

AN APPRAISAL OF HEAVY METALS AND PHYSICOCHEMICAL PARAMETERS OF SOIL AT MANTA WATERSHED AND UPLAND IN ABAK, AKWA IBOM STATE, NIGERIA

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Abstract

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The analysis of some heavy metals and physicochemical properties of soil in Manta watershed and Manta upland soils were carried out through a randomized field study. The soil samples were collected at different locations of Manta land (ML) and Manta watershed (MW) at 0-15cm and 15-30cm respectively, using Unicam AAS Model 939 to analyze for Iron (Fe), Lead (Pb), Copper (Cu) and Zinc (Zn). The physicochemical status of MW shows that the soil texture was sandy loam with a mean sand content varies from 91.80 to 92.60% while the pH values were recorded at 4.98 to 4.73, EC 0.06 to 0.08, OM 3.09 to 2.49, and TN showed no significant difference between the two locations, while Av. P (10.22 to 5.42) and Ca, Mg, Na, and K showed low significance. EC changed moderately throughout the sites. The heavy metal concentrations were as follows: ML; iron (Fe) were 33.97 mg/kg (0-15 cm) > 33.84 mg/kg (15-30 cm), lead (Pb) levels were 6.71 > 4.95 mg/kg, copper (Cu) levels are 5.33 > 5.29 mg/kg, and zinc (Zn) levels are 5.46 > 5.36 mg/kg. In contrast, MW; iron (Fe) levels were 32.30 mg/kg (0-15 cm) > 31.47 mg/kg (15-30 cm), lead (Pb) levels are 6.10 > 3.23 mg/kg, copper (Cu) levels are 5.31 > 5.29 mg/kg, and zinc (Zn) levels were 5.21 > 5.00 mg/kg. The MW soil indicate good drainage and low water-holding capacity as well as low nutrient availability and mineral retention, posing no health hazards to grazing animals, humans, or freshwater bodies according to the WHO/FAO recommendation against the soil of ML.

Keywords: *Physicochemical Properties, Heavy Metal Parameters, Manta Watershed.*

Introduction

Soils are the main resources for agricultural production, and enhancement of its quality is vital for both agricultural and environmental protection (USDA, 2021). Maintenance of soil fertility status is a vital component of good sustainable land management (which sustained soil integrity and plant nutrition). In recent years there is a maximum increase in the decline of physicochemical and biological properties of the soil due to environmental factors which affects soil aggregate stability, water holding capacity and organic matter status among others leading to loss in soil quality status, low productivity and poor crop yield (Makinde *et al.*, 2011), The role of heavy metals in the ecosystem is increasingly becoming an issue of global concern, especially as it makes up a vital component of human life (Adekola and Mitchell, 2011). Heavy metals are natural constituents of rock and sediment and are vital for animals and plants growth, but much accumulation contaminate the environment as it toxicity threatened human's life (Dnthwange *et al.*, 2012). Heavy metals disrupt ecological services due to their pollutive and bio-accumulative nature in the soil and water bodies,

and also served as sinks to pesticide and trace elements (Ekpo *et al.*, 2014). The World Health Organization (WHO) estimated that about a quarter of diseases facing mankind occurs due to their prolonged exposure to environmental pollution induced by heavy metals in the soil (Kimani (2007). Soil is a stable component of the environment, though the most undervalued, misused and abused of the earth resources (Borlaug, 2000). Soil contamination has become a serious problem according to Wuana and Okieinen (2011), it is seen as the final sink for pollutants such as heavy metals discharged into the environment. Ahmad and Goni (2010), stated that heavy metals pollution of agricultural soil and vegetables is one of the most severe ecological problems because of its toxicity on plant, animal and human beings, and their lack of biodegradability. These attributes create eventual threats to the environment and can impair human health through numerous absorption pathways such as direct ingestion and skin contact. Too much buildup of trace elements in agricultural soils through anthropogenic interruption such as agricultural practices, waste-water discharge and irrigation may result in low soil fertility which can affect food quality/quantity and safety (Sharma *et al.*, 2006); and diet through the soil-food chain conduit, inhalation and oral intake (Lu *et al.*, 2007).

Most soils in southern Nigeria are acidic resulting from their parent material make-up, heavy leaching and weathering (Umoh *et al.*, 2018). Sunday *et al* (2020), corroborate this, and added that sandy soil is highly prone to leaching of cationic nutrients (K and P), which further impoverish the soil through nutrient losses and deficiencies. The maintenance of soil fertility is vital in accomplishing and maintaining high crop production by removing the acidity through organic wastes amendment such lime (Singh *et al.*, 2008). Increased acidity and soil nutrient imbalance have drawn the attention of researchers to the use of agricultural waste that could serve as lime and fertilizer for efficient soil productivity. Soil productivity maintenance in the other hand is a major constraint of tropical agricultural system. Understanding environmental status of soil such as soil composition and heavy metals, soil management and its effect on soil properties is scarce (especially along the Ikot Oku Mfang -,Ukpom- Manta- Ediene- Ibagwa watershed corridor), which could be useful for erosion control, water infiltration and nutrient conservation (Udoh *et al.*, 2009). It is therefore important to investigate the soil physicochemical properties and heavy metal status to ascertain the soil quality and its safety for crop production for human consumption along the watershed corridor. The objective of the study was to determine the physicochemical properties and heavy metal status of Manta watershed and upland soils.

The study was conducted at two locations in Manta, Abak in Akwa Ibom State which lies between Latitudes 4°32'N and 5°33'N and longitudes 7°25'E and 8°25'E. The areas experience the normal Niger Delta climatic conditions. The major occupation of the people includes agricultural activities of farming and sand mining. There are two main seasons, the wet and dry seasons and these depend on the movement of the Inter-Tropical Discontinuity (ITD) which is the zone separating the warm humid maritime air mass with its associated South westerly winds from North easterly winds. The rainfall pattern is bi-modal, with rainfall beginning in about early March and ends around mid-November (Udumoh *et al.*, 2019). The wet season has features including high proportion of total annual rainfall, with peak in July and September with moisture stress period between 2-3 weeks in August, often called "August Break". The dry season has its existence between late November to early March with features like: very high temperature with annual mean monthly temperature of 28°C to 30°C, having the period with highest temperature between January and March (described as a period of overhead passage of the sun), and harmattan with dry dusty wind between early December and late January (Uduak *et al.*, 2018). Abak has a mean annual rainfall of about 2484mm, mean annual temperature of 27°C, with varying relative humidity through the year from 70⁰-80% (Udumoh *et al.*, 2019). The state is located within the humid forest of Nigeria, due to population

pressure and increasing number of settlements, there is a drastic transformation of the natural vegetation to secondary forest.

Materials And Methods

Study Area: The study was conducted at two locations in Manta, Abak in Akwa Ibom State which lies between Latitudes $4^{\circ}32'N$ and $5^{\circ}33'N$ and longitudes $7^{\circ}25'E$ and $8^{\circ}25'E$. The areas experience the normal Niger Delta climatic conditions. The major occupation of the people includes agricultural activities of farming and sand mining. There are the two main seasons the wet and dry seasons and these depends on the movement of the Inter-Tropical Discontinuity (ITD) which is the zone separating the warm humid maritime air mass with its associated South westerly winds from North easterly winds. The rainfall pattern is bi-modal, with rainfall beginning in about early March and ends around mid-November (Udumoh *et al.*, 2019). The wet season has features including high proportion of total annual rainfall, with peak in July and September with moisture stress period between 2-3 weeks in August, often called “August Break”. The dry season has its existence between late November to early March with features like: very high temperature with annual mean monthly temperature of $28^{\circ}C$ to $30^{\circ}C$, having the period with highest temperature between January and March (described as a period of overhead passage of the sun), and harmattan with dry dusty wind between early December and late January (Uduak *et al.*, 2018). Abak has a mean annual rainfall of about 2484mm, mean annual temperature of $27^{\circ}C$, with varying relative humidity through the year from 70° - 80% (Udumoh *et al.*, 2019). The state is located within the humid forest of Nigeria, due to population pressure and increasing number of settlements, there is drastic transformation of the natural vegetation.

Geology and Soils: The state is underlain by one geological formation; the coastal plain sands comprising largely of poorly consolidated sands. They are dominated by low activity clays, low organic matter content and are susceptible to accelerated erosion and soil degradation (Peters *et al.*, 1989). The overall effect is that; large area has been brought under cultivation, urbanization and degradation. Population pressure coupled with poor management and improper land use has led to forest depletion with the attendant soil degradation and low productivity. Human intervention through agriculture, construction, environmental modification and quest for the fuel wood, timber non/timber forest product has greatly altered the vegetation of the area.

Sample Collection: The soil samples were collected at the two locations at Manta; (Manta land (ML) and Manta watershed (MW)), Abak Local Government Areas with the aid of soil auger from four points. There were all collected during rainy seasons and at the depths of 0-15 and 15-30cm respectively. The samples were placed in labeled polythene bags prior for analysis. A total of Eight (8) composite samples were obtained for the analysis.

Routine Analysis of the Soil Sample: Physical and chemical properties of the soil were analysed according to the standard laboratory procedures highlighted by by Udoh *et al* (2009). The physical properties determined include particle size distribution, while the chemical properties determined include; Texture: Particle size distribution was determined by the hydrometer method using sodium hexameta phosphate as dispersing agent (Klute, 1986). Soil pH: The soil pH was measured in soil to water ratio of 1:2.5 using a glass electrode pH meter. Electrical Conductivity: This was measured in the extract from 1:2.5 soils: water suspension using a conductivity bridge. Organic Carbon: Soil organic carbon was determined by wet oxidation method as described by Spark (1996). The value was multiplied with factors of 1.72 to obtained organic matter. Total Nitrogen: The nitrogen in the soil was determined by micro Kjeldahi method. Available Phosphorous: Available P in the soil was determined by Murphy and Riley method as described by Udoh *et al.*, (2009) after extraction by

Bray P⁻¹ extractant. Exchangeable Base: The exchangeable cation in the soil was extracted using in NH₄OAC K and Na in the extracts was measured using flame photometry while Mg and Ca were determined by atomic absorption spectrophotometry. Effective Cation Exchangeable Capacity (ECEC): ECEC was obtained by the summation of the exchangeable cation and exchangeable acidity. Percentage Base Saturation: The percentage base saturation (% BS) was determined based on this standard formula;

: % BS = Summation of Exchangeable Bases X 100 as used by Dimka and Nedi (2023).

Metal pollution index (MPI). Metal pollution index (MPI) was utilized for the evaluation of the correlation among metals in the soils and the control sample (Lacatusu, 2000). Extraction and Analysis of Heavy Metals: Determination of Heavy Metals in Soil: The air dried soil samples (5g) were placed in a Teflon beaker and digestion was carried out using concentrated nitric (10cm³) and concentrated perchloric (5cm³) acids in the ratio of 2:1 (Gokoglu and Yerlikaya, 2003). This was allowed to cool before leaching the residue with 5 cm³ of 20% HNO₃. Digested samples were filtered and made up to 50 cm³ with deionized water. B Blank determinations were treated in the same method but without sample. Solution of samples were then taken and aspirated into Atomic Adsorption Spectrophotometer Unicam Solaar 969 model (AAS) to determine the following metal; Iron (Fe), Zinc (Zn), Copper (Cu) and Lead (Pb).

Statistical Analysis: Data generated from the laboratory were subjected to analysis of variance and means compared using least significant difference at $p < 0.05$. (Gomez and Gomez, 1984).

Results and Discussions

Soil Physicochemical Properties of the Study Area: The result and discussion from the analyzed of physicochemical properties of the soil under two depths, 0-15 and 15-30 cm in two dissimilar locations (Manta Land (ML) and Manta Watershed (MW)) are presented in Table 1.1. Soil Texture show that the sand content was predominantly sandy loam; with a mean sand content ranging from 91.80 to 92.60% suggesting that the soil has a good drainage capacity but may have low water-holding capacity and nutrient retention within the two depths and locations. The depth variations for Manta land and manta watershed (0-15, 15-30 cm) show that the pH values are slightly acidic (4.73 to 4.98), which is generally favorable for most plants and low metals in the soil while Manta watershed (0-15, 15-30) remains slightly acidic to neutral (4.30 to 4.95) showing the pH of the soil decrease in depth due to low levels of heavy metals. A slight decrease depth in EC of Manta Land and Manta watershed; (0-15, 15-30 cm) had 0.08 to 0.06 indicating a potential decrease in salinity showing a low level of salinity in the two locations. Organic matter (OM) content of (0-15, 15-30 cm) were lower, the value raging from (2.49 to 3.09%), suggesting a limited nutrient supply and Manta watershed (0-15,15-30) organic matter content were slightly lower than the 0-15 cm depth and is varying from (2.66 to 2.99%). Total Nitrogen (TN) had low significant different within the two locations, Manta land had (0.11, 0.10) compare to Manta watershed with (0.03, 0.03), indicating a potential nutrient deficiency while Available Phosphorus (Av. P) were 0-15, 15-30 had (10.22, 7.08 mg/kg), (9.04, 5.42) which may indicate a deficiency of Available phosphorus in the both locations. Calcium (Ca) content had low significance in both depths (0-15, 15-30) and locations and ranges from 0.96, 1.00; 0.44, 0.07 cmol/kg respectively while Magnesium (Mg) content was the same and was very low in concentration in depth and locations; varying from 0.30, 0.33 and 0.30, 0.31 cmol/kg. Sodium (Na) and Potassium (K) content were lower, varying from 0.09, 0.10; 0.05, 0.05 and 0.12, 0.13; 0.07, 0.06 cmol/kg and were typically low, which suggested that Ca, Mg, Na and K levels remain constant within the varying depths and sites. The result also shows that top soil (0-15 cm) horizon has slightly more Ca, Mg, Na and K than the sub soil (15-30 cm) horizon. Manta Land

marginally had higher concentrations of calcium, magnesium, sodium, and potassium compared to the Manta Watershed which may promote plant health and soil fertility. Cation exchange capacity (CEC) (0-15, 15-30 cm) were moderate and varying from (2.40 to 2.64 cmol/kg) indicating a moderate ability to retain nutrients in the soil and base saturation (Bs) significantly low (64.17 to 65.22%), suggesting a potential need for liming to increase soil pH and nutrient availability while Manta watershed (0-15,15-30) of CEC and Bs had (1.91 to 2.30 cmol/kg), (71.88 to 73.68%) respectively implying a decreased in the ability to retain nutrients and mineral elements (Udo et al., 2009).

Heavy Metal concentration: The heavy metal concentration of Fe, Pb, Cu, Ze from two locations (Manta Land (ML) Manta Watershed (MW)) and two depths (0-15, 15-30 cm) are presented in Table 1.2 and Figure 1.1. The result from the analysis show that Iron (Fe) within the locations and depth had no significant different, the value was ML (0-15, 15-30 at respectively 33.84 and 33.97 MW (0-15, 15-30 at 31.47, 32.30. ML and Fe concentrations are generally high across all depth intervals, with a slight decrease in mean values as the depth increases from 0-15 cm to 15-30 cm while MW concentrations were lower suggesting some variation due to soil characteristics or environmental influences. This should be as the result of waterlogged conditions, low organic matter and high pH. The pH level of the soil significantly influences iron availability (Pawlowski and Kobierski, 2023). In acidic soil, iron tends to form insoluble unavailable as was observed by Alloway (2017). Lead (Pb) concentration at ML show high compounds, making it less available for plant uptake. The soil pH can also lead to competition with other nutrients like manganese and phosphorus which may precipitate and render iron significant within 0-15cm depth and low within 15-30 cm while MW indicate high within 0-15 and lower at 15-30 the depth, the values were 6.71, 4.95; 3.23, 6.10 respectively. This show that Manta land experience low leaching potential which cause high accumulation of heavy metals compare to MW which is close to water body thereby leaching nutrient away (Sunday *et al.*, 2020). Cu and Zn had no significant different within the locations and depth; ML had 0-15, 15-30 cm (5.33, 5.29), (5.46, 5.36) while MW had 0-15, 15-30cm, (5.29, 5.31), (5.00, 5.21) respectively. The result shows that the amount of heavy metals presence in soil can pose significant health risks, based on the findings of Benson and Ebong (2005), that the accumulation of heavy metals in soil can degrade soil quality, hinder crop development and result in reduced yields.

Table 1.1: Soil Physicochemical Properties

	Depth	Sand (%)	Silt (%)	Clay (%)	pH (H ₂ O)	EC ds/cm	OM (%)	TN (%)	Av. P (mg/kg)	Ca Mg Na K EA ECEC Bsat						
										(Cmol/kg)						
Mean	0-15	92.60	4.91	2.49	4.73	0.08	3.09	0.11	10.22	1.00	0.33	0.09	0.12	0.86	2.40	64.17
SD		2.01	0.87	0.50	0.23	0.03	0.64	0.01	1.07	0.50	0.08	0.02	0.02	0.06	0.20	4.86
Mean	15-30	92.03	5.00	2.97	4.98	0.06	2.66	0.10	7.08	0.96	0.31	0.10	0.13	0.80	2.30	65.22
SD		2.63	0.87	0.46	0.97	0.05	0.20	0.05	0.62	0.05	0.07	0.00	0.10	0.26	0.61	5.01
Mean	0-15	92.33	4.71	2.93	4.30	0.80	1.05	0.03	9.04	0.98	0.30	0.05	0.07	0.51	1.91	73.68
SD		2.52	0.62	0.40	0.61	0.60	0.09	0.01	0.07	0.07	0.13	0.04	0.06	0.22	0.87	1.15
Mean	15-30	91.80	5.21	2.99	4.95	0.80	0.93	0.03	5.42	0.96	0.31	0.05	0.06	0.54	1.92	71.88
SD		1.71	0.26	0.49	0.43	0.60	0.40	0.01	0.52	0.44	0.10	0.04	0.01	0.05	0.39	1.82

ML= Manta land MW = Manta watershed EC = electrical conductivity, OM = organic matter, TN = total nitrogen, Av.P = available phosphorus, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, EA = exchangeable acidity, ECEC = effective cation exchange capacity, Bsat = base saturation.



Table 1.2: The Level of Heavy Metal Concentration of Fe, Pb, Cu, Zn

		Depth	Fe	Pb	Cu	Zn
Mean		0-15	33.84	6.71	5.33	5.46
Standard Deviation	Manta		1.00	1.00	1.00	0.20
Mean	Land	15-30	33.97	4.95	5.29	5.36
Standard Deviation			0.02	1.00	1.00	0.20
Mean		0-15	31.47	3.23	5.29	5.00
Standard Deviation			31.47	3.23	5.29	5.00
Mean	Manta	15-30	32.30	6.10	5.31	5.21
Standard Deviation	Watershed		2.00	1.00	0.30	0.20

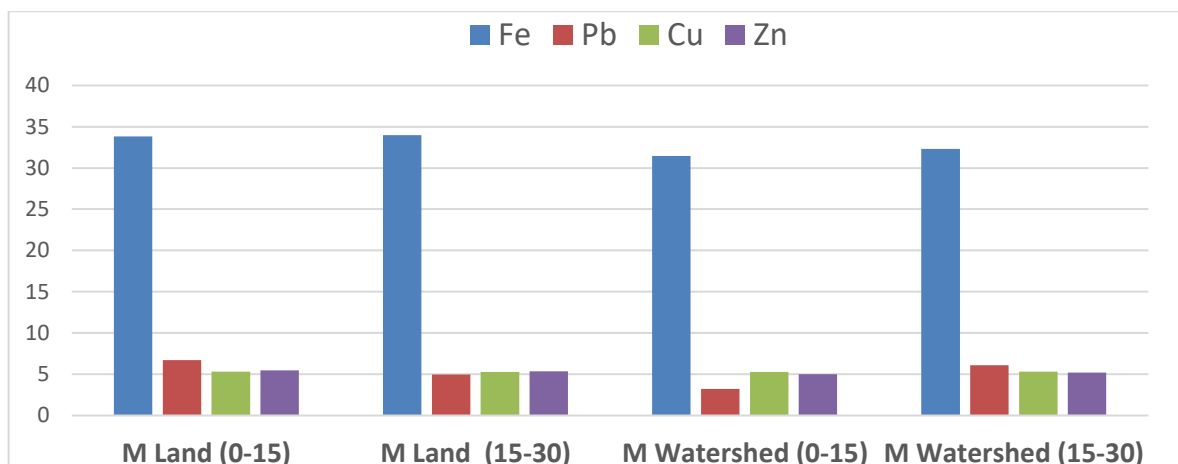


Figure 1.1 Heavy Metals in the Two Locations

Conclusion and Recommendation

This research reveals that there is no alteration in the physicochemical status of the two soils under study. The heavy metals were not contaminated, but remained within permissible limit of agricultural soils as recommended by WHO/FAO. Therefore, it poses no potential hazards to terrestrial wellbeing (organisms such as grazing animal, humans) and water bodies (such as streams). It was also observed that organic matter and all other physicochemical properties were low with soil texture predominantly sandy loam. This type of soil is characterized by good drainage and low water-holding capacity, resulting in low nutrient availability and retention. The presence of minerals elements which is seen in low levels of heavy metals present in the soil suggest that the place will experience poor yield and plant growth may occur if appropriate management and remediation procedures such as addition of organic manure (and appropriate inorganic manure) are applied besides the avoidance of tillage to reduce soil detachment that accelerated soil erosion.

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References

- Adekola, O., & Mitchell, G. (2011). The Niger Delta Wetlands: Threats to Ecosystem Services, Their Significance to Human Wellbeing And Some Possible Responses. *Global Environmental Change*, 21(2), 354–364. <https://doi.org/10.1016/j.gloenvcha.2010.09.009>
- Ahmad, J. U., & Goni, M. A. (2010). Heavy metal contamination in water, soil, and vegetables of the industrial areas in Dhaka, Bangladesh. *Environmental Monitoring and Assessment*, 166, 347–357. <https://doi.org/10.1007/s10661-009-1006-6>
- Alloway, B. J. (2013). *Heavy metals in soils* (3rd ed.). John Wiley & Sons.
- Ayoola, O. T., & Makinde, E. A. (2009). Maize growth, yield and soil nutrient changes with nitrogen-enriched organic fertilizers. *African Journal of Food, Agriculture, Nutrition and Development*, 9(1), 530–592.
- Benson, N., & Ebong, G. (2005). Heavy metals in vegetables commonly grown in a tropical garden Ultisol. *Journal of Sustainable Tropical Agricultural Research*, 16, 77–80
- Dimka, M. O. and Nedi, A. M. (2023). Characterization and Clasification of Soils on a Toposequence around Dutse, Jigawa State, Nigeria. *Discover Soil*, 1, 12. doi.org
- Ekpo, F. E., Ukpog, E. J., & Udoumoh, I. D. J. (2014). Bioaccumulation of heavy metals in soil and arable crops grown in abandoned Peacock Paint Industry in Ikot Ekan, Etinan LGA, Akwa Ibom State, Nigeria. *Universal Journal of Environmental Research and Technology*, 4(1), 39–45.
- Food and Agriculture Organization. (2006). *Guidelines for soil description*. FAO.
- Gökoglu, N., & Yerlikaya, P. (2003). Determination of heavy metals in soil and plant samples by atomic absorption spectrometry. *Turkish Journal of Chemistry*, 27(2), 135–141.
- Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research* (2nd ed.). Wiley.
- Kimani, N. G. (2007). *Environmental pollution and impacts to public health: Implication of the Dandora municipal dumping site in Nairobi, Kenya*. United Nations Environment Programme.
- Klute, A. (Ed.). (1986). *Methods of soil analysis: Part 1—Physical and mineralogical methods* (pp. 635–662). ASA & SSSA.
- Lu, Y., Zhu, F., & Chen, J. (2007). Chemical fractionation of heavy metals in urban soils of Guangzhou, China. *Environmental Monitoring and Assessment*, 134, 429–439.
- Makinde, S. O., Usilo, M. I., Makinde, E. A., & Ayeni, L. S. (2011). Comparative effect of mineral fertilizer and organic manure on growth, nutrient content, and yield of *Corchorus olitorius* and *Celosia argentea*. *Research Knowledge*, 2(6), 257–264.
- Pawlowski, M., & Kobierski, M. (2023). Distribution of iron forms in different types of black earths in the Chełmno Lake District (Northern Poland) as an indicator of soil-forming processes. *Soil Science Annual*, 74(3). <https://doi.org/10.37501/soilsa/176686>
- Peters, S. W., Usoro, E. J., Obot, U. W. & Okpon, S. N. (1989). *Akwa Ibom State Physical Background, Soil, Land Use and Ecological Problems (Technical Report of the Task Force on Soil and Land Use Survey)*. Government Printer, Uyo. pp 602

- Sharma, R. K., Agrawal, M., & Marshall, F. (2007). Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. *Ecotoxicology and Environmental Safety*, 66, 258–266. <https://doi.org/10.1016/j.ecoenv.2005.11.007>
- Singh, K. P., Prakash, V. K., & Srivastava, S. A. K. (2008). Effect of tillage management on energy-use efficiency and economics of soybean (*Glycine max*)-based cropping systems under rainfed conditions in the North-West Himalayan region. *Soil and Tillage Research*, 100, 78–82
- Sparks, D.L. (Ed.). (1996). *Methods of Soil Analysis: Part 3 – Chemical Methods*. SSSA Book Series No. 5. *Soil Science Society of America*, Madison, WI.
- Sunday, A. E., Umoh, F. O., & Sifon, M. (2020). Assessment of phosphorus leaching potentials on soils from diverse parent materials in Akwa Ibom State. In *Proceedings of the 44th Conference of the Soil Science Society of Nigeria* (pp. 486–497).
- Udo, E. J., Ibia, T. O., Ogunwale, J. A., Ano, A. O., & Esu, I. E. (2009). *Manual of soil, plant and water analysis*. Sibon Books Ltd.
- Udumoh, I. D. J., Uduak, I. G., & Bassey, D. E. (2019). Effect of Gramoxone herbicide on soil microbial population at Obio Akpa, Southeast Nigeria. *Journal of Agriculture, Environmental Resource and Management*, 4(2), 530–540.
- Uduak, I. G., Ndubuisi-Nnaji, U. U and Udumoh, I. D. J. (2018). Selected Properties and Problems of Some Coastal Plain Soils in Akwa Ibom State. *Journal of Community and Communication Research* ISSN 2635-3318 vol. 2 no 1 pp 73-79.
- Umoh, F. O., & Osodeke, V. E. (2016). Estimation of phosphorus requirement of mungbean (*Vigna radiata*) in acid soils of Southeastern Nigeria using P-sorption isotherm. *American-Eurasian Journal of Agriculture and Environmental Science*, 16(3), 487–493.
- Umoh, F. O., Osodeke, V. E., & Akpan, U. S. (2018). Assessment of potassium leaching behavior in selected soils of Southeastern Nigeria. *International Journal of Sustainable Agricultural Research*, 3(1), 10–18.
- Westerman, P. W., & Bicudo, J. R. (2003). Management considerations for organic waste use in agriculture. *Bioresource Technology*, 96(2), 215–221.
- World Health Organization. (2010). *Exposure to cadmium: A major public health concern*. WHO.
- Wuana, R. A., & Okieimen, F. E. (2011). Heavy metals in contaminated soils: A review of sources, chemistry, risks and best available strategies for remediation. *ISRN Ecology*, 2011, 1–20. <https://doi.org/10.5402/2011/402647>