Original Research Article

ASSESSMENT OF HEAVY METALS CONCENTRATION IN SWAMPY AGRICULTURAL SOIL OF NASARAWA WEST, NIGERIA

ABSTRACT

Aim: This research was carried out to investigate the concentration of heavy metals in swampy agricultural soil of Nasarawa west, Nigeria.

Study design: To compare the swampy soil heavy metal concentrations with regulatory standard or allowable values by the World Health Organization (WHO) and other National and International standards.

Place and duration of study: Department of Physics, Nasarawa State University Keffi between January, 2018 and October, 2018.

Methodology: Ten soil samples from each of thefive sampling locations (Karu, Keffi, Kokona, Nasarawa, and Toto) were randomly collected. A total of fifty (50) soil sampleswere collected within the period of one week. The collected samples were stored in polyethylene bag and labeled properly and taken to the Center for Energy Research and Development (CERD) at Obafemi Awolowo University Ile- ife Osun State, Nigeria. At CERD, elemental analysis was carried out for the fifty sample using X- ray fluorescent spectrometry analyzer.

Result: The range of mean concentration of Zn, As, Cd, Pb, Fe, Ni, and Cu (in KR, KF, KK, NS, and TT locations) are 243.60- 502.80mg/kg, 7.40- 37.00mg/kg, 260.90- 524.50mg/kg, 167.80-336.60mg/kg, 20222.90- 58170.50mg/kg, 342.20- 555.10mg/kg, and 266.60- 515.90mg/kg respectively. The average mean of all the sample locations are found to be higher than the WHO allowable concentration limits of As (20mg/kg), Pb (100mg/kg), Cd (3mg/kg), Zn (300mg/kg), Fe (n.a), Ni (50mg/kg), and Cu (100mg/kg)respectively.There is high concentration Zn, As, Cd, Pb, Fe, Ni, and Cu in the swampy soil.

Conclusion: The results indicates that the swampy agricultural soils of Nasarawa west (Karu, Keffi, Kokona, Nasarawa, and Toto) are contaminated with toxic metals (Zn, As, Cd, Pb, Fe, Ni, and Cu).

Key words: Heavy metals, XRF Spectrometry analysis, and Swampy Agricultural Soil.

INTRODUCTION

Soil is a major sink for heavy metals released into the environment by industrial and human activities. Nonetheless, heavy metals above certain limits exhibit adverse ecological effects and are toxic to plants, animals and humans at large [9, 10, 11]. Heavy metals are common environmental pollutants and are released into soils from natural or anthropogenicsources. The main natural sources of metals in soils are weathering of parent material and soil erosion [1,2].Mining, manufacturing, and the use of synthetic products (e.g. pesticides, paints, batteries, industrial waste, and land application of industrial or domestic sludge) can result in heavy metal contamination of urban and agricultural soils. Heavy metals released into the soil natural sources are rarely at toxic levels. Potentially contaminated soils may occur at old landfill sites (particularly those that accepted industrial wastes), old orchards that used insecticides containing arsenic as an active ingredient, fields that had past applications of waste water or municipal sludge, areas in or around mining waste piles and tailings, industrial areas where chemicals may have been dumped on the ground, or in areas downwind from industrial sites [4, 14].

The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants[6, 13]. Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal-human), drinking of contaminated ground water, reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems [7,8].

Excess heavy metal accumulation in soils is toxic to humans and other animals. Exposure to heavy metals is normally chronic (exposure over a longer period of time), due to food chain transfer. Acute (immediate) poisoning from heavy metals is rare through ingestion or dermal contact, but is possible [2,13].

These heavy metals may adversely affect soil ecology, agricultural production or product quality, and ground water quality, and will ultimately harm to health of living organism by food chain. These effects are closely related to the biological availability of heavy metals, which in turn are controlled by the metal ion speciation in the soil [15].Therefore, the determination of free metal ion concentrations in soil solution becomes important. The free metal ion concentration not only depends on the total metal content in soils, but also on the metal species that exist in the soil. In addition, some environmental conditions (e.g., pH, concentration of complexing ligands in solution, and the soil colloid) [3, 6, 8].

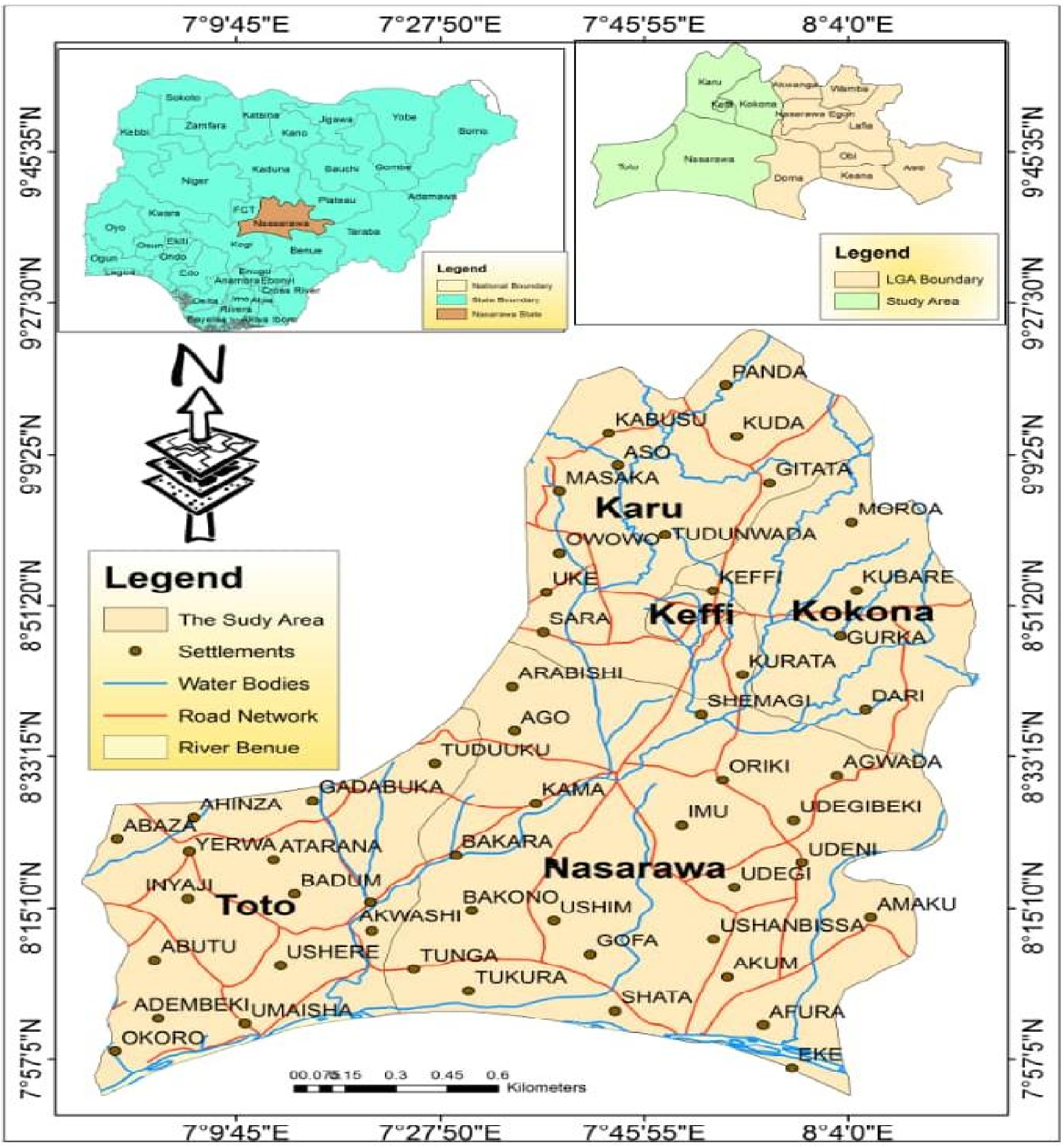
Recent reports affirmedthat heavy metal (Pb, Cd, Fe, Zn, Ni,) availability and distribution pattern in soil varies with industrial and mining activities being practiced [2, 4, 16]. In Nasarawa state, mining is one of the major occupation of the inhabitants of the area. These activity contributes to the high heavy metal concentration in soil and farm produce cultivated in the soil.This study was necessary to ascertain the levels of these toxic metals in soils, especially being agricultural soil, where rice among other farm produce is cultivated.

MATERIALS AND METHOD

This research work centered on Nasarawa West which consist of five (05) Local Government Areas, Karu, Keffi, Kokona, Nasarawa and Toto. In Nasarawa West, soils are found along the flood plains which are always swampy in nature due to availability of water all the year round. The forest soils are rich in humus and late rite soils. They are found in most part of the state and very good for crop production. Nasarawa West has arable land for commercial farming, fishery development, wild life and forestry conservation. Agriculture therefore, is the mainstay of the economy because majority of the populace are involved in subsistence farming.

Soil samples were collected from swampy agricultural soil in five major town of Nasarawa west namely namely Karu (KR), Keffi (KF), Kokona (KK), Nasarawa (NS) and Toto (TT). One Swampy agricultural soil farm land was identified at random from each of the location and 10 soil samples was taken at about 5 – 10m distances between the sample points from each sample location. The sampling sites are shown in (Figure 1).

The soil surface was cleared with a hand trowel to a depth of approximately 10 – 15cm before the samples were collected using a plastic spoon at 10 – 15cm depth. After every collection, the hand trowel and spoon were washed with soap and rinsed with distilled water to avoid sample contamination [12]. The collected samples were air dried under ambient temperature, Pulverised, using agate pestle and mortar, and allowed to pass through 2.0 mm sieved to remove stones and pebbles, packaged properly in a plastic container and labeled with code numbers for easy identification.The < 2 mm fraction of the soil was used for all soil analyses.



Fgure 1: Map of the study area

Ten soil samples from each sampling location were randomly collectedfrom each of the sample location. A total of fifty (50) soil samples were collected within the period of one week. The collected samples were stored in polyethylene bag and labeled properly and taken to the Center for Energy Research and Development (CERD) at Obafemi Awolowo University Ile- Ife

Osun State, Nigeria. At CERD, elemental analysis was carried out for the fifty sample using X-ray fluorescent spectrometry analyzer. The spectrometer brand name is ECLIPSE Ш supplied by AMTEK INC. MA; USA with Model number: XR-100CR which is a high performance X-ray Detector with preamplifier and a cooler system which uses a thermoelectrically cooled Si-PIN photodiode as an X-ray detector. The detector is coupled to the pocket MCA 8000A Multichannel Analyzer. The resolution of the detector for the 5.9 keV peak of 55Fe is 220 eV FWHM with 12µs shaping time constant for the standard setting and 186 eV FWHM with 20µs time constant for the optional setting. The quantitative analysis of samples was carried out using the XRF-FP Quantitative Analysis Software package. It converts elemental peak intensities to elemental concentrations and or film thickness.

The samples to be irradiated are placed in the sample chamber. The sample chamber has connections to it, which are at angle 45₀ to it respectively, the source X-ray tube and the Si-PIN photodiode detector. The source X-ray tube is maintained at a voltage of 25kV and a current of 50µA and each of the samples is irradiated for 1000sec.00

Quality control measure was taken to ensure reliability of results. Samples were handled carefully to avoid contamination. Recovery test was carried out on the XRF machine by spiking analyzes.

RESULT AND DISCUSSION

Heavy metals distribution: Zinc, Arsenic, Cadmium, Lead, Iron, Nickel, and Copper in swampy agricultural soil of Nasarawa west was analyzed and presented in Table 1. Figures 2- 6 show the concentration of heavy element in all the ten samples collectedfrom sample collection points (PT1 to PT10) from each sample location (KR, KF, KK, NS and NS) and the WHO standard limits.The results indicatethatthe level of heavy metals in swampy agricultural soil of Nasarawa west are above the WHO and some othercountries allowable limits.

Table 1:Mean Concentration of Elements in Swampy Agricultural Soils of Nasarawa west.

Location	**Latitude**	**Longitude**	**Heavy Metals Concentrations (mg/kg)**						
			Zn	As	Cd	Pb	Fe	Ni	Cu
KR	8053158.906''N	7050146.444''E	339.10	37.00	331.00	336.60	46293.60	342.20	486.60
KF	8052116.506''N	7052122.801''E	367.60	23.63	260.90	323.89	48766.90	525.00	515.90
KK	8050122.62''N	7058180.33''E	502.80	16.88	524.50	328.33	58170.50	462.10	314.10
NS	8040126.084''N	7048135.844''E	243.60	16.75	387.30	167.80	20222.90	352.20	266.60
TT	803011.566''N	7031119.116''E	426.70	7.40	345.40	291.10	46495.90	555.10	453.10

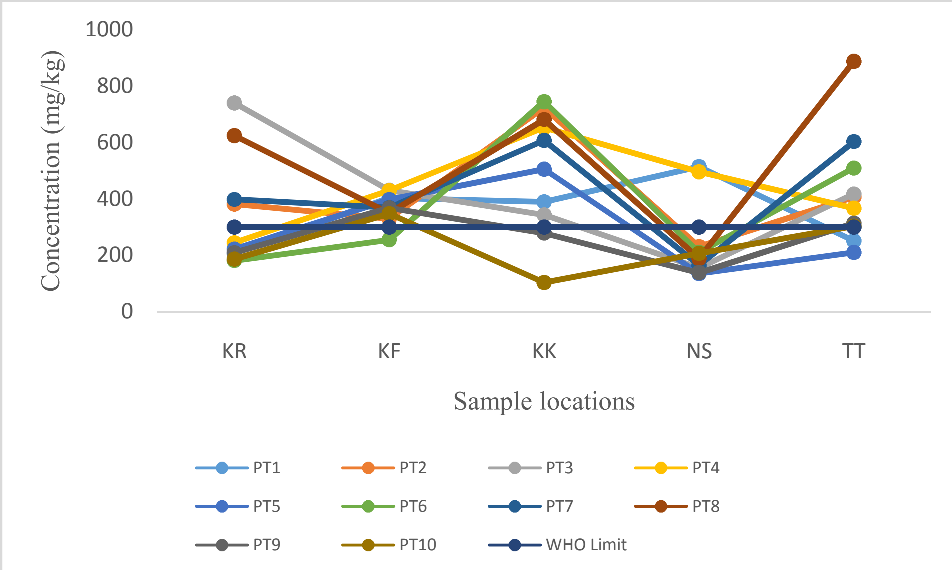


Figure 2. Concentration of Zinc in swampy agricultural soil of Nasarawa west.

Zinc was observed in the swampy soil samples with values ranging between 207- 740mg/kg, 255- 230mg/kg, 103- 745mg/kg, 135- 514mg/kg, and 210- 887mg/kg for Karu (KR), Keffi(KF), Kokona (KK), Nasarawa (NS) and Toto (TT) L.G.A respectively (Table 2). The values recorded for all the swampy soil sample from the study areas exceed the 60- 300 mg/kg range accepted by WHO[2, 4, 16]. It was found that the concentration of Zn exceed the permissible limitset by WHO and can cause health risk in humans and plants grown on the areas.High concentration values of zinc may be due to natural occurrence of zinc in soil with about 70 mg/kg in crustal rocks

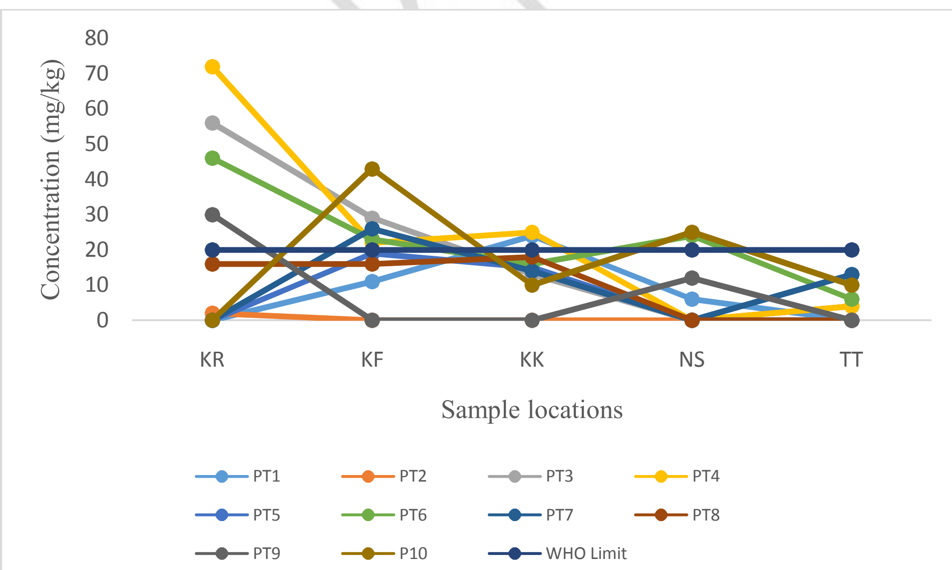


Figure 3. Concentration of Arsenic in swampy agricultural soil of Nasarawa west.

Arsenic detected in the soil sample from Karu (KR), Keffi (KF), Kokona (KK), Nasarawa (NS), and Toto (TT) L.G.A has concentration range of 2- 72mg/kg, 11- 43mg/kg, 10- 25mg/kg, 6- 25mg/kg and 4- 13mg/kg respectively. As is therefore within the permissible limit allowed by the WHO and may not cause harm to the inhabitant of that area[2, 4, 16].

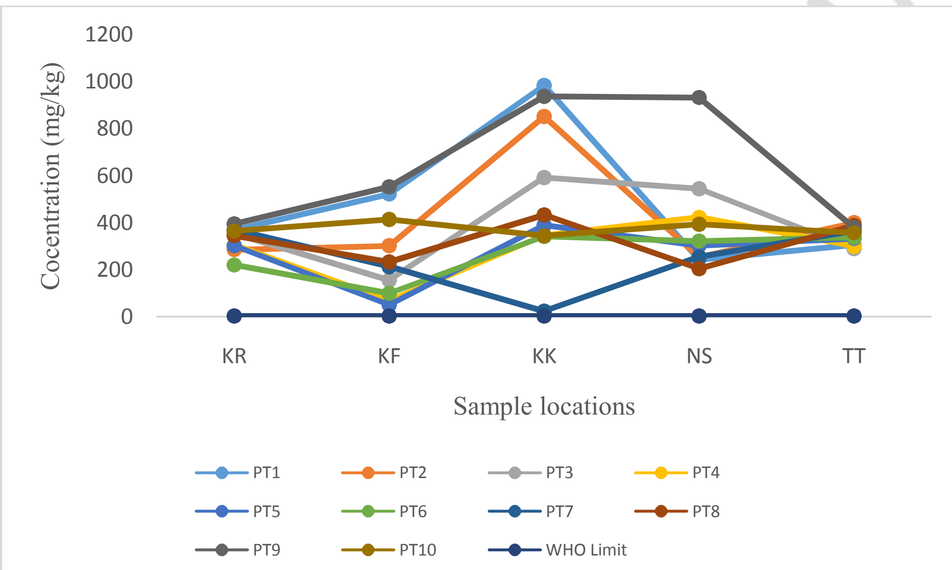


Figure 4. Concentration of Cadmium in swampy agricultural soil of Nasarawa west.

Cadmium was found in the sample with values ranging between 220- 395mg/kg, 68- 553mg/kg, 23- 985mg/kg, 204- 933mg/kg, and 289- 400mg/kg for Karu (KR), Keffi (KF), Kokona (KK), Nasarawa (NS), and Toto (TT) respectively. These values werefound to be far above the WHO limit of 3mg/kg[2, 4, 16]. The swampy soils in the area is highly contaminated with cadmium and can significantly affect the health of the humans, animals and plant.

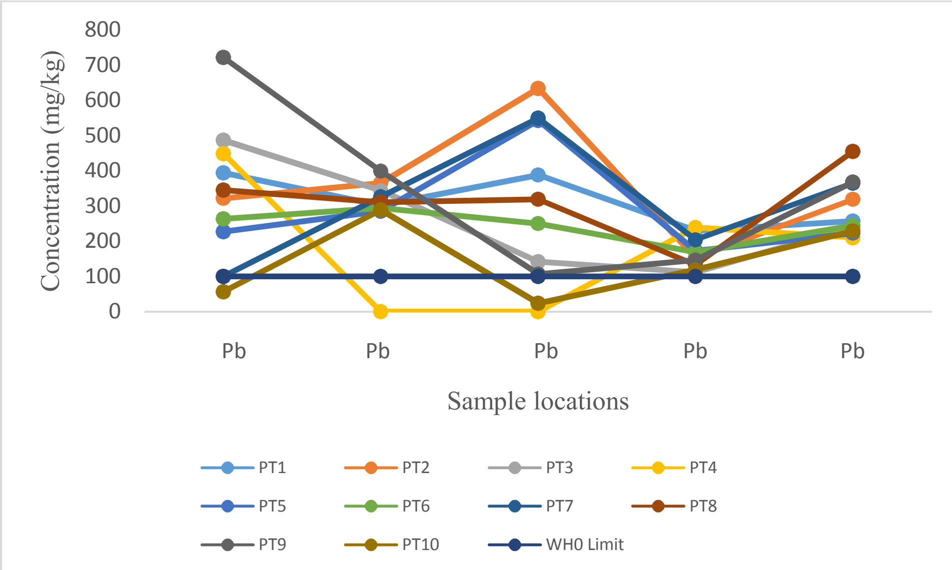


Figure 5. Concentration of Lead in swampy agricultural soil of Nasarawa west.

The determined concentration of Pb in the swampy soil samples showed a range of 57-487mg/kg, 385- 399mg/kg, 24- 634mg/kg, 112- 239mg/kg, and 210- 455mg/kg for Karu (KR), Keffi (KF), Kokona (KK), Nasarawa (NS), and Toto (TT) respectively. Pb wasfound to be higher than the WHO limit of 100mg/kg[2, 4, 16]. The samples are therefore contaminated with Pb which can cause adverse health effect in humans.

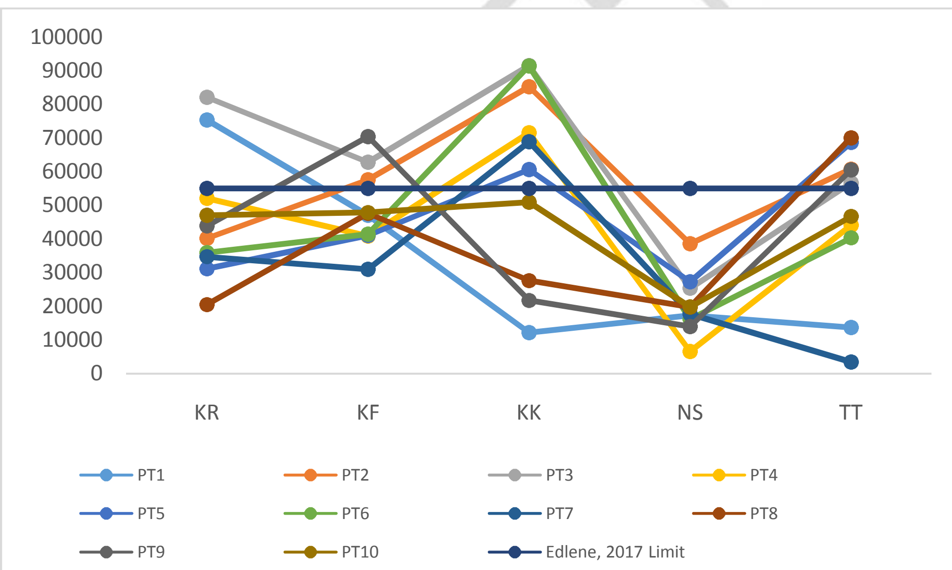


Figure 6. Concentration of Iron in swampy agricultural soil of Nasarawa west.

Iron (Fe) was observed to be the most abundant metal in the swampy soil of Nasarawa west with values between 31119- 82106mg/kg, 30991- 70441mg/kg, 12117- 91528mg/kg, 6577-38604mg/kg, and 3392- 70086mg/kg for Karu (KR), Keffi (KF), Kokona (KK), Nasarawa (NS), and Toto (TT) respectively. These values were found to be above the FEPA guideline of

400mg/kg[4, 16]. The swampy agricultural soil is contaminated with iron (Fe) which is pollution level is excessive.

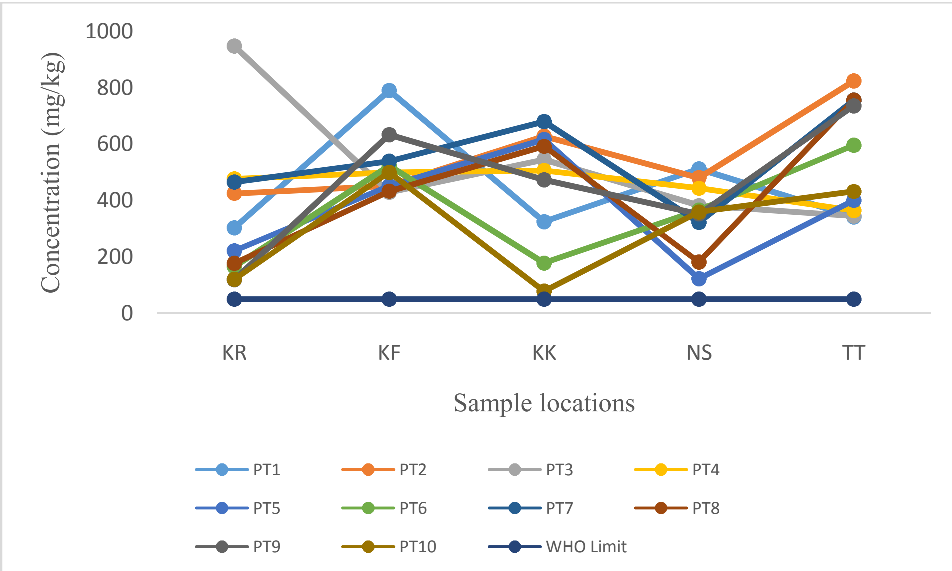


Figure 7. Concentration of Nickel in swampy agricultural soil of Nasarawa west.

Nickel detected in the soil sample from Karu (KR), Keffi (KF), Kokona (KK), Nasarawa (NS), and Toto (TT) L.G.A has concentration range of 119- 948mg/kg, 429- 790mg/kg, 78- 680mg/kg, 123- 512mg/kg and 342- 756mg/kg respectively. These values wereis 447.32mg/kg and was found to be above the WHO allowable limit of 5- 50mg/kg[2, 4,16]. Ni is therefore found to be above the permissible limit and may cause harm to the inhabitant of that area.

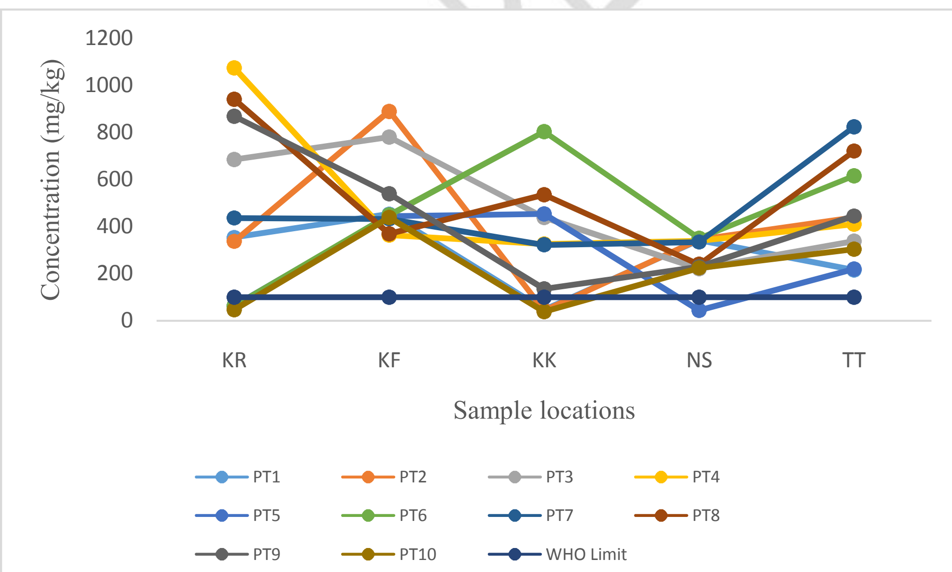


Figure 8. Concentration of Copper in swampy agricultural soil of Nasarawa west.

Copper was found in the sample with values ranging between 62- 1074mg/kg, 364- 890mg/kg, 38- 804mg/kg, 44- 350mg/kg, and 215- 824mg/kg for Karu (KR), Keffi (KF), Kokona (KK), Nasarawa (NS), and Toto (TT) respectively. These values were found to be far above the WHO limit of 100mg/kg[2, 4, 16]. The swampy soils in the area is contaminated with copper and can significantly affect the health of the humans, animals and plant in the area.

Table 2. Maximum allowable limit of heavy metals concentrations in soil for different countries [16].

Countries	Allowable limits for different Countries and WHO (mg/kg)						
	As	Pb	Cd	Zn	Fe	Ni	Cu
Germany	50.00	70.00	1.00	150.00	NA	50.00	40.00
UK	32.00	450.00	1.40	200.00	NA	130.00	63.00
Australia	20.00	300.00	3.00	200.00	NA	60.00	100.00
Canada	20.00	200.00	3.00	500.00	NA	100.00	150.00
China	30.00	80.00	0.50	250.00	NA	50.00	100.00
FAO/ WHO Guidelines	20.00	100.00	3.00	300.00	NA	50.00	100.00
EU Guidelines	NA	300.00	3.00	300.00	NA	75.00	140.00
U.S. EPA	75.00	420.00	85.00	7500.00	NA	75.00	4300.00
U.S. Standard	NA	300.00	400.00	3000.00	NA	NA	200.00
FEPA Guidelines	NA	1.60	NA	400.00	400.00	NA	80.00
Present Study	**20.33**	**289.54**	**369.82**	**375.96**	**43989.96**	**447.32**	**407.26**

Note: NA = Not Available

CONCLUSION

The heavy metal contamination levels of swampy agricultural soil of Nasarawa west were analyzed and determined. Results indicate that the swampy soils of Nasarawa west contained considerable high levels of heavy metals (Zn, As, Cd, Pb, Fe, Ni and Cu).The results indicate that the swampy agricultural soils of Nasarawa west (Karu, Keffi, Kokona, Nasarawa and Toto) are contaminated with toxic metals. It was observe that the crops grown on these swampy soils are mostly cereal plants: rice (Oryza sativa). Fertilizer application and use of waste as manures to yield more farm produce has been the practice in the areas. Food crops grown in these areas can take up these toxic heavy metals which can adversely affect the health of plants, animals and humans. In addition, it was discovered that the consumption of vegetables grown along the drain, may in some instances constitute possible health hazards to humans.

REFERENCE

1. Yoon J, Cao X, Zhou Q, Ma LQ. Accumulation of Pb, Cu and Zn in native plants growing on a contaminated Florida site. Sci Total Environ. 2007;368:456–464
2. Edith Bolanle Agbaji, Stephen Eyije Abechiand Solomon Arome Emmanuel. Assessment of Heavy Metals Level of Soil in Kakuri Industrial Area of Kaduna, Nigeria. Journal of Scientific Research & Reports 2015, 4(1): 68-78.
3. A. Ene, I.V. Popescu, C. Stihi. .Applications of proton-induced Xray emission technique inmaterials and environmental science, Ovidius Univ. Ann. Chem. 2009, 20 (1), 35
4. United State Department of Agriculture. Natural Resources Conservation Service. Soil Quality Institute 411S. Urban Technical Note No. 3, 2000.
5. Ediene, V.F., &Umoetok, S.B.A. Concentration of Heavy Metals in Soils at the Municipal Dumpsite in Calabar Metropolis. Asian Journal of Environment & Ecology.2017,3(2): 1-11, 2017.
6. Maslin P, Maier RM. Rhamnolipidenhanced mineralization of phenanthrene in organic-metal co-contaminated soils. Bioremediation Journal. 2000;4(4):295–308.
7. McLaughlin MJ, Zarcinas BA, Stevens DP, Cook N. Soil testing for heavy metals. Communications in Soil Science and Plant Analysis. 2000;31(11–14):1661–1700.
8. Ling W, Shen Q, Gao Y, Gu X, Yang Z. Use of bentonite to control therelease of copper from contaminated soils. Australian Journal of Soil Research. 2007;45(8):618–623
9. Abdulla, C. K., Jawaid, M., AbdulKhalil, H.P.S., Zaidon, A., & Hadiyane, A. Composite of palm and polymer Bio Resources. 2012;7(3):2948-2959.
10. Akoto O, Ephraim JH, Darko G. Heavy metal pollution in surface soils in the vicinity of abundant railway servicing workshop in Kumasi, Ghanaian. Journal of Environmental Research. 2008;2(4):359–364.
11. De la Rosa G, Peralta-Videa JR, GardeaTorresdey JL. Utilization of ICP/OES for the determination of trace metals binding to different humic fractions. Journal of Hazardous Materials. 2003;97:207-218.
12. Awofolu O.R. A survey of trace metals in vegetation, soil and lower animals along some selected major roads on metropolitan city of Lagos. Journal of Environmental Monitoring and Assessment. 2005;105:413-447.
13. Suleiman KABIRU, Rufai YAKUBU, Aminu LUKMAN, Toba AKINTOLA, Mathias ALEGBEMI and Fatimat MUSA. Heavy Metal Content of Soil in Garki Area Council of Abuja, Nigerian Journal of Chemical Society of Nigeria, 2018; 43(1): 165 – 173.
14. Mohammed, & Folorunsho, J. O. Heavy metals concentration in soil and Amaranthus retroflexus grown on irrigated farmlands in the Makera Area, Kaduna, Nigeria. Journal of Geography and Regional Planning.2015, 8(8): 210-217. DOI: 10.5897/JGRP2015.0498
15. J. J. Musa, H. I. Mustapha, J. D. Bala, Y. Y. Ibrahim, M. P. Akos, E. S. Daniel, F. M. Oguche, & I. A. Kuti. Heavy Metals in Agricultural Soils in Nigeria: A Review. Arid Zone Journal of Engineering, Technology and Environment, October, 2017, 13(5):593-603.
16. Caspah, K., Manny, M., Morgan, M. Health Risk Assessment of Heavy Metals in Soils from Witwatersrand Gold Mining Basin, South Africa. International Journal of Environmental Research and Public Health, 2016; 663(13): 123-131.