PROPERTIES OF SOILS AS AFFECTED BY PETRO-INDUSTRIAL WASTES IN ELEME AREA OF RIVERS STATE NIGERIA

Ihem, E.E
Department of Soil Science and Technology, Federal University of Technology, P.M.B 1526, Owerri, Imo State.
Correspondence: eeihem2000@yahoo.com

Abstract
Petroleum industries are associated with wastes which sometimes are deposited on soils leading to changes in the properties and quality. The study investigated properties of some sites in Eleme, Rivers State, Nigeria. Surface sampling (0-15 cm depth) was carried out at three locations in Eleme (Indorama, PHRC and Adjacent site of PHRC). Routine soil analysis was performed on some physico-chemical parameters and selected heavy metals. Soil samples collected were subjected to the analysis of variance using Gen stat statistical package and means were separated at (P>0.05). Results obtained showed that sols of the area have high percentage sand (>80%), while bulk density was below the critical level (<1.50 g/cm^3). Soils of the polluted sites showed lower pH (<4.94) than the unpolluted soil (05.48). Soil organic carbon (15.63 g kg^{-1}), TN (1.53 g kg^{-1}), TEA (1.52 Cmol/kg) were appreciably higher in soils affected by petroleum wastes than the control sites with OC (10.53 g kg^{-1}), TN (1.06 g kg^{-1}) and TEA (0.25Cmol/kg). However, unaffected sites had higher TEB (11.75 Cmol/kg), ECEC (12.00) and BS (97.84) than affected sites with TEB (7.02 Cmol/kg), ECEC (8.54) and BS (82.74). Cadmium (Cd), Lead (Pb) and Chromium (Cr) were significantly higher (p=0.5) in concentration on soils affected by petroleum wastes than the control. From the affected soil, Cd (0.17 mg/kg), Pb (0.40 mg/kg) and Cr (0.07 mg/kg) while the control were Cd (0.01 mg/kg), Pb (0.02 mg/kg) and Cr (0.02 mg/kg). Selected heavy metals concentration in both affected and unaffected soils were below the permissible limit by WHO.

Keywords: Industrial waste, edaphic properties, heavy metals, permissible limit, soil quality.

Introduction

Petroleum industries have eventually created economic boom and at the same time led to environmental and socio-economic problems in Nigeria (Ibekwe *et al.,* 2006). Wastes released by petrochemical industries are characterized by the presence of large quantities of polyclic and aromatic hydrocarbons (Suleimanov, 1995). These chemicals are harmful to seed germination and vegetation cover (Gulshan and Dastic, 2012). Ineffective purification systems on these industrial wastes may become injurious leading to the accumulation of toxic products into the soils and water bodies (Bay *et al.,* 2013). It could also cause acidification of the soils (Iwegbu *et al.,* 2006). Nwazue (2011) reported that petroleum pollution severely affect soil and water chemistry. Sometimes, farmers dam the flow of this wastes (industrial effluents) for irrigation purposes due to the presence of N.P.K and other essential elements present in them (Niroula, 2003). These waste materials when dumped can leach the toxic substances into soil down to the underground water causing water pollution at that point (Pathak *et al.,* 2011). Large quantity of wastes are often generated from human activities and dumped on soils which may have long effect on the soils (Obire and Nwanbet, 2002; Uchegbu, 2008). Petroleum wastes containing heavy metals may enter the food chain and consumed by man (Niemeijer and Mazzucato, 2002; Setyorini and Ipinmoroti, 2001).

Ukagwu *et al.,* (2014; Magwu *et al.*, 2001) reported that industrial wastes can increase concentration of heavy metals, toxic chemicals and suspended sediments. A wide range of pollutants are continuously introduced into the terrestrial and aquatic environment due to human activities and may cause indiscriminate dumping of refuse.

Udiba *et al.,* (2014, Okere *et al.,* 2014; Nazir *et al.,* 2015) reported that oil exploration and exploitation, agricultural and domestic wastes run-off into soils and water. These have made soils unproductive and drinking water unavailable (Patil *et al.,* 2012).

Soil polluted by the effluents from petrochemical industries tend to reduce soil fertility status (Dewis and Frietas, 1990). Excessive amounts of heavy metals such as Pb, Cr, and Hg produced via petroleum wastes can lead to chronic poisoning in soils and underground water, highly toxic also bio-accumulate in tissues of aquatic organisms (Shesterin, 2010; Temitope *et al.,* 2016).

Farming is one of the socio-economic activities of the Eleme Communities while crude-oil pollution is one of the major problems degrading their soils. Farmers may be unable to ascertain fertility status and quality of soils except when there is yield decline given the technical level of traditional farming inherent in the area. Yet, Eleme is densely populated, implying yield from these affected soils end in the food chain of inhabitants.

But, there is paucity of information of health of these soils, making scientific investigations of these soils needful. The major objective of this study was to evaluate the influence of petroleum wastes on soil properties in Eleme area of Rivers State.

Materials and Methods

Study Area

The study was conducted two different sites in Eleme, (Indorama Petrochemical Company aid Port-Harcourt Refinery Company). Eleme lies on latitude $4^0$45'N and longitude $7^0$5'E.

Soils of the area are formed from Deltaic/Coastal plain sand. It has a humid tropical climate with annual rainfall of over 3000 mm. Temperature ranges from 25 to 31^0C and a relative humidity of about 87%. Eleme lies within the typical tropical rainforest zone of Nigeria.

Field Studies

Five samples sampling (0-15cm) were collected from each of the locations as well as the adjacent site that represented the control, making a total of fifteen (15) samples. Undisturbed core samples were also collected in replicates from the epipedons for bulk density and soil moisture content determinations.

Laboratory Studies

Soil samples collected were air-dried, and sieved to remove materials greater than 2 mm fraction. Particle size distribution was determined by the hydrometer method using sodium hexametaphosphate (calgon) as the dispersant (Gee and Or, 2002).

Bulk density was determined by the undisturbed core method of soil-water suspension method using a standard pH meter (Thomas, 1996). Organic carbon was determined by Walkley and Black wet digestion method (Nelson and Sommers, 1982). Exchangeable bases were estimated by the neutral ammonium acetate procedure (Thomas, 1982). Calcium and Magnesium were determined using ethylene diaminetetracetic acid (EDTA), while sodium and potassium were determined using flame photometer Exchangeable acidity (H^+ and Al^{3+}). Total nitrogen was determined using microkjedahl digestion method (Bremner, 1996). Available phosphorus was estimated according to the method of Olson and Sommers (1990). Digestion of soil samples for cadmium concentration was carried out with mixture of concentrated HNO_3 and $HClO_4$ at a ratio of 2:1. Cadmium was extracted using 0.5 MHCL (Hesser, 1997). Cadmium concentration in the supernatant was determined using Atomic absorption spectrophotometer. Chromium and Lead were also determined using Atomic Absorption Spectrophotometer (AAS). Bulk Scientific Model 500A as described by Juo, (1982).

Data obtained were analyzed by Genstat Statistical Version. Analysis of Variance (ANOVA) was used in separating the means at 5% level of probability. Correlation and regression analysis were used to establish degree of relationship among some soil properties and heavy metals.

RESULTS AND DISCUSSION

Physical and Chemical Properties

The physical properties of the soils used for the experiment is presented on Table 1. The sand content was higher in unpolluted soils with a mean value of 875.6gkg-1 than the polluted sites with mean value range of 843.6 – 869.6gkg-1. The sandiness of soils could be attributed to the sandy nature of parent material, being derived from coastal plain sand. The percent materials have been noted to influence the texture of the native soils (Akamigbo and Asadu, 1983); Igwe *et al.*, (1999), Jenny (1980); Akamigbo, 2010).

Table 1: Selected Physical Properties of the studied locations

Location	Sand g/kg	Silt g/kg	Clay g/kg	TC	BD g/cm3	TP %	MC g/kg
Control	875.6	61.2	63.2		1.222	52.276	97.3
Indorama	843.6	39.2	117.2		1.302	49.142	125.2
PHRC	869.6	55.2	75.2		1.49	41.798	150.36
LSD(0.05)	**51.49(NS)**	**33.84(NS)**	**31.05**		**0.085**	**3.321**	**12.15**

NB: This table shows the mean result of the replications of each study sites
Where:
TC = Textural Class; BD = Bulk Density; TP = Total Porosity; MC = Moisture Content; LS = Loamy Sand; NS = No significant difference; * = Significant at P = 0.05

The lowest value of clay was found in the unpolluted soils with a mean value of 63.2 g kg^{-1} while the highest values were found in the polluted Soils with the mean value range of 75.2 – 117.2 g kg-1. The low clay content may be as a result of high rainfall status of the area which favoured high rate of leaching. It could also be as a result of pedogenic process of translocation in which clay materials were moved down the profile pits (Onweremadu *et al.*, 2007). Akamigbo (1999) also reported that climatic factors such as high precipitation and temperature in the southeastern Nigeria could cause low clay contents. Sorting of soil materials by biological and agricultural activities, clay content migration could cause low clay contents (Malgwi *et al.,* 2000; Adegbenro *et al.,* 2011).

Bulk density values were low in unpolluted soils (1.22 g cm^{-3}) than the polluted soils with values range of 1.30 – 1.49 g cm^{-3}. The low bulk density recorded in the control indicated that the soils are not compacted and have high porosity (Attah, 2010). This is beneficial to root activity, water infiltration into soils and overall performance of crops. Higher bulk density recorded in the polluted sites could be attributed to the weight of oil and its sealing effects which might clogged and compact soils pores. This indicated a poor environment for root growth and undesirable infiltration and drainage (Chude, *et al.,* 2011). Results of the chemical properties of the studied soils are shown in Table 2. Soils of both affected and unaffected were slightly acidic. The acidic conditions in the coastal plain sand could be attributed to the presence of high exchange acidity and high rainfall pattern of the study site which tend to render soils prone to erosion and high base leaching as reported earlier by Udo, *et al.,* (2009) and Adegbenro *et al.,* (2011).

Heavy metal in soils has the potential to influence soil pH and at low pH values, most of the heavy metals and trace elements become more available and biotoxic (Onweremadu, 2007; Ihem *et al.,* (2015); Udonne and Onwuma, (2013).

Generally, the organic carbon content and total nitrogen values of soils were high (>0.2) according to the ratings of Esu (1991). However, control recorded lower mean value of 10.53gkg^{-1} OC and 1.28 – 1.53gkg^{-1} TN respectively. These high values could be attributed to hydrocarbon deposits on the soils that are high in inorganic carbons (Ihem *et al.,* 2015). For the control high OC could be attributed to the soil origin, organic residues from plants and organic manure inputs from farmers (Edicha, 2010). The result showed that there was higher value of TEB in the control (11.75) than polluted soils (7.02 – 10.15). This could be attributed to the parent material and low rate of rainfall and leaching in the site. Lower values in polluted sites may be due to the influence of the hydrocarbons with high TEA.

High ECEC (12.00 Cmol kg^{-1}) for control and 8.54 – 10.34 Cmol kg^{-1} for polluted soils is in line with the findings of (Alloway, 1996) that ECEC increases as OC content of soil increases.

Table 3, shows the concentration of cadmium (Cd), Lead (Pb) and Chromium (Cr) in the studied site. The result showed that the concentration of these three heavy metals were higher in polluted soils than the unpolluted soils; for control Cd = 0.01mgkg-1, Pb = 0.02mgkg-1 and Cr = 0.02mgkg-1, while polluted soil values ranged as Cd = (0.17 – 0.20mg/kg^{-1}, Pb = 0.20 – 0.40$mgkg^{-1}$ and Cr = 0.07$mgkg^{-1}$). This results showed that these heavy metal values in the studied soils according to Denneman and Robberse, (1990) are below the critical limit. However, these values are above the permissible limits of plant (0.02) according to the ratings of WHO, (1996). In which case, it may cause toxicity to plants and detrimental to human health through food chain. (Rehman and Sohail, 2010) and Abbas *et al*., 2008

Figure 2, shows the relationship among the heavy metals studied. The result shows that increase in Cd will lead to an increase in Pb and Cr. Increase in Cr, also led to an increase of Cd content.

Meanwhile, Cd and Cr expressed the closest relationship (Figure 1). Table 4, shows correlation coefficients of the selected heavy metals with some soil properties in the polluted and control soils. This coefficient measures the strength of a linear relationship between any two variables on a scale of -1 (perfect inverse relation) through 0 (no relation) to +1 (perfect relation). Cadium, Chromium and Lead had a significant negative correlation with avail. P. Cd vs Avail. P($r = -0.72$, $P<0.05$) Cr Vs Avail. P($r = -0.95$; $P<0.05$) and Pb vs Avail. P($r = -0.80$; $P<0.05$). This shows that heavy metals in the studied soils had less influence on the availability of phosphorus. Wild, (1996) stated that increased concentration of heavy metals reduces availability of P.

These selected heavy metals therefore, had a good relationship with the available P in both the polluted and unpolluted soils. This process may lead to the accumulation of phosphorus in the soils of the area which in turn will boast crop production. The three heavy metals (Cd, Cr, and Pb) also had a positive significant relationship with TN ($r = 0.57$, 0.78 and 0.97 at $P<0.05$), respectively. It is known that the bioavailability of metals in soil depends on pH, organic matter, and total metal content competing cations in soil solution (Sauve *et al.,* 2000; Udom *et al.,* 2004), thus leading to plant uptake and leaching to ground water.

The result in Table 4, also suggested that, Cr and Pb, had a significant ($p=0.05$) negative relationships with moisture content, magnesium, pH and total exchangeable bases. This implies that a decrease in the concentration of these heavy metals will promote the availability of these soil properties.

Heavy metals tend to acidify soils thereby making basic cations unavailable. This association is probably due to the variable composition of the basement complex formation (Ahmad, 2008) and this may lead to low yield of crops (Okoronkwo *et al.,* 2006). Manta *et al.,* (2002) and Tume *et al.,* (2006) reported that soil pH with increase in the concentration of heavy metals while the reverse becomes the case.

Conclusions

The result of the study generally revealed that petroleum waste significantly influenced soil properties. The selected heavy metals (Cd, Cr and Pb) however did not exceed the critical limit of 0.2 mg kg^{-1} in soils but exceeded the permissible limit of plants which might be injurious to health when consumed through food chain. The concentrations of Cd, Cr and Pb were found to be higher in polluted soils than the unaffected soils, with mean value ranges of (0.17 – 0.20, 0.20 – 0.40 and 0.70 mg kg-1 in polluted and (0.01–0.02) mg kg^{-1} in unpolluted soils for Cd, Cr and Pb, respectively.

Generally, the selected heavy metals for the study (Cd, Cr and Pb) had good relationship with the basic soil properties is available P, ECEC, pH, TEB, TP and MC. This may be hazardous for agricultural purposes since the bioavailability of heavy metals depends on their total concentration in soils. Increase in the concentration of these three metals in soil is expected to cause higher level of these metals in growing crops through food chain and ground water through seepage or leaching. Therefore, effective measures should be employed in the remediation of the polluted soils and world standard of waste management should be employed.

Table 2: Selected chemical properties of the studies locations

Location	pH (KCL)	pH (H_2O)	OC g/kg	TN g/kg	Avail. P mg/kg	Ca	Mg	K	Na	TEA	TEB	ECEC	BS
Control	6.13	5.48	10.53	1.06	15.05	7.02	4.23	0.50	0.00	0.25	11.75	12.00	97.84
Indorama	5.88	5.46	12.28	1.28	4.82	5.57	4.40	0.18	0.00	0.21	10.15	10.35	97.95
PHRC	5.36	4.94	15.63	1.53	5.45	3.61	3.20	0.21	0.00	1.52	7.02	8.54	82.74
$LSD_{(0.05)}$	**0.508**	**0.358**	**1.496**	**0.086**	**1.601**	**1.06**	**2.575**	**0.68**	**0.001**	**1.011**	**3.014**	**3.024**	**11.5**

NB: * = Significant at p = 0.05; NS = No Significant difference; OC =Organic Carbon; TN = Total Nitrogen; TEA = Total Exchangeable Acidity; TEB = Total Exchangeable Bases; ECEC =Effective Cation Exchange Capacity; BS = Base Saturation

Table 3: Concentration of Heavy Metals present in the Studied Locations

Location	CD mg/kg	Pd	Cr
Control	0.0062	0.02	0.00672
Indorama	0.1974	0.2002	0.0704
Indorama	0.1682	0.3988	0.0704
LSD(0.05)	**0.108**	**0.036**	**0.015**

Key: * = Significant at p = 0.05; Cd = Cadmium; Pb = Lead; Cr = Chromium

Table 4: Correlation between heavy metals and physicochemical properties

Soil property	Cd	Cr	Pd
Avail. P	-0.723**	-0.946**	-0.802**
BD	0.438	0.641*	0.895**
BS	-0.186	-0.445	-0.682*
Ca	-0.494	-0.716**	-0.905**
Clay	0.389	0.515*	0.077
ECEC	-0.301	-0.551*	-0.651*
MC	0.474	0.736**	0.910**
Mg	0.037	-0.214	-0.307
OC	0.469	0.720**	0.920**
pH(H_2O)	-0.452	-0.531*	-0.773**
Sand	-0.319	-0.267	-0.030
TEA	0.178	0.417	0.659*
TEB	-0.318	-0.613*	-0.780**
TN	0.568*	0.784**	0.967**
TP	-0.439	-0.641*	-0.896**

NB: * and ** = Significant at 0.05 and 0.01; probability levels respectively
BD = bulk density; BS = Base Saturation; MC = Moisture content; OC = Organic carbon; ECEC = Effective Cation Exchange Capacity; TEA = Total Exchangeable Acidity; TEB = Total Exchangeable Base; TP = Total porosity; TN = Total Nitrogen

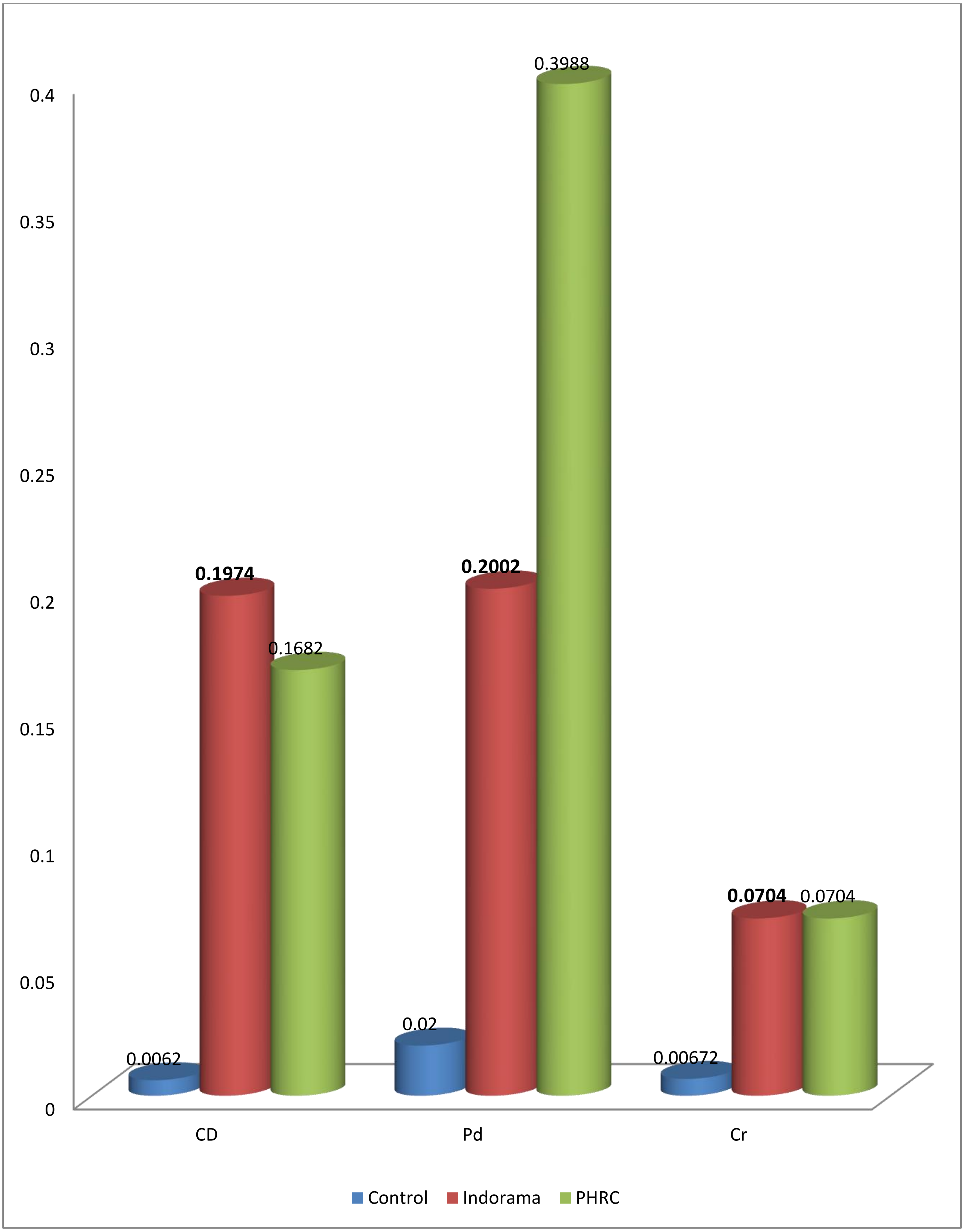
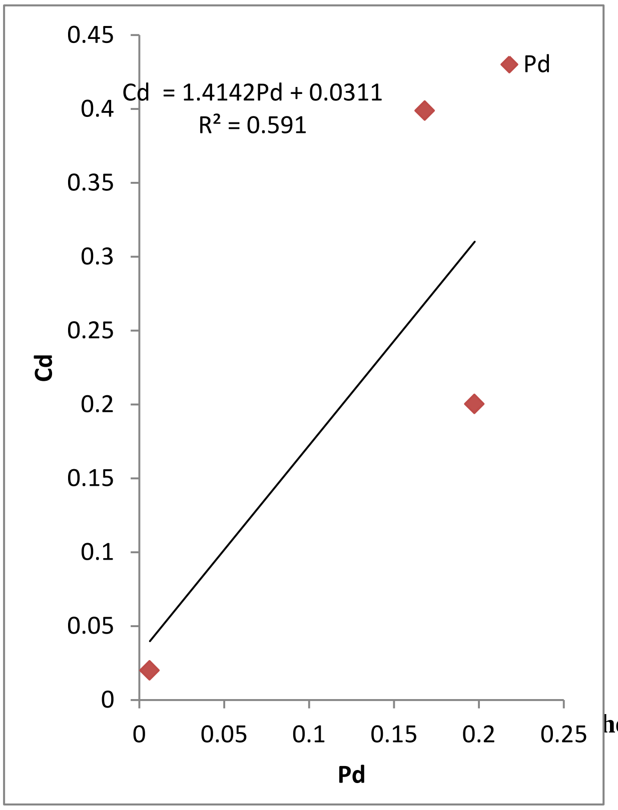
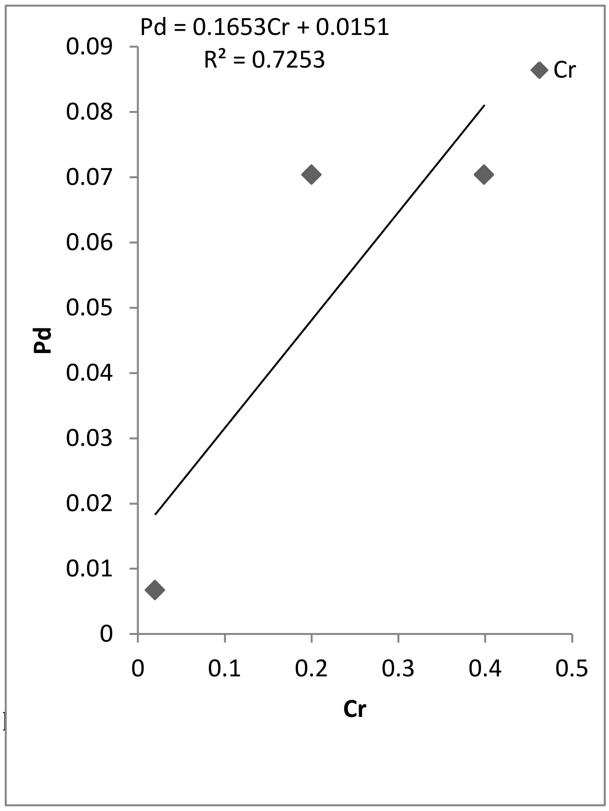
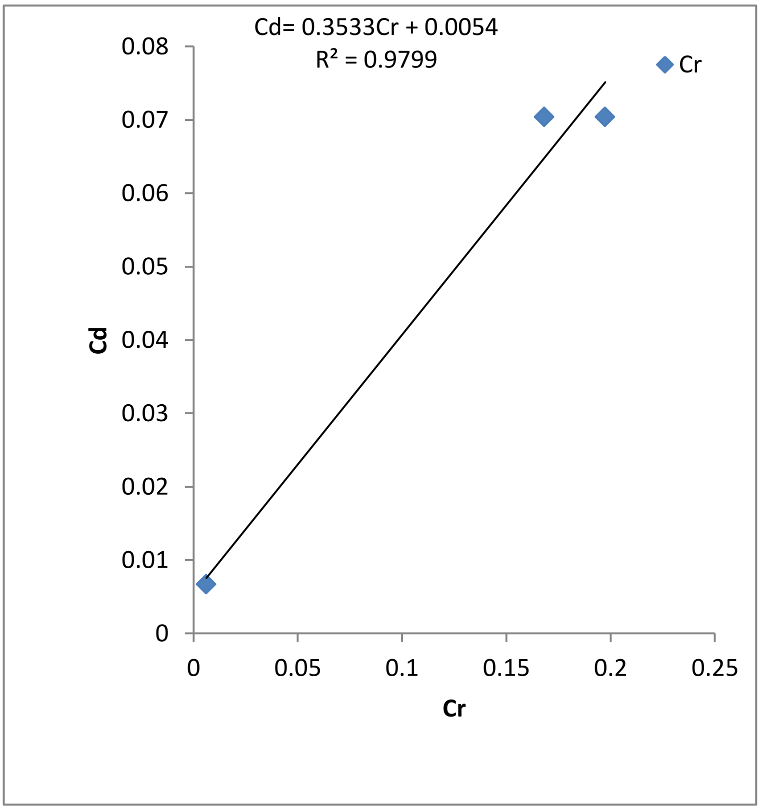


Fig. 1: Distribution of heavy metals in the three studied locations


Cd = 1.4142Pd + 0.0311
R² = 0.591
Pd
Cd
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0
0.05
0.1
0.15
0.2
0.25
Pd


Pd = 0.1653Cr + 0.0151
R² = 0.7253
Cr
Pd
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0
0.1
0.2
0.3
0.4
0.5
Cr


Cd= 0.3533Cr + 0.0054
R² = 0.9799
Cr
Cd
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0
0.05
0.1
0.15
0.2
0.25
Cr

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