Assessment of Some Soil Health Indicators and Their Distribution Along Salanta River, Kano- Nigeria

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Abstract

Soil health is essential for the integrity of terrestrial ecosystems to remain intact and recover from disturbances. The paper aimed at assessing the spatial distribution and the relationship of some soil health indicators. Two square kilometer of irrigated land was delineated within which ten soil samples were collected using point composite sampling from 0 – 15cm depth. The soil samples collected were analyzed for pH, soil enzymes, chromium and lead. The data were analyzed using descriptive and inferential statistics using Micro soft excel. The results show that all the soil health indicators: SOC, pH, enzymes, Cr and Pb were found to be higher in all the point near the river. The high values of SOC and soil enzymes nearby the river bank is attributed to pH (7.7) values, which reduce the effect of Cr and Pb on soil enzmes activities. The relationship among the soil health indicators revealed that pH is negatively (r = -0.36) correlated with dehydrogenase and significantly correlated with urease (r = 0.57) and phosphatase (r = 0.43) at α *value of 0.05 probability level. The determination of pH, OC and enzymes activities reflect the microbial activities in the soil of the area and thes variables are sensitive biological indicators of heavy metals contamination in soil and could be considered as soil health indicators. Minimum tillage and application of organic fertilizer improves the structural stability of the soil, thereby reducing the solubility and availability of heavy metals in soil and also improve soil quality.*

Keywords: soil enzymes, heavy metals, soil quality, lead, soil microbes, Chromium

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Introduction

Soil health is established through the interactions of soil's physical (soil texture, bulk density, and porosity), chemical (pH, Cu, Cr, Cd and Pb) and biological properties (dehydrogenase, phosphatase, urease, microbial biomass carbon and microbial respiration). Therefore, soil health is considered as the capacity of a soil to function, within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality, and promote plant, animal, and human health (Doran and Parkin 1994). This reflects the ability of the soil to mineralize nutrients and moderate pH that allows the nutrients to be held in the soil and available to plants as needed. Soil health can be interpreted based on the inherited qualities and on the geographical circumstance of the soil. The generic aspects of soil health will be considered as broad productive option, absorbency, recycline, storing, water runoff quality, retention and release of pollutants, high soil carbon storage and little leakage of nutrient from the soil.

Soil enzymes are indispensable catalyst for decomposition of soil organic materials, nutrient recycling and strappingly influence energy transformation and environmental quality. Additionally, soil enzymes provide early recognition of changes in soil health because they respond to change in soil management and environmental factors (Rozylo and Bohacz, 2019; Rao et al., 2017).

Soil enzyme activities are progressively renowned as crucial indicators for soil ecological functions (Huang et al., 2017). In addition, soil contaminants affected the structure and diversity of soil microbial communities and inhibited soil enzyme activities, therefore, damaging microbial metabolic abilities, decreasing soil ecological functions and weakening soil resistance to other disturbances (Duan et al., 2018). Soil microbes synthesize various enzymes which act as biological catalysts to facilitate different reactions and metabolic processes to decompose organic pollutants and release essential elements for both microorganisms and plants (Moreno et al., 2003).

Heavy metal contamination results to serious transformation in the diversity and population of soil microbes which inhabit their activities in soil such as enzymataic and nitrogen fixation (Xie-feng et al., 2019). Increased industrial and socio-economic development results in the released of large amount of effluent which is used by farmers to irrigate their land and consequently contaminated the soil (Xiaowen et al., 2019). The application of wastewater/ effluents to agricultural soils is a useful source of soil nutrients, particularly nitrogen and phosphorous and also organic matter that can potentially improve soil fertility and physical properties (Mohammed, 2018). Thus, continuous application of effluents without proper management 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 due to the toxic heavy metals contained in the effluent which were detected (Bin et al., 2019; Hedi et al., 2019). The environmental contamination with toxic heavy metals is a serious problem world wide. This is because these containants reduce the soil quality by affecting soil microbial activities, soil enzmes inclusive (Oludare et al., 2019). Sources of soil enzymes include living and dead soil microbes, plant roots and residues, and soil animals. Enzymes stabilized in the soil matrix accumulate or form complexes with clay and organic matter complexes, but are no longer associated with viable cells (Aman et al., 2019).

Enzymes are sensitive indicators of heavy metal contamination (Oliveira and Pampulha, 2006) However, the rate of reduction in enzyme activities varies from metal to metal, enzyme to enzyme and degree of metal contamination (Smejkalova et al., 2003). Stuczynski et al. (2003) observed strong inhibiting effects of Pb on urease (r = - 0.73) and of Zn on dehydrogenase (r = -0.68), arylsulfatase, acid and alkaline phosphatase activities (r = - 0.59) in soil. Yang et al. (2006)

observed sensitivity of dehydrogenase activity in the following order: Hg > Pb > Cr > Cd > Cu, whereas order for urease was Hg > Cd > Cr > Cu > Pb. Shuqing et al. (2006) also found a greater influence of Cd than that of Pb on the alkaline phosphatase, urease and catalase activities in contaminated soils. They further reported a significant decrease in invertase activity with Pb (1000 mg kg-1) and significant declines in phosphatase, urease and catalase activities with Cd (100 mg kg-1) in soils.

Amalo et al., (2019) study the spatial distribution and contamination assessment of heavy metals in Woji Creek. However, the relationship between the heavy metals and some soil health indicators were not considered and also the study was carried out in forest ecological zone of Nigeria, which varied from the Sudan savanna ecological zone of Nigeria where this research was conducted. Based on these problems, the study was aimed at assessing the distribution of soil enzymes and some soil quality parameters, which was achieved by exploring the spatial distribution and the relationship between enzymes and some chemical properties of soil.

Materials and Methods

Study Area

The study conducted along the River Salanta which passed through Sharada industrial area and is located within Kano Municipal Local Government Area, lies between latitude 12^{o} 10ˈ N to 12^{o} 12ˈ N and longitude 8^{o} 33ˈ E to 8^{o}35ˈE (Fig. 1) and covers the radius of 6 – 8 km^2 from the city (Mohammed, 2010). The climate of the area is tropical wet and dry type, coded as AW by Koppen, although climatic change is believed to have occurred in the past (Ayoade, 1983; Adamu, 2014). The rainfall in the area normally started around June, reach it’s peak around August, ceased round October and mostly the rains come in heavy showers (Tanko, 2004), which favored the activities of soil microbes thereby enhance the carbon input, rapid mineralization rate, dilution and mixing of soil minerals (Brady and Weil, 2002), this facilitate the leaching and run-off of the dissolved minerals in the soil of the area.

Materials

The materials used in this work include global positioning system (GPS) used for recording the coordinates of sampled points, soil auger and spade for soil sampling, polythene bags for storing soil samples, marker for labeling the soil samples, pH meter for determine the soil pH and Atomic Absorption Spectrophotometer (AAS, 210 VGP American Model) was used for assessing the heavy metal concentration of the soils. It was selected because of its sensitivity, reliability, affordability, versatility, accuracy and precision (Khamms et al., 2009).

Pre –field planning activities involved the use of a base map made from goggle earth imagery of the areas. The map formed the base information whereby the sampling location was delineated from 2 square Kilometer (Fig. 1). The transect line (2 km^2) was drawn along the river thereby five traverse lines were drawn perpendicular to the river and then sampling points are identified along the traverse line at 200 m interval (Fig. 1).

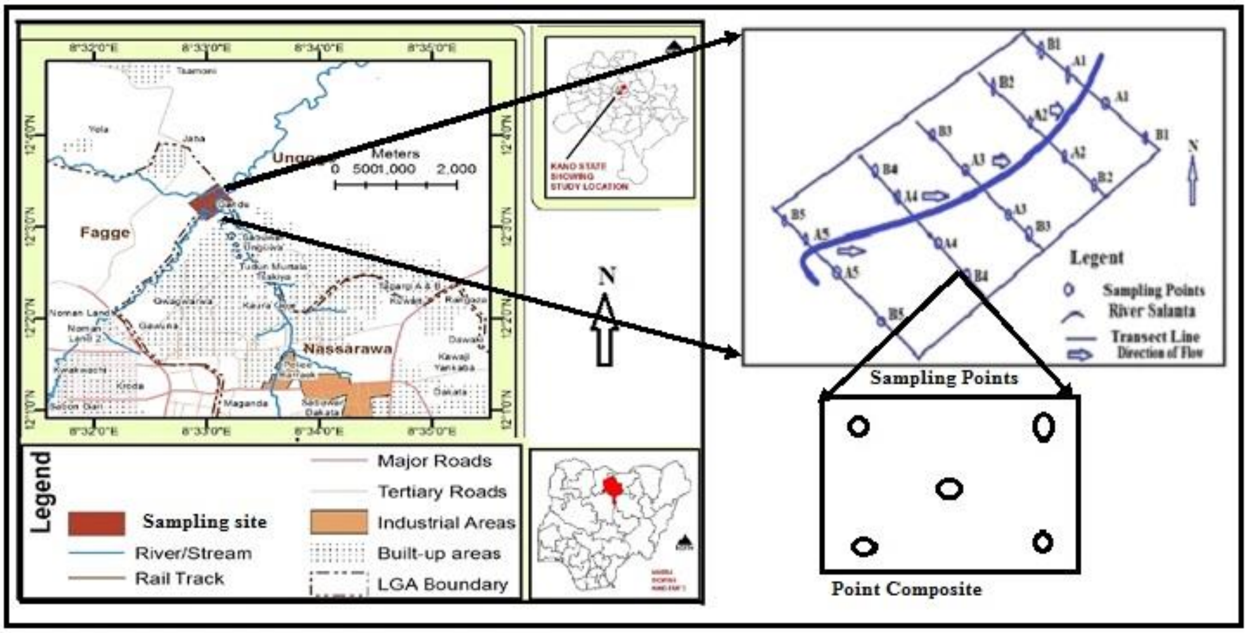

Fig. 1: Study Area Showing Sampling Points

The Sharada industrial was purposively selected because it is one of the major industrial areas in Kano metropolis and there is high industrial activities which lead to the releases of huge amount of effluents in to the River Salanta. The study site is an area where farmers used waste water/effluent for irrigation. In each sampling point identified, point composite sampling technique was adopted due to the homogeneity of the study location whereby the samples were collected using soil augar and spade from the surface to depth of 0 – 15cm. Ten samples were collected for the entire analysis. The soil samples collected were placed in to polythene bags, labeled appropriately, air dried and then taken to the laboratory for the analysis of soil reaction (pH), some soil enzymes (dehydrogenase, urease and phosphatase), Cr and, Pb.

Laboratory Procedues

The soil was digested through wet digestion method as described by Anderson (1974). Five millilitre (5 ml) of tri-acid mixtures (HNO_3, H_2SO_4 and HCL) were added and then heated to 240 ^oC and allowed to cool at room temperature and then filtered through Whatman No. 42 filter papers. Atomic Absorption Spectrophotometer (AAS, 210 VGP, American Model) was set up at a wavelength for Cr (358 nm) and Pb (220 nm). The digested and filtered samples were aspirated and the results were dispensed on the read out unit of atomic absorption spectrophotometer and the concentration of Cr and Pb was calculated from equation 1.

$$\text{The concentration of Cr and Pb} = \frac{\frac{X}{Y}\, X\, V.F\, X100}{1000\, X\, W.T} \qquad 1$$

Where: X is the Absurbance, Y is the Slope, V.F is equal to 100 and 10g is the Weight of soil sample (Sarkar and Haldar, 2005).

Soil Reaction (pH) was determined using glass electrode by immersing it into the suspension using pH meter with 25 ml of 1.0 (N) KCl. The organic carbon was determined as described by Walkley and Black (1934) using 10 ml of 1(N) $K_2Cr_2O_7$. Blank determination was carried out simultaneously using all the reagents similarly, but without any soil sample and then blank value was recorded. The organic carbon was calculated using equation 2 as described by Sarkar and Haldar (2005).

$$\text{Organic Carbon (\%)} = \left[\frac{10(B-T)}{B}\ x\ 0.003\ x\ \frac{100}{w}\right] \qquad 2.$$

Where: B is the Volume in ml of ferrous ammonium sulphate solution required for blank titration, T is the volume of ferrous ammonium sulphate (ml) needed for sample titration and W is the weight of soil sample in *g*.

Dehydrogenase activity: The dehydrogenase activity was analysed using tryphynyl tetrazolium chloride as a subtrate as described by Thalmann (1968) in the modification described by Alef and Nannipieri (1995); Nannipieri et al. (2003). The red color intensity was measured by using a spectrophotometer (CECIL model no. 2010) at a wavelength of 485nm and the result being expressed in microgram TPF kg^{-1} d^{-1}.

Alkaline phosphatase activity: Alkaline phosphatase was determined using p-nitrophynyl phosphate as described by Alef and Nannipieri (1995); Nannipieri et al. (2003). The yellow colour intensity was measured at 400 nm wavelength using a spectrophotometer CECIL model no 2010.

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); Nannipieri *et al.* (2003). The urease was calculated using equation 3.

Urease activity (Mg u-N/kg) $= \frac{C\ X\ 50}{DWT\ X\ 5}$ 3.

Where: C is the measured NH_4-N concentration, dwt is the dry weight of 1 g moist soil, 5 is the weight of used soil in the test and 50 is the total volume of the soil suspension.

The data obtained were analysed using statistical tools such as Statistical Parkage for Social Science (SPSS) and MS Excel where descriptive statistics such as mean which is used to find the mean value of soil enzymes, pH and some heavy metals. Inferential statistic such as standard deviation and coefficient of variability were used to find the variability among the parameters and also linear regression model was used to determine the relationship between the soil enzymes and Cr and Pb.

Results and Discussion

The distribution of selected soil enzyme, OC, pH, Cr and Pb were evaluated and presented in table 1, which shows that there is high mean value of phosphotase (0.114 mg PNP/kg) followed by urease (0.018 mg u-N/kg) and then dehydrogenase activitiy (0.006 TPF/kg).

Table 1. Mean distribution of enzymes and some soil health indicators

Soil Health Indicator	Mean	Standard Error	Standard Deviation
Dehydrogenase (TPF kg-1 d-1)	0.006	0.001	0.004
Urease (Mg U-N/kg)	0.018	0.001	0.005
Phosphotase (Mg/Kg)	0.114	0.008	0.035
OC (%)	2.45	0.214	0.957
pH (Kcl)	7.716	0.31	1.384
Cr (Mg/Kg)	32.469	3.405	15.225
Pb(Mg/Kg)	38.696	3.2	14.31

The organic carbon distribution (Fig. 2) shows that the organic carbon values are found to be higher near the river bank where there is high flow of of effluent.

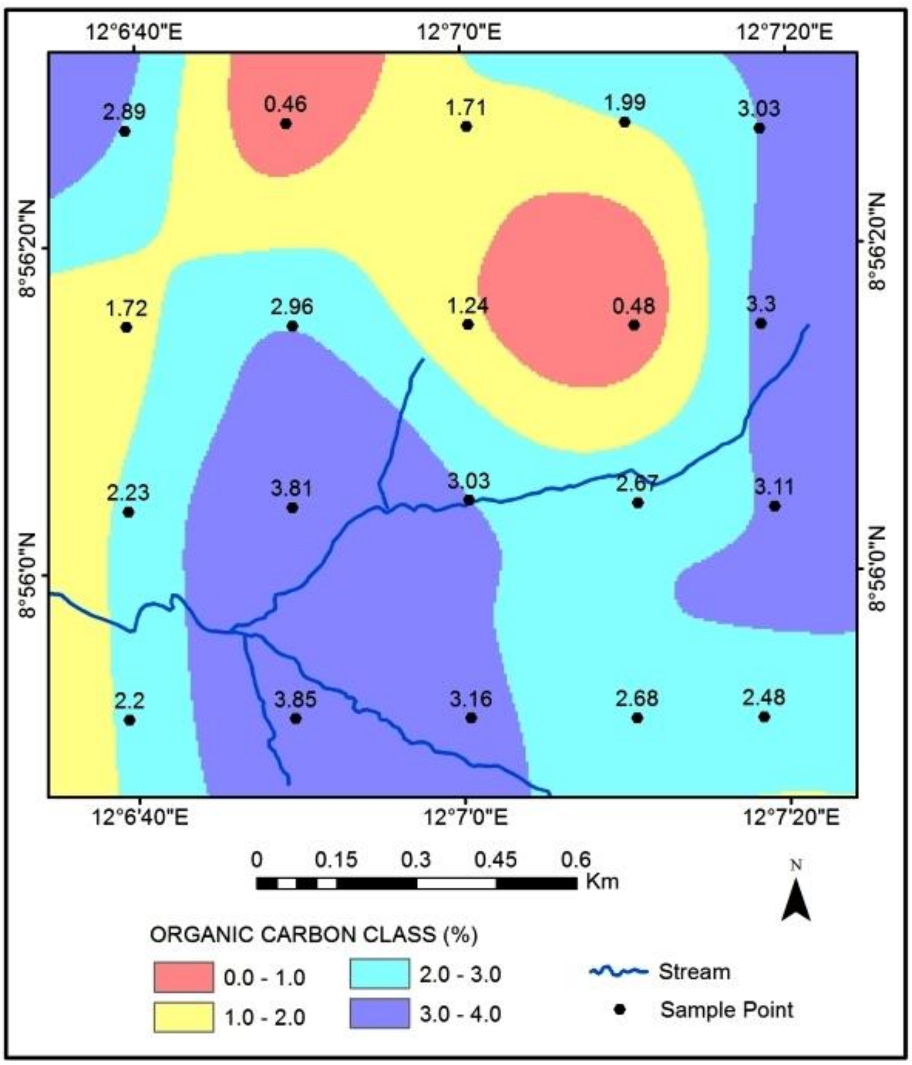

Fig.2 : Distribution of Organic carbon

The mean values of soil organic carbon (SOC) shows that, it ranges from 3.85 to 0.46% (Fig. 3) with mean value s of 2.45%. The mean values of SOC is considered as medium level based on the rating of London (1991). The values of SOC obtained is in consistance with the values obtained by Chukulobe and Saeed (2014), while it is higher than the values reported by Haliru *et al.* (2014).

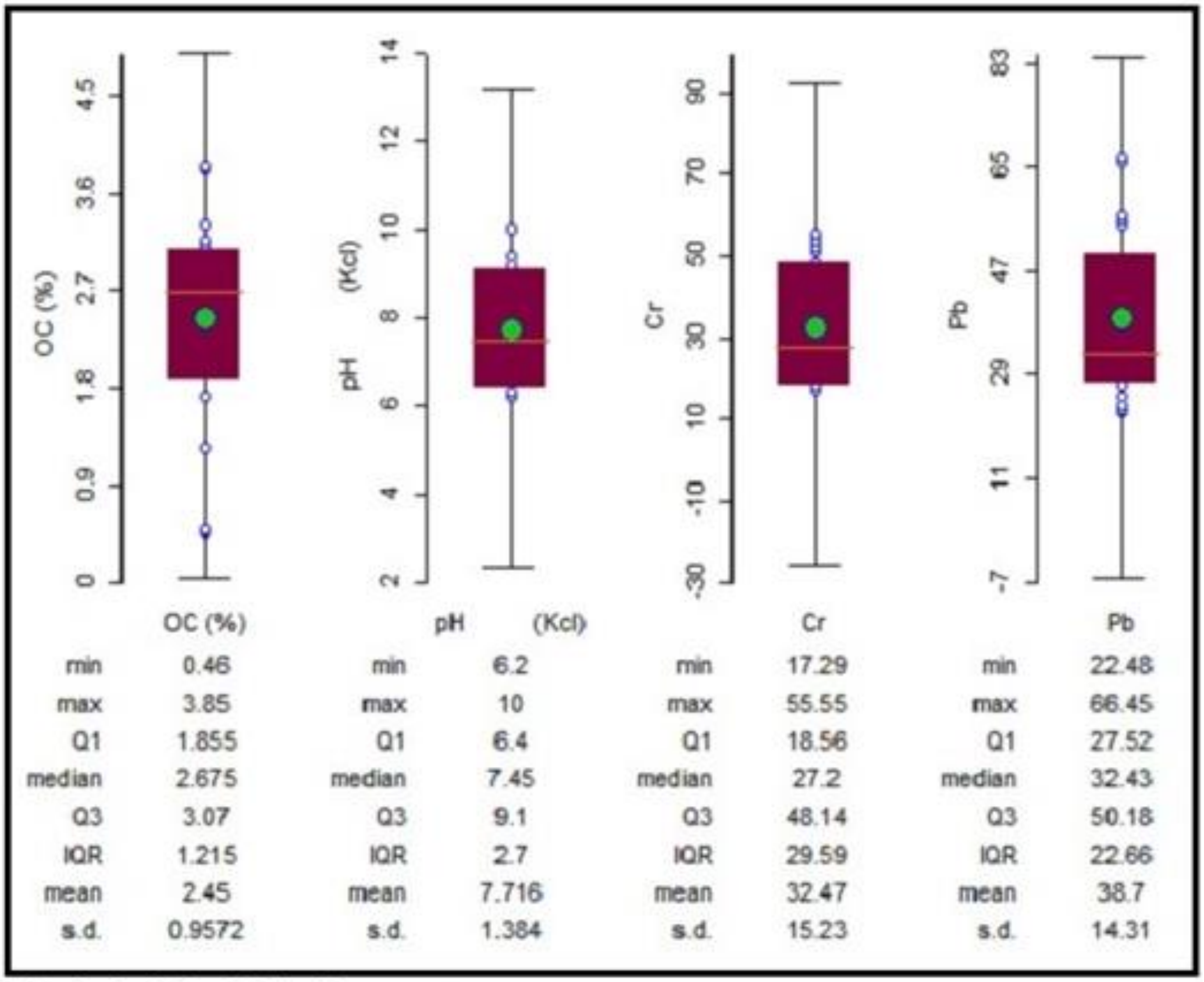

Fig. 3 :Soil Health Indicators

The level of SOC in the area is related with the microbial activity. This is because the organic materials decomposion depends on the availability of the materials, soil moisture and the population and, activity of soil microbes, so high SOC indicates high activities of soil microbes, soil enzymes inclusive. The SOC of the soil is the major source of some soil nutrients particularly N, S, and P, and therefore, considered as the major source of SOC.

The distribution of soil pH shows that the pH ranges from 10 to 6.2 with mean values of 7.71 which is considered as alkaline. This indicates that, the pH value obtained in this studies is within the level that favour the solubility, availability and toxicity of soil nutrient to plant and also favour the activity of soil microbes which increase the soil enzymes. This is adduced by Brady and Weil (2002), who explained that the pH values ranging from 7.39 to 8.60 favour the high rate of microbial activity in the soil. The distribution of soil pH (Fig. 4) shows that the pH

values is found to be higher close to the river and decreases away from the river. This implies that high amount of effluent close to the river significantly increase the pH value.

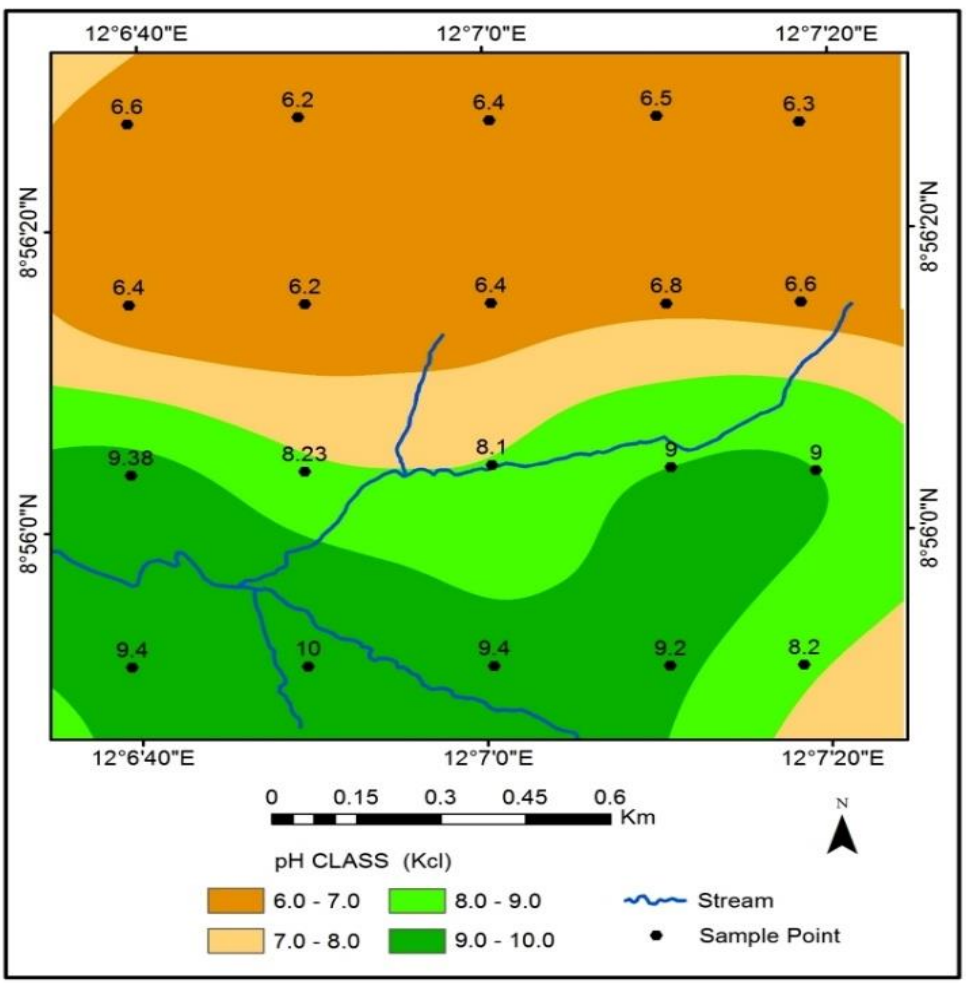

Fig. 4: pH distribution in the area

High level of soil pH (Fig. 5) in the area close to the river determine the ability of the soil to retained and immobilize some soil contaminants (Cr and Pb) and therefore, considered as simple indicator of soil health condition because it influences the chemical and biological reaction in the soil ecosystem. The findings also show that high pH value corresponds with the high SOC in the area. This is probably attributed to the fact that at this pH level, the decomposition of organic carbon is higher, which led to the production of high concentration of organic carbon in the soil of the area.

The findings also revealed that high pH values in the area is associated with low concentration of Cr and Pb, which is due to the fact that at high pH Cr and Pb are affected in term of their dissolution and toxcity because they are not in soluble form for plant and soil microbes to absorb. This is supported by Tan (2009) who reported that heavy metals are insoluble and unavailable to crops and soil microbes under high pH values. It was also discovered that there is matual dependancy between soil pH and enzymes. This is further supported by Fernandez-Calvino et al. (2010) who explained that low pH values supressed potential enzymes activity in the soil.

The distribution of Cr and Pb (Fig. 5) shows that Cr (32.46 mg/kg) is found to be lower than Pb (38.7 mg/kg) in the area (Fig. 4). This is probably attributed to the fact that their source in the soil varies and depends on the industrial products and composition of raw materials used. This implies that the value of Cr and Pb in the soil of the area may cause some ecological risk particularly for the consumers of the crops grown in the area if there is continouos accumulation in the area.

The spatial distribution of Cr and Pb (Fig. 5) shows that there is an increase in the concentration of Cr and Pb from the point close to the river than point far away from the river. This indicates that there is mobility of Cr and Pb through leaching from their source to the point far away from the river. The concentration of Cr and Pb obtained in the area may not necessarily be effective because the pH values (7.76) is within the level that may not allow the solubiility, availability and toxicity of the Cr and Pb to plant and soil microbes, so that their availability and mobility will be deminished. Therefore, the toxiciy effect of Cr and Pb such as displacement of essential metal from their normal binding site on biological molecules, inhibition of dehydrogenase, urease and phosphotase function and disruption of acid structure (Chen and Chen, 2001) may not be effective. Thus, the Cr and Pb inhibition to dehydrogenase, urease and phosphotase is likely to be low.

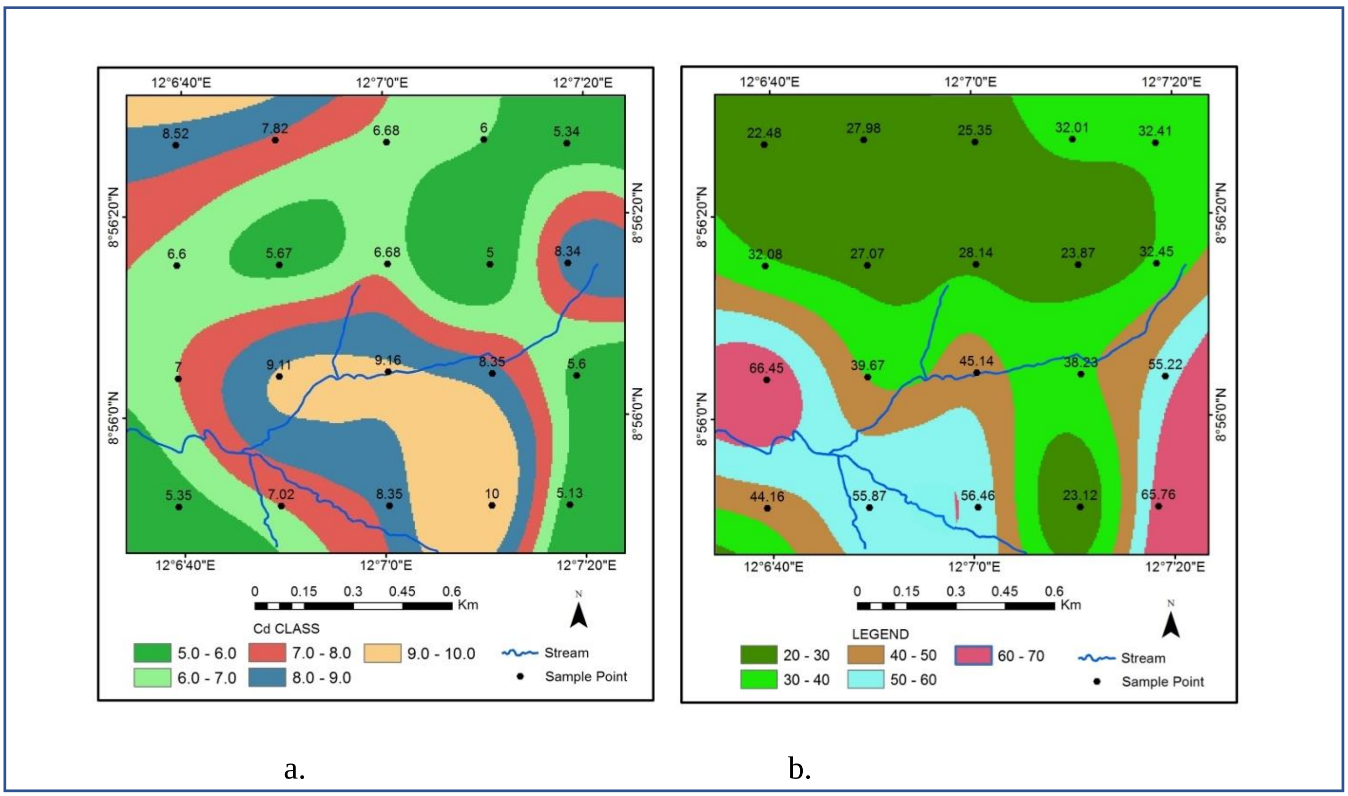

Fig. 5: Distribution of heavy metals, a. Cr & b. Pb

Regression analysis was used in clarifying the response of OC, pH, dehydrogenase, urease and phosphatase under different values of Cr and Pb at **α** values of 0.05 level of confidence limit (Fig. 6). The relationship between enzymes (dehydrogenase, urease and phosphatase) and soil pH show that there is negative correlation between dehydrogenase and soil pH (r = -0.36). This indicates that decrease in soil pH will decrease the dehydrogenase activity in the soil of the area. However, the urease and phosphatase enzymes were positively and significantly correlated with soil pH with correlation coefficient and p – values of 0.57; 0.004* and 0.43 0.05* for urease and phosphatase enzymes respectively (Fig. 6). This implies that an increase in soil pH will increase the enzyme activities of the soil since soil pH has significant positive impact of soil enzymes and therefore considered soil enzymes as strong biological indicator of soil health.

This is supported by Kolay (2002), who reported that soil pH strongly affects the soil enzymes level by modifying the ionic form of the active size of the enzyme, which consequently affects the shape of the enzymes and the affinity of the substract to enzyme. This is further supported by Moeskop et al (2010) whose explained that soil reaction (pH) is considered to be among the best predictor of soil enzymes.

The regression analysis (Fig. 6) shows that the coefficientof determination values between dehydrogenase, Cr and Pb is r^2 = 0.24 and r^2 = 0.12 for Cr and Pb respectively. This implies that cahnge in dehydrogenase activity in the area was explained by 24% and 12% for Cr and Pb respectively leaving the remaining percentage for other factors to be explained. The analysis also revealed that the coefficient of determination values between urease and Cr, and Pb was found to be r^2 = 0.22 and r^2 = 0.24 respectively, this implies that the variation of urease in the soil of the area will be explained by Cr and Pb with 22% and 24% respectively leaving the remaining percentage to be explained by other factors. However, the variation of phasphotase in the area will be explained by 16% and 0.8% for Cr and Pb respectively.

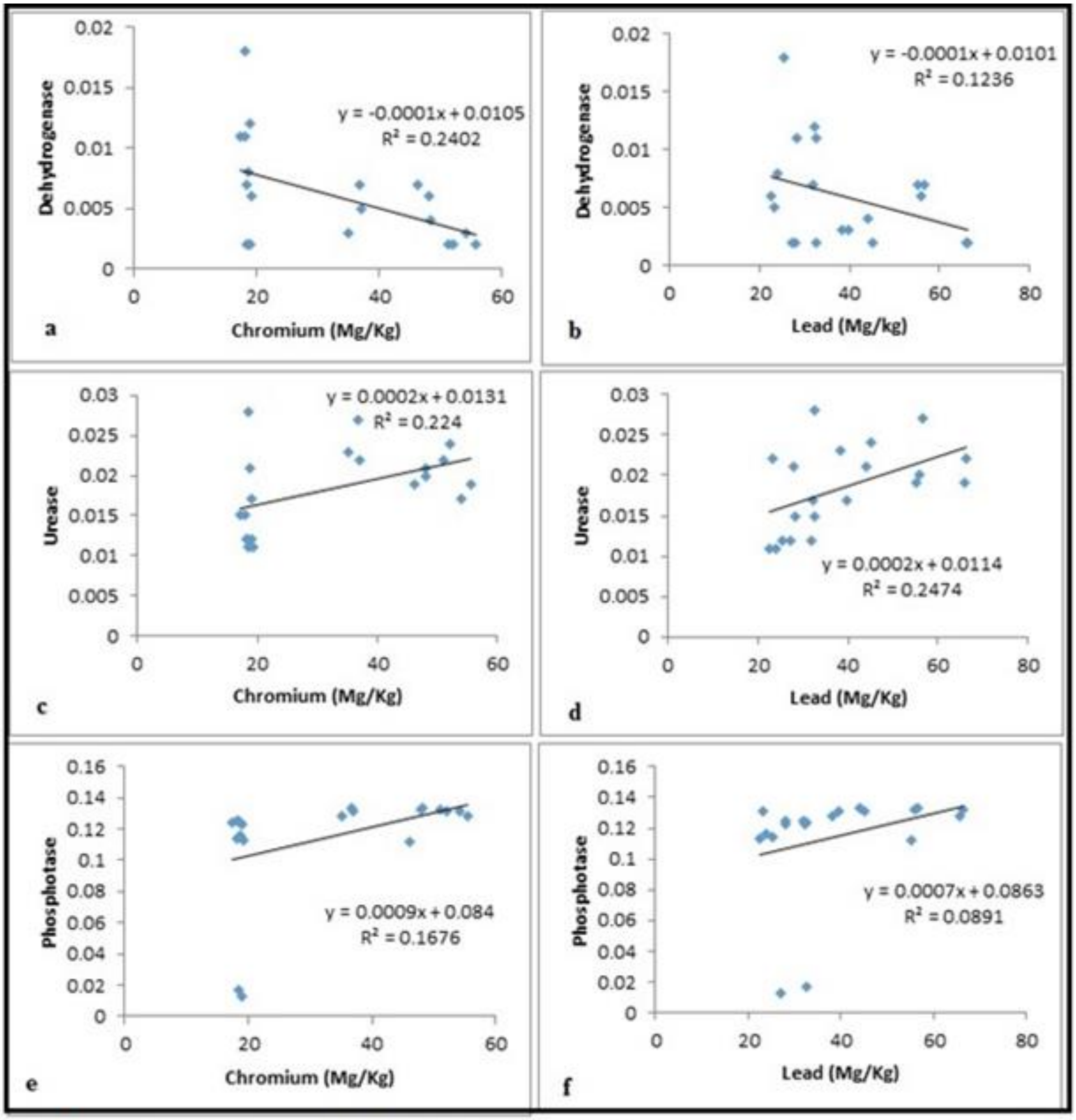

Fig. 6 :Relationship Between Soil Enzymes and Heavy metals: a and b (Dehyrogenase and Cr, and Pb), c and d (Urease and Cr, and Pb), e and f (Phosphotase and Cr, and Pb)

Conclusion

From the findings, it was concluded that low values of Cr and Pb are due to the pH values of the area. However, despite the resilience of soil microbes to heavy metals toxicity due to high pH, the Cr and Pb are strongly antagonistic to the activity of dehydrogeneas, urease and phosphatase activities. The determination of pH, OC, dehydrogenase, urease and phosphatase activities reflects the microbial activities in the soil and therefore, considered as sensitive biological indicators of Cr and Pb contamination in soil and could be considered as soil health indicators.

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