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Review Article

Assessment of the Effects of Some Heavy Metals on Biological Properties of Soil around Sharada Industrial Area of Kano, Nigeria

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Abstract

This research assessed the effects of heavy metals on biological properties of soils in Kano metropolis in view of the fact that the contamination of the soil by toxic heavy metals has become an issue of global concern; more so because information on the effect of heavy metals on biological properties of soils in Kano metropolis is limited and inadequate for promoting the very crucial environmental sustainability and harmony. Field investigation and laboratory analysis were the main sources of generating data for the study. The study area was divided into two locations: effluent-affected and control locations. Each of the locations was divided into 4 grid squares within which samples were collected. The properties investigated include: Microbial biomass carbon, phosphate and urease. The results of the analyses were subjected to statistical analyses using SPSS software and Microsoft excel to undertake t-test of means, ANOVA, correlation and regression at 95% confident limit. The results revealed that all heavy metals were found to be higher in the effluent-affected locations and that rainfall enhanced the dilution and leaching of the heavy metals in the soil, resulting in the low mean values of heavy metals in the wet season.Microbial biomass carbon, phosphatase and urease activities were found to be higher in all the effluent-affected locations as a result of the resistance of soil microbes to heavy metals toxicity coupled with high pH and temperature. Microbial biomass carbon negatively correlated with Cd (r = -0.54*), phosphatase was negatively correlated with Cd (r = -0.22) and Ni (r = -0.09), while urease was negatively correlated with Cd (r = -0.26*) and Ni (r = -0.008). The results in general indicate that the determination of the biological properties of the soils reflects the microbial activities in soils and so these properties are considered as soil quality indicators. The study recommends reduction of aerial contamination from industrial operation. Private treatment plant should be established for the treatment of the effluent. The treatment system charge for the cost of treatment and monitoring for compliance are to be by government.

Keywords: Biological; Microbial biomass carbon; Phosphotase; Pollution; and Urease

Introduction

Soil is the medium of life and foundation of human existence, the contact of lithosphere, atmosphere and biosphere - has been affected by numerous chemical and biological processes in the past and the present, ranging from hundred to millions of years (Kolay, 2002; Tan, 2009). Soil serves as a medium through which plant grows, the habitat of various forms and types of living organisms and almost all living organisms on the earth depend either directly or indirectly on the resources provided by the soil (Brady and Weil, 1999; Hall, 2008). Insurances of sustainable life, i.e., bound to the preservation of the natural courses of the processes and are ultimately secured by the “quality of soil” in physical, chemical, and biological terms. Soil also acts as a key component of natural ecosystems. Indeed, environmental sustainability largely depends on sustainable soil ecosystem and any alteration as result of either pollution or contamination ultimately alters the soil ecosystems and agricultural activities are also greatly affected (Hankard et al., 2004; Ayeni, Ndakidemi, Snyman and Odendaal, 2010).

Contamination and subsequent pollution of the environment by toxic heavy metals has become an issue of global concern due to their sources, widespread distribution and multiple effects on ecosystem (Ofoegbu et al., 2013). Pollution is one of the most serious problems around the world today in which thousands of millions of world inhabitants suffer health problems related to industrial and atmospheric pollutants (Frac and Stefania, 2011).

Pollution in relation to soil is concerned with the presence of heavy metals in the soils, the metals are considered heavy when their density is greater than 6 or 5 Mg/m^{-3}(Wild, 1996; Lal, 2006). In recent years, with the development of global economy, both type and content of heavy metals in the soil caused by human activities have gradually increased resulting in the deterioration of the environment (Sayyed and Sayadi, 2011; Raju, Somashekar and Prakash, 2013). The contamination of soils by heavy metals has significant problem which leads to negative influence on soil properties and limitation of productive and environmental functions. The accumulation of heavy metals in soil which results in the bioaccumulation in edible parts of vegetables represents a direct pathway for their incorporation into the human food chain (Shun-hong et al., 2011; Chiroma, Ebewele and Hymore, 2014).

The application of wastewater/ effluents to agricultural soils is a useful source of plant nutrients, particularly nitrogen and phosphorous and also organic matter that can potentially improve soil fertility and physical properties (Gibbs et al., 2006). Many organic pollutants, being biodegradable, are less persistent, and presumably have transient and less serious effects as they are eventually metabolized to carbon dioxide and inorganic substances. Among the inorganic chemicals, heavy metals are often present in appreciable quantities and chelated by the organic matter in the effluents.

When effluents are applied, the metals enter the soil and get fixed to the soil components. Thus continuous application of effluents tends to accumulate large quantities of heavy metals in soil, which persists there for an indefinite period of time to have long lasting effects in the soil environment (Kabata-Pendias and Pendias, 2002). The soil microbial community has a fundamental role in the process of organic matter degradation and mineralization, which allows the recycling of nutrients (Castaldi, Rutigliano and Virzo De Santos, 2004). Heavy metals affect the number, diversity and microbial activity of soil microorganisms because at low concentration of heavy metals could simulate microbial growth and increase microbial biomass, while high concentration could decrease soil microbial biomass significantly. In addition, the enzymes in the soil play an important role in the process of organic matter decomposition and nutrient cycling (Chao, Li Qin and Wen, 2014). Concern about heavy metals in soil derives not only from their toxicity to living organisms inhabiting soil but also for their immobilization within different organic and inorganic colloids. In the immobilized form they can persist for long time before being again available to living organisms including plants (Nannipieri et al., 2003).

Material and Methods

The materials used in this work include global positioning system (GPS) for recording the coordinate of sampling point, soil auger and spade for soil sampling, polythene bags for storing soil samples collected, marker for labeling the samples, pH meter for determine the soil pH, electrical conductivity meter to record the electrical conductivity and Atomic Absorption Spectrophotometer (AAS, 210 VGP American Model) was used for assessing the heavy metal concentration of the soil and it was selected because of its sensitivity, reliability, affordability, versatility, accuracy and precision (Khamms, Al-Ayash and Jasin, 2009).

Research Design

The research design in this work is the experimental design whereby two types of population are recognized: effluent affected locations and non-effluent affected locations

- ***Effluent affected locations***: Where farmers used waste water directly from contaminated stream to irrigate their land. Some farmers used untreated sewage sludge as manure (Tanko, 2004 and Mohammed, 2010). This location is considered as contaminated location.

- ***Non-effluent affected locations***: Locations adjacent to the contaminated location where farmers use less contaminated underground water from boreholes and hand dug wells for irrigation because their farms are somehow far away from the contaminated stream channels and considered as control locations.

Sources of Data

Primary as well as secondary source of data were used in this research. The primary data was collected from the field work and laboratory analysis of some heavy metals and biological properties.

Data Collection Techniques

A base map was used in which 4 grids were superimposed on each study locations of 1 km2. From each square samples were collected using composite methods. In general, data was collected through appropriate procedures.

Laboratory Analyses

Determination of Phosphorus: One gramme (1g) of air-dried soil was placed into 15m centrifuge tube and 7ml of NH_4F and25m of 0.5N HCl were added to 460ml distilled water and shaken with mechanical shaker for 1 minute, centrifuged at 200 rpm for 15 minutes and then filtered into volumetric flask. 5ml aliquot of soil extract was pipetted in to 25ml volumetric flask and 10ml of distilled water was added and allowed to cool for 15 minutes. The available phosphorus was determined in the extract on a spectrophotometer at 882nm by reading the absorbance.

Urease activity: The urease activity was determined spectrometrically at wave lengh of 410nm, following the modified methods of Zantu and Bremner (1975) described by Alef and Nannipieri (1995) and Nannipieri et al. (2003). 5g of moist soils was placed in to 50 ml volumetric flask and 0.2ml of toluene and 9 ml tris buffer were added and mixed. 1 ml of urea solution was added and mixed again for 10-40 seconds. The flask was stopped and incubated for 2 hours at 37^{o}C. After the incubation, 35 ml of KCL-Ag_2SO_4 solution was added and swirled for 10-45 seconds and them cooled at room temperature. 50 ml of KCl-Ag_2SO_4 solution was added and mixed thoroughly. This procedure was repeated for the control sample but 1 ml of 0.2M urea solution was added after addition of 35 ml of KCL-Ag_2SO_4 solution.

The ammonia released was estimated by 5 ml of boric acid indicators was pippetted in to Erlenmeyer flask and also 20 ml of resultant soil suspension was placed in to 100 ml distilled flask and then 0.2g MgO and distilled thereafter 30 ml was collected in to Erlenmeyer flask and was titred with 0.005M H_2SO_4 and 1ml of H_2SO_4.

Microbial Biomass Carbon: The microbial biomass carbon was determined by fumigation-extraction methods as described by Vance et al. (1987)in the modification described by Nannipieri et al. (2003). 15g of fresh soil sample was placed in to two 50ml beakers and the beakers were placed in to two paired dessicators (control and Fumugated). In the fumigated dessicator, 100ml beaker containing 25ml chloroform (alkohol free) was placed in the centre of the dessicator, boiling chips were added to the chloroform which assisted in rapid volatilization of the chloroform. The second dessicator contain non-fumugated (control) samples in which the dessicator was closed and the sealant were uniformely distributed.

Vacuum was applied to the fumugated treatment up till chloroform boiled. The dessicators were closed and stored in dark condition for 72 hours at room temperature. The vacuum pump was used repeatedly in evacuating fumugated treatment. The dessicators were opened and the soil samples were transfered in to the shaking bottle. 50ml of 0.5M $K_2\ SO_4$ were added and shaked on a wrist action shaker for 25 minutes and the suspension were filtered with Whatman paper No. 42 filter paper. The samples were digested and the microbial biomass carbon was analysed with calorimeter.

Statistical Analyses

The data obtained from the laboratory analyses were presented in tables. Statistical analyses was performed by Statistical Package for Social Science (SPSS) and MS Excel where descriptive statistics such as mean which is used to find the mean value of heavy metals, biological properties. Similarly, inferential statistic such as standard deviation and coefficient of variability were used to find the degree of variability of heavy metals and biological properties among the study locations.

The variability of the mean value of heavy metals and biological properties among the study location and the control locations were evaluated using analyses of variance and also between contaminated and control location using student t-test at 0.05 confidential level. The relationship between heavy metals, chemical and biological properties were assessed using pearson's correlation and also regression was used in clarifying the response of biological properties under different values of heavy metals at 0.05 level of confidence limit as describe by Buba (2008) and Falola (2008).

Results and Discussion

Concentration of Some Heavy Metals in Sharada Industrial Area

The mean values and standard deviation of heavy metals namely Cd, Fe and Ni are evaluated and presented on Table 1 which shows that there is spatial variation in the concentration of each individual heavy metals among the study locations. This shows that some heavy metals such as Fe, Cd, and Ni are found to be higher in concentration in the study locations. The spatial variation in the individual heavy metals in the study area is probably attributed to the fact that their concentration in soil varies from one metal to another because some are relatively abundant in nature such as Fe and Ni, while some are rare and can be toxic even at low concentration such as Cd, also depend on the concentration of heavy metal in the waste discharge in to the study locations (Lal, 2006). This is contended by Abdu, Abdulkadir, Agbenin and Andreas (2010a) and Yusuf (2002) who reported that some heavy metals like Cd, Fe and Ni dominated in bio sewage sludge.

	Statistics	***Cd***	***Fe***	***Ni***
	Mean	3.402	36.11	66.62
	±SD	1.38	6.71	15.68
Contaminated	CV%	40.56	18.58	23.53
	Mean	12.56	29.35	30.69
	±SD	3.4	14.01	6.9
Control	CV%	27.07	47.73	22.48

Table 1: Distribution of Some Heavy Metals in Sharada Industrial Area Heavy metals (Mg/kg).

The mean values of all selected heavy metals in Sharada contaminated locations were found to be higher than the same heavy metals in their respective control locations as shown on Table 1. Which is probably attributed to the industrial and domestic waste released in to Sharada contaminated locations contributed in contaminating or increases heavy metals load in to the soil of the locations. This is contended by Lal (2006), Liu et al. (2007) and Wuand and Okieimen (2011) who reported in their findings that major causes of the presence or increases load of heavy metals in the soil could be attributed to some factors such as discharge of industrial and domestic waste, sewage sludge and effluent. The results obtained in this work is in line with the results obtained by Binns, Maconachie and Tanko (2003), Mohammed (2010) and Chukulobe and Saeed (2014) who reported higher mean values of heavy metals in contaminated locations than their respective control locations and attributted it to industrial and domestic waste released in to contaminated locations. The results indicates that mean values of Fe, Cd and Ni were found to be higher than the mean values obtained by Idodo-Umeh and Egbeibu (2010),Bichi and Bello (2013) and Dawaki, Dikko, Noma and Aliyu (2013).

Biological Properties of Soil in Sharada Industrial Area

The biological properties considered in this research are microbial biomass carbon, phosphatase and urease). The soil samples collected during wet seasons from four locations were analyzed and the results presented on Table 2.

Enzymatic activities				
Statistics	***Microbial biomass carbon (mg C/kg)***	***Phosphatase (mg PNP/kg)***	***Urease (Mg u-N/kg)***	***Temperature (°C)***
Contaminated Location				
Mean	2.66	0.035	0.024	26
Range	2.58-2.74-2	0.029-0.037	0.023-0.025	25-28.0
Control Location				
Mean	3	0.033	0.0155	25.8
Range	2.72-3.68	0.029-0.035	0.013-0.017	25-27.0
Source: Field work (2016)				

Table 2: Biological Properties of Soil and Temperature in Sharada Industrial Area.

Soil Microbial Biomass Carbon: The distribution of microbial biomass carbon in the study locations as shown on table 2, shows that contaminated locations have the highest mean values of microbial biomass carbon of 0.19gC/kg for Sharada contaminated area, while its control measured 0.15gC/kg. The high mean values of microbial biomass carbon were found in contaminated locations was due to high temperature as shown on Table 2. This indicates that microbial biomass carbon influenced markedly by soil temperature changes. This is explained by Brady and Weil (1999) that soil microbial activities virtually ceases below 5˚C and increase more than double for every 10˚C rise in temperature up to an optimum of about 35˚C to 40˚C.

Phosphotase Activities

Alkaline phosphotase activities in the soil of the study locations show that there is spatial variation in the distribution of phosphotase activities among the study locations. The mean values of phosphatase were found to be higher in contaminated locations with mean values of 0.13 mg PNP/kg for contaminated location, while its control locations recorded lowest mean values of the phosphatase activities 0.10mgPNP/kg. The high activities of alkaline phosphatase in contaminated locations which is probably due to the high temperature in the locations which greatly influence microbial processes in the soil and also due to high phosphorus content of the soil of the study locations.

Urease Activities

The urease activities in the soil is responsible for the hydrolyses of urea fertilizer applied to the soil in ammonia (NH_3) and carbondioxide (CO_2) with the constant rise in soil pH. This in turn, result in rapid nitrogen loss to the atmosphere through ammonia (NH_3) volatilization. The values of urease ranges from 0.018 to 0.026 Mg u-N/kg, 0.01 to 0.026 Mg u-N/kg, for contaminated and control locations respectively as shown in Table 2. The contaminated locations have highest mean values of urease activities 0.021 Mg u-N/kg contaminated locations than their respective control locations 0.015 Mg u-N/kg

Pollution Level of Heavy Metals in Soil of Sharada Industrial Area

The mean values of heavy metals in the study area were compared with the European Union Regulatory Values as shown on Table 3 which indicates that Cd, Fe and Ni in the study location were found to be higher than European Union Regulatory Values. This indicates that the soils of the study locations could be at risk of being polluted by Cd, Fe and Ni if there is continues accumulation of heavy metals in the soil especially Cd and Fe whose found to be higher than EU values, this may pose a great ecological risk and health problem due to the bioaccumulation of crops grown in the area which may subsequently be consumed by human being and animals.

Study locations	***Cd***	***Fe***	***Ni***
Sharada contaminated	7.5	111.1	76.04
Sharada control	6.66	33.14	57.68
EU values (mg/kg)	3	81	75
Source: CEC, (2001) and Field work (2016)			

Table 3: Comparison of Some Heavy Metals (mg/kg) of the Area with European Union Standard.

Conclusion

From the findings, it was concluded that there is gradual accumulation of some heavy metals in the study location (Sharada Industrial area), however Cd, Fe and Ni are found to be above European Regulatory Values therefore, the soil is polluted with heavy metals. There is also variation of heavy metals due to rainfall effect which facilitated the dilution of heavy metals, oxidation reaction, leaching and runoff which are capable of removing heavy metals from subsurface. Higher microbial biomass carbon and enzymatic activities (phosphotase and urease) in contaminated area is due to high temperature in the area.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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