to Mg, Na, K, SAR, Pb, Cd, and Cr. Soil alkaline phosphatase in addition to being affected by organic carbon, is also being influenced by soil pH. Soil phosphotriesterase activity was negatively correlated to all but two water quality parameters namely: O. C and Cu. Dehydrogenase activity showed positive correlations to Na, K, SAR, and Cd. It was negatively correlated to all other water quality parameters. Throughout the interactions, there were no significant correlations between the microbiological enzyme activities and water chemical properties.

Table ix: Correlation of Microbial Enzyme Activities with Chemical Properties of Soil.

	ALKALINE PHOSPHATASE ACTIVITY (g/g)	ACID PHOSPHATASE ACTIVITY (g/g)	UREASE (ugN/g dry soil)	DEHYDROGENASE ACTIVITY (mg TPF/kg dry soil)	PHOSPHOTRIESTERASE ACTIVITY (ugPNP/g dry soil)
pH	.126	.442	-.050	.333	-.087
EC μ^2 □ cm	.405	-.175	.143	.470	-.122
%N	-.021	-.228	.019	-.003	-.116
AP mg □ kg	.054	-.209	.147	-.214	-.240
Ca Cmol/kg	.340	.000	-.010	.289	-.078
Mg Cmol/kg	.279	-.044	.196	-.005	-.162
K Cmol/kg	.252	-.099	.027	.322	-.142
Na Cmol/kg	.067	.142	.202	.589*	-.283
% OC	.172	-.050	.082	-.047	.011
Pb mg/kg	-.176	-.384	.007	-.235	-.382
Cd mg/kg	-.166	-.268	.038	-.299	-.354
Cr mg/kg	.014	-.487	.284	.004	-.307
Zn mg/kg	-.211	-.484	.004	-.310	-.345
Cu mg/kg	-.383	-.378	-.269	-.471	-.283

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Correlation of Microbial Enzyme Activities with Chemical Properties of Soil.

Soil urease activity was closely and positively correlated to soil %N, available P, Mg, K, Na, %O.C, EC, Pb, Cd, Cr and Zn. It showed a negative correlation to PH, Ca, and Cu properties of the soil. Soil organic carbon, had a positive direct effect on alkaline phosphatase activity and alkaline phosphatase activity showed positive correlations with most of the soil properties except for %N, Pb, Cd, Zn, and Cu, with which it was negatively correlated. Acid phosphatase activity showed a negative correlation to all but one soil property (pH) with which it was positively correlated. Whereas, Ca had no effect on acid phosphatase activity. Na was significantly correlated to dehydrogenase activity and the enzyme activity showed close positive correlations to pH, EC, Ca, K, Na, and Cr. With all other soil properties, dehydrogenase activity showed a negative correlation. Phosphotriesterase activity was negatively correlated to all soil properties except for %O.C with which it showed a positive correlation. There was no perfect positive or perfect negative correlation in all the values considered.

CONCLUSION AND RECOMMENDATIONS

The results of analysis and evaluation of water samples from five locations in Minna, Niger state for irrigation purposes revealed that the water is suitable for irrigation based on results of EC, SAR, Specific ion toxicities, and Heavy metal analysis. Their suitability/quality for irrigation purposes occurred in the following order Kanfanin Kutare >Gidan Mangoro> Morris > Opposite Federal Secretariat >Ketaren Gwari. Water sampled from Ketaren Gwari are noted to be in the zone of increasing problems and turned out to be the least suitable for irrigation purposes. Dehydrogenase, Urease and Alkaline phosphatase activities were positively correlated with most of the water quality parameters which indicates that an increase in the concentration of the chemical properties of irrigation water will lead to a significant increase in the activities of Dehydrogenase, Urease and Alkaline

Phosphatase. Meanwhile, Acid phosphatase and Phosphotriesterase activities, were negatively correlated with most of the water quality parameters which implies that an increase in the concentrations of the water quality parameters will result in a significant decrease in the activities of Acid Phosphatase and Phosphotriesterase activities. Urease and Acid phosphatase activities showed positive correlations with most of the soil quality parameters while Alkaline phosphatase, Dehydrogenase and Phosphotriesterase showed negative correlations with most of the soil quality parameters. Alkaline Phosphatase activity was relatively low in the soils across treatment locations as supported by Nannipieri *et al.*, (2011). Soil reaction of the entire area indicated that the soil in the sampled area was suitable for soil microbial enzymatic activities.

Kanfanin Kutare showed low to non-detectible levels of heavy metal contamination. The site showed excellent organic carbon content as well as excellent chemical and physical properties of soil, plants and water, more than all other sites. Based on heavy metal concentration, all the water sources and soils of the treatment locations showed low to non-detectible concentrations of heavy metals. Whereas, Gidan Mangoro, Morris and Ketaren Gwari locations show high levels of Cadmium in plants which exceeded the FAO (2015) permissible limits of Cadmium in vegetables at 0.1mg/kg.

It is recommended that continued monitoring of irrigation water quality should always be conducted. As for the high saline content of the water sampled in Ketaren Gwari, adequate drainage is requisite. Once good drainage is assured, the soil can be irrigated with clean water. Also, salt tolerant crops can be cultivated instead of the norm. Also, the irrigation water and soil across sites is low in heavy metal contents and therefore, suitable for agriculture on the basis of heavy metal concentration. But continued seasonal analysis of heavy metals is advised in order to monitor their loading across the sites.

Periodic additions of Organic matter to the soil is of utmost importance as this detoxifies and remediates the soil and also, serve as sources of nutrients for micro-organisms consumption, proliferation and other enzymatic activities.

Farm owners should be sensitized on the appropriate amounts of chemicals to be added into the soil per time such as fertilizers, pesticides, insecticides and fungicides, so as to preserve the health of the soil and the end products of cultivation. Sensitization campaigns should also be carried out to educate the general public on the dangers of polluting this water ways and alternative measures of refuse and chemical dumping should be offered to them.

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