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VERTICAL AND LATERAL DISTRIBUTION OF HEAVY METALS IN SOILS AFFECTED BY INDUSTRIAL AND MUNICIPAL WASTES IN PORT HARCOURT, NIGERIA

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Abstract: **The distribution of some selected heavy metals (Lead, Mercury, Cadmium, Nickel, Chromium, and Iron) of five undisturbed soil profiles in Port Harcourt Metropolis affected by industrial and municipal wastes was assessed vertically and laterally, to ascertain the nature and extent of contamination, mobility particularly with respect to distance from the impact point, depth in the soil profile, and chemical form of metal in the soil. It was found that the concentration of the metals in the top-soil (0-5cm) at each site within impact point was very high. However, levels of these metals decreased with distance, with all metals reaching background levels at 100m away which show little relation to the metal loading at the surface horizon. Samples taken deeper in the profiles (30-60cm) nearly devoid of organic matter did not show elevated metal levels compared with the sites 100m away from the source. High concentration of heavy metals at the impact points of the study area could cause adverse effects on plant quality and yield, and also on human health.**

Keywords: **Distribution; Heavy metals; Soils; Wastes.**

1. INTRODUCTION

Heavy metals pollution, not only result in adverse effects on various parameters relating to plant quality and yield but also cause changes in the size, composition and activity of the microbial community (Yao and Huang 2003). Therefore, heavy metals are considered as one of the major sources of soil pollution. Heavy metals pollution of the soil is caused by various metals especially Cu, Ni, Cd, Zn, Cr, and Pb (Hinojosa et al. 2004; Ideriah et al. 2004; Masindi and Muedi, 2018). The adverse effects of heavy metals on soil biological and biochemical properties are well documented. The soil properties: organic matter, clay contents and pH have major influences on the extent of the effects of metals on biological and biochemical properties. Heavy metals indirectly affect soil enzymatic activities by shifting the microbial community which synthesizes enzymes (Karaca et al. 2010). Heavy metals exhibit toxic effects towards soil biota by affecting key microbial processes and decrease the number and activity of soil microorganisms. Conversely, long-term heavy metal effects can increase bacterial community tolerance as well as the tolerance of fungi such as Arbuscular mycorrhizal (AM) fungi, which can play an important role in the restoration of contaminated ecosystems (Mora et al., 2005).

Knowledge of the basic chemistry, environmental, and associated health effects of heavy metals is also necessary in understanding their speciation, bioavailability, and remedial options. The fate and transport of a heavy metals in soil depends significantly on the chemical form and speciation of the metal. Once in the soil, heavy metals are adsorbed by initial fast reactions (minutes, hours), followed by slow adsorption reactions (days, years) and are, therefore, redistributed into different

chemical forms with varying bioavailability, mobility, and toxicity (Tchounwo et al. 2012; Ogbonna et al. 2009). This, distribution is believed to be controlled by reactions of heavy metals in soils such as; mineral precipitation and dissolution, ion exchange, adsorption, and desorption, aqueous complexation, biological immobilization and mobilization, and plant uptake. This work therefore, aim to determine the distribution of heavy metals in soils of Port Harcourt environment affected by industrial and municipal wastes.

2. MATERIALS AND METHODS

The research was carried out in Port Harcourt metropolis, a heavily populated and industrialized area of the Rivers State located within latitudes 6º58´N to 7º6´N and Longitude 4º40´E to 4º55´E. It falls almost entirely within the lowland swamp forest ecological zone and is flanked in the east, west and southern limits by mangrove swamp forest.

Sample Collection

Five locations occupying at least several hectares with undisturbed profiles were sampled and labeled as Top, Middle and Bottom soils. All sites at a given location were sampled along a straight line and down the gradient at 50m apart. Three different sites were sampled at each location. Composite samples were randomly taken to a depth of 0-5cm, 5-30cm, and 30-60cm at the impact point, while other locations were sampled only to a depth of 0-5cm at 50m and 100m away from the impact point, respectively.

Interpretation of Sample Label:

Location I

TAMT = Trans-Amadi Industrial layout, Michelin - Top soil

TAMM= Trans-Amadi Industrial layout, Michelin - Middle soil

TAMB = Trans-Amadi Industrial layout, Michelin - Bottom soil

Location II

TAGT = Trans-Amadi Industrial layout, Gas producers - Top soil

TAGM =Trans-Amadi Industrial layout, Gas producers - Middle soil

TAGB = Trans-Amadi Industrial layout, Gas producers - Bottom soil

Location III

EBPT = Eastern by-pass - Top soil

EBPM = Eastern by-pass - Middle soil

EBPB = Eastern by-pass - Bottom soil

Location IV

EWRT = East-West Road, Rumuokoro - Top soil

EWRM = East-West Road, Rumuokoro - Middle soil

EWRB = East-West Road, Rumuokoro - Bottom soil

Location V

PTBT = Port Harcourt Township, Borokiri - Top soil

PTBM = Port Harcourt Township, Borokiri - Middle soil

PTBB = Port Harcourt Township, Borokiri - Bottom soil

The samples were air-dried, grounded using agate mortar and pestle, sieved through a 2mm sieve mesh, coned and quartered. Each sieved finest soil particles were stored in a soft labelled polythene bags until the analysis. The Burrel (1974) in-vitro digestion method was used as follows: 1g of the dried, sieved soil sample was placed in a Kjeldahl flask of 100cm^3 capacity

and labelled accordingly for identification purpose. To each of the 25 samples in the Kjeldahl flasks, 5 ml of distilled water followed with 5 ml of concentrated H_2SO_4 (Analar) was added carefully. 10ml of Nitric acid and 1 ml of perchloric acid were introduced into the flasks and shaken to homogeneity. The flasks were then cooled under tap water as exothermic reaction evolved due to the mixture of concentrated H_2SO_4 and water. Each Kjeldahl flask with its content was placed on a heating mantle in a fume chamber and heated gently for 20 minutes, after which the heat was increased from 50^0C to 100^oC. This was heated until the homogenized mixed digest turned into a clear solution with milky coloured precipitates. The Kjeldahl flask was removed from the heating source and allowed to cool and 50ml of distilled water was added into the flask. The content of the flask, after adding 50ml of distilled water, was filtered with whatman No 42 fluted filter paper into a 100ml standard volumetric flask through 60 cm glass funnel and the solution was made up to 100ml mark with distilled water. The filtrate was transferred into a 100ml plastic bottle since most of the metallic constituents of solution would adhere to the glass wall and were taken to Atomic Absorption Spectrometric for test of Lead (Pb), Mercury (Hg), Iron (Fe), Nickel (Ni), Cadmium (Cd), Chromium (Cr) and Zinc (Zn) at their specific wavelengths. The flame atomic absorption spectrophotometer used was fitted with a deuterium lamp for background correction.

3. RESULTS AND DISCUSSION

(a) Vertical distribution of the heavy metals Analyzed

Vertical distribution of heavy metals in all the locations, follow the same trend. The heavy metals concentration of the surface soils are higher than the sub-soils. Samples taken deeper in the profiles (30-60 cm) didn't show elevated metal levels compared with the distant sites, but with all metals reaching background levels.

Results show that metals concentration (mg/kg) decreases down the profile. Concentration of Pb was in the following order: 0.400(0 -5 cm) > 0.292(5- 30 cm)> 0.098mg/kg (30- 60 cm). Similar results were obtained for Hg, Cd, and Zn as follows: Mercury (Hg) had 0.186 (0 -5 cm) >0.131 (5- 30 cm) > 0.098mg/kg (30 -60 cm). Cadmium (Cd) had 0.024 (0-5 cm) > 0.010 (5- 30 cm) > 0.004mg/kg (30 -60 cm). Zinc (Zn) had 0.086 (0- 5 cm)> 0.029 (5-30 cm)> 0.008mg/kg (30-60 cm), respectively. The same trend was obtained for the other metals.

An illustration of the vertical distribution of heavy metals (Figs.1-7) using the Bar charts shows that total concentration of Lead (mg/kg) is highest in TAM I, followed by EBP III, followed by PTB V, followed by TAG II, and lastly EWR IV. Mercury total concentration in TAM I > TAG II> EBP III > PTB V> EWR IV. Also, total concentration of Iron in EWR IV > EBP III >PTB V > TAM I > TAG II. Chromium total concentration in PTB V > EBP III > EWR IV > TAM I > TAG II. Total concentration of Nickel in TAG II >EBP III > EWR IV > TAM I > PTB V. Zinc total concentration in PTB V > EBP III > EWR IV > TAM I > TAG II. Total concentration of Cadmium in EBP III > PTB V > TAM I > TAG II > EWR IV.

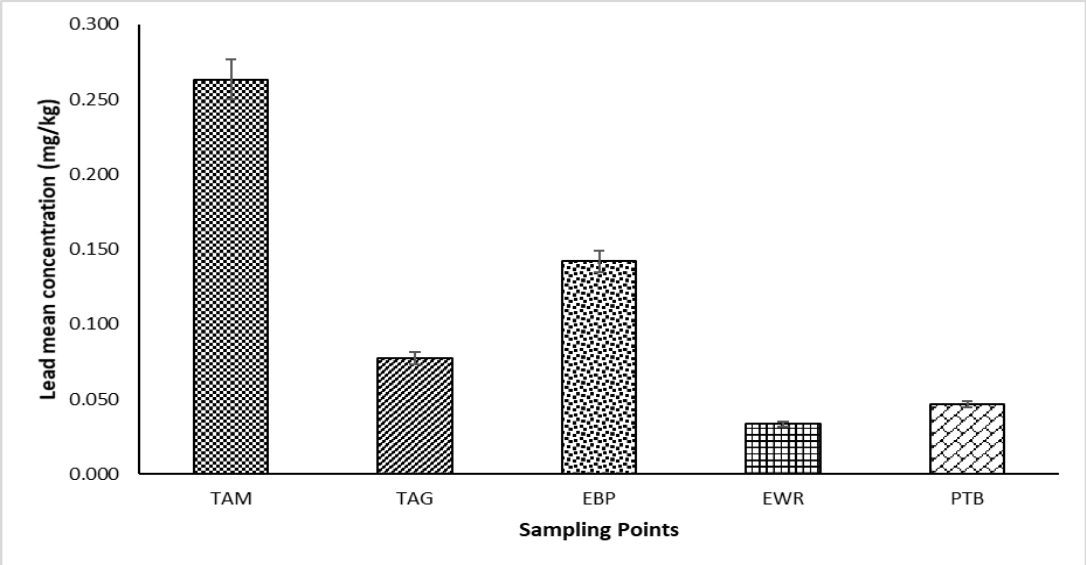

Fig. 1: Vertical distribution of Lead

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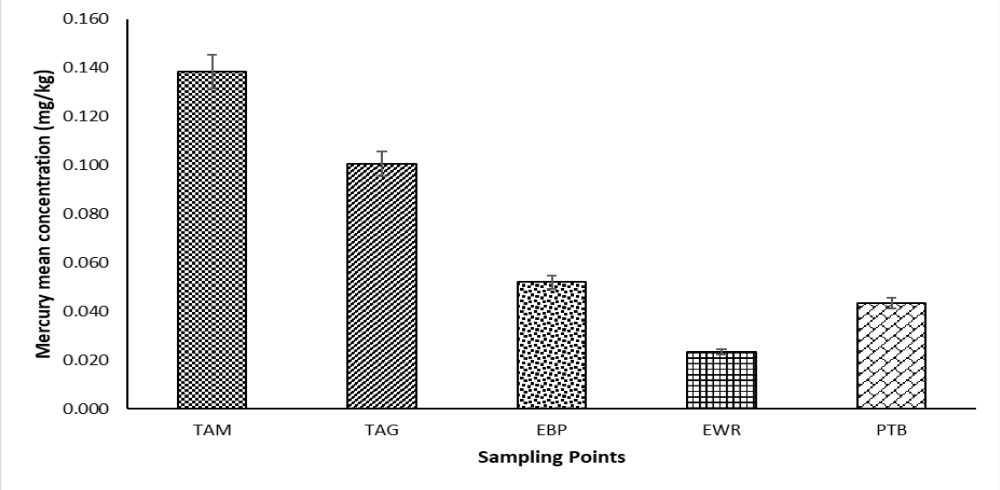

Fig. 2: Vertical distribution of Mercury

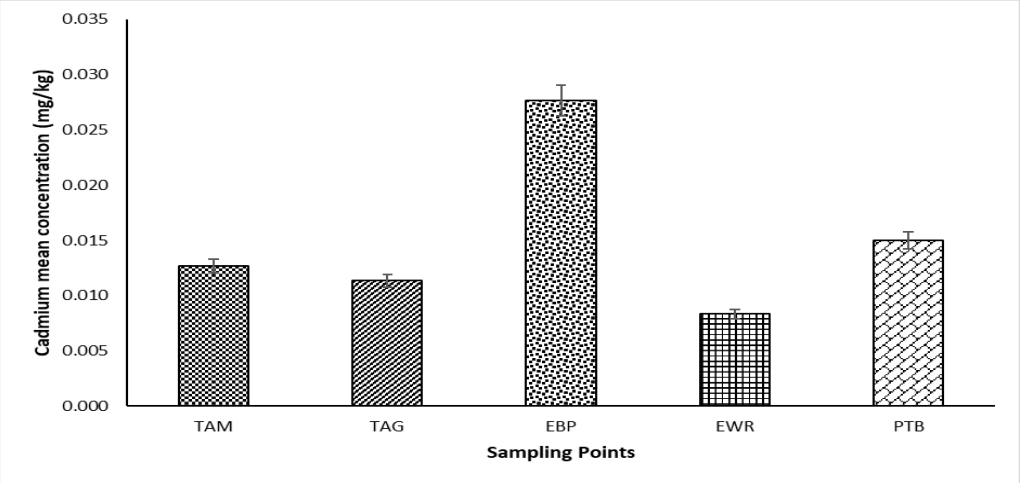

Fig. 3: Vertical distribution of Cadmium

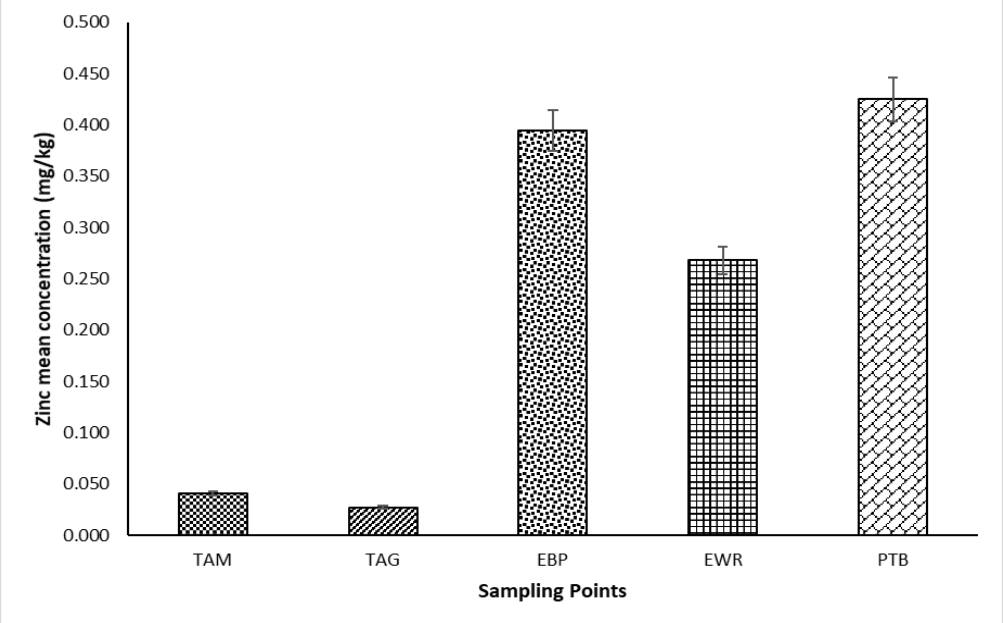

Fig. 4: Vertical distribution of Zinc

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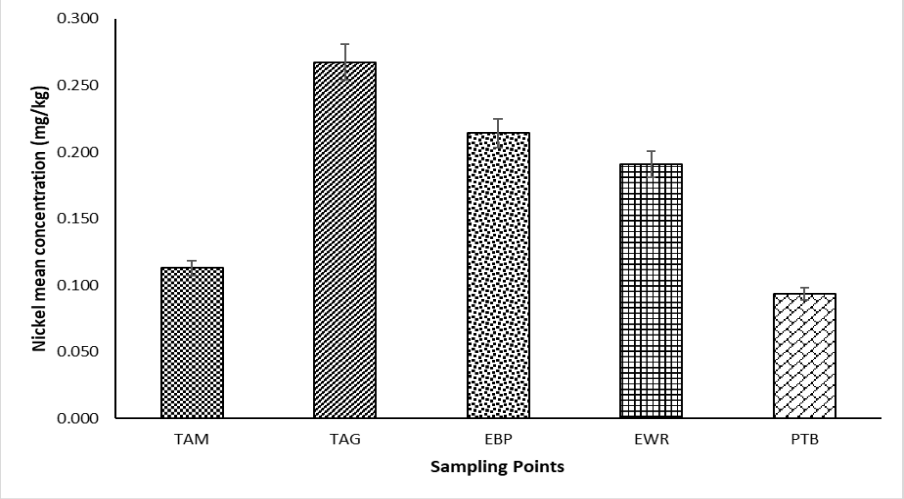

Fig. 5: Vertical distribution of Nickel

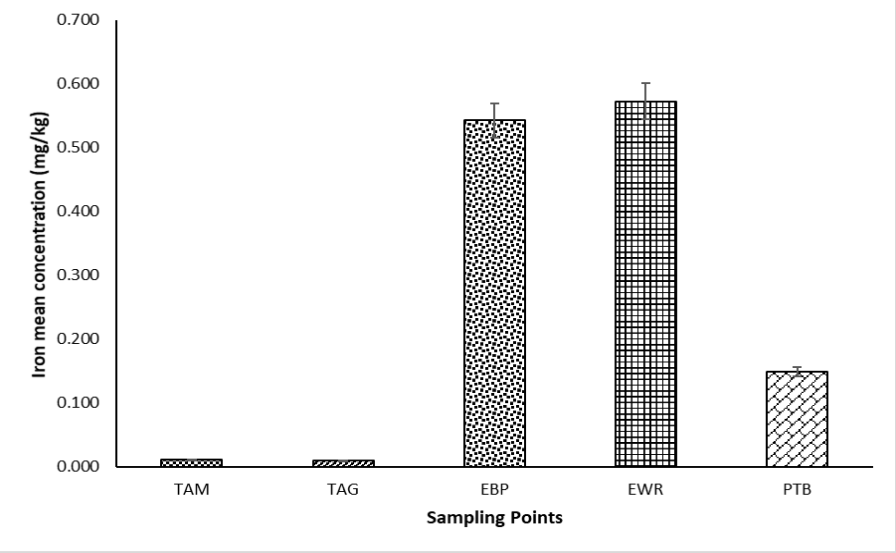

Fig. 6: Vertical distribution of Lead

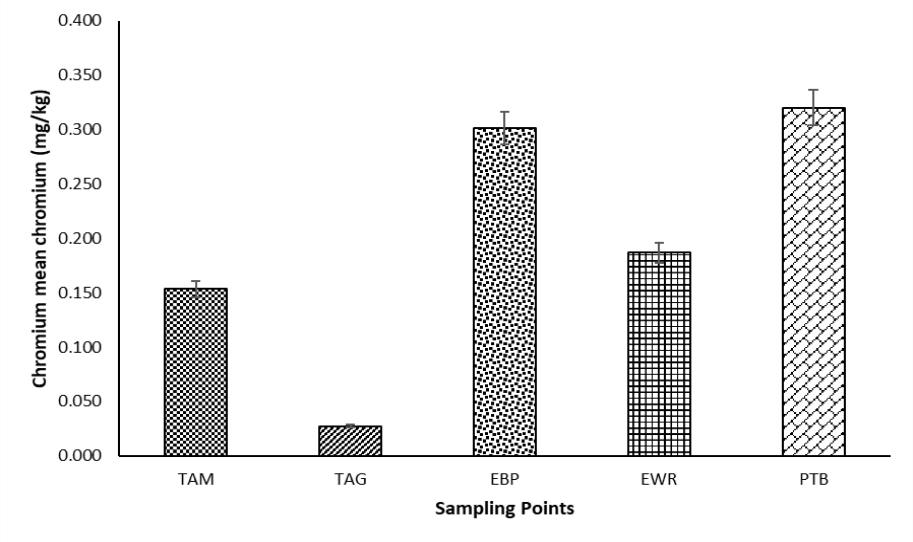

Fig. 7: Vertical distribution of Chromium

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(b) Lateral Distribution of the Heavy Metals Analyzed

Heavy metals content of the top 0- 5cm soil samples decreased rapidly with distance from the major impact point. The lateral distribution of metal contents of the top 0- 5cm soil is illustrated in Figs. 8 - 14 in a plot of concentration of heavy metals in top 0-5 cm soils as a function of distance from the impact point. Results in Fig. 8 shows that metal concentration for Pb (mg/kg) decreased from the impact point in the following order: 0.400(impact point) >0.288 (50m away) > 0.099mg/kg (100m away). Similar results were obtained in Figs. 9-12, where Hg decreased from 0.186 (at impact point) to 0.005 (50m away) and to 0.001mg/kg (100m away). Zinc (Zn) decreased from 0.086 (impact point) to 0.080 (50m away) and to 0.013mg/kg (100m away), respectively. The other metals follow the same trend.

Widespread (lateral) distribution can be affected by surface flow or splash erosion. The concentration of metals could also, be affected by the duration of dumping, quantity of material and soil characteristics. The low heavy metals content of the sub-soils may be due to immobility of these metals, and low leaching from surface soils (Kabala and Singh, 2001).

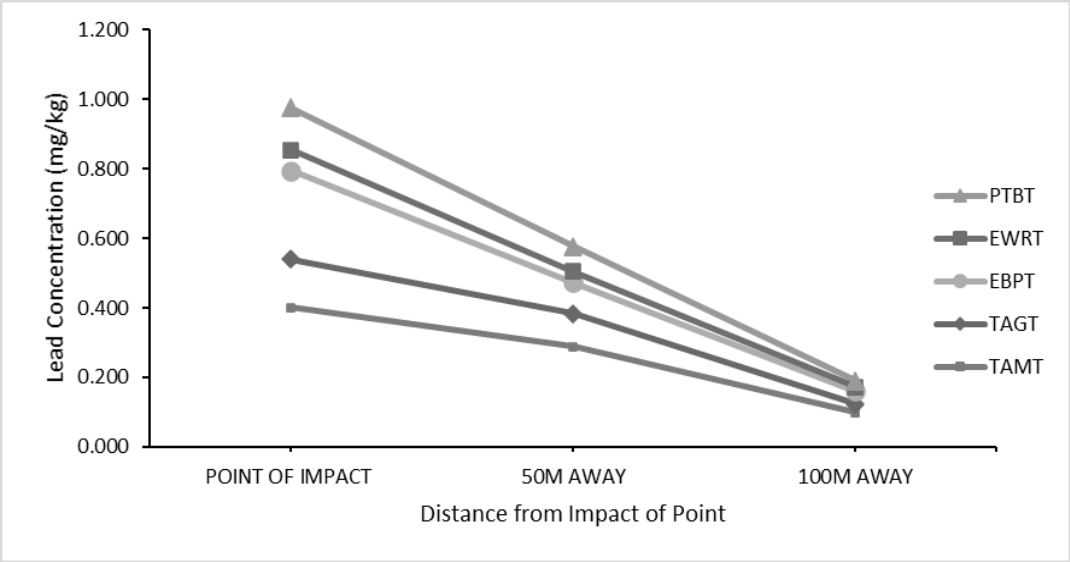

Fig. 8: The effect of distance from the impact point on the concentration of Lead

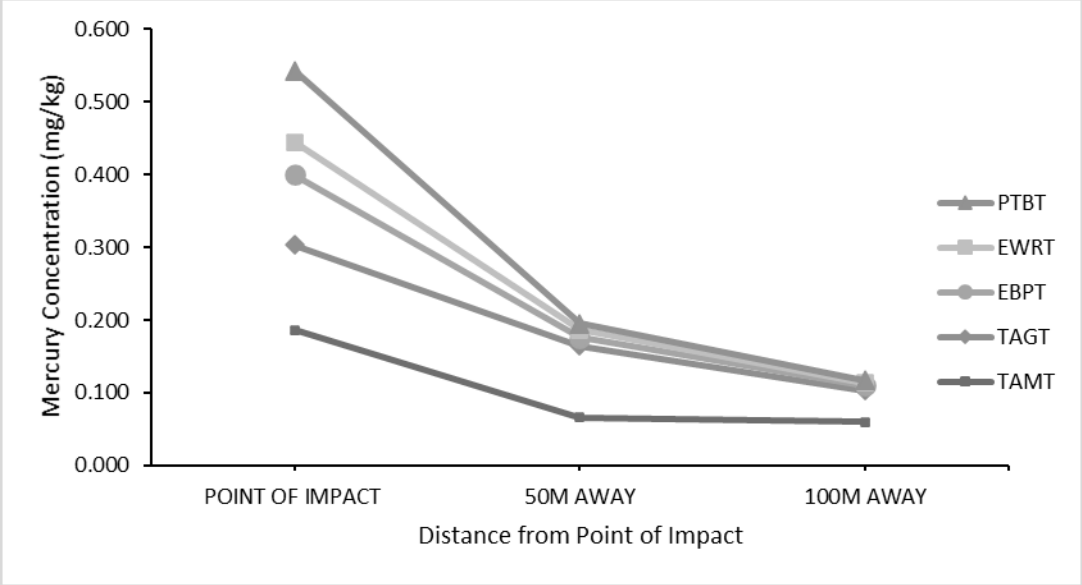

Fig. 9: The effect of distance from the impact point on the concentration of Mercury

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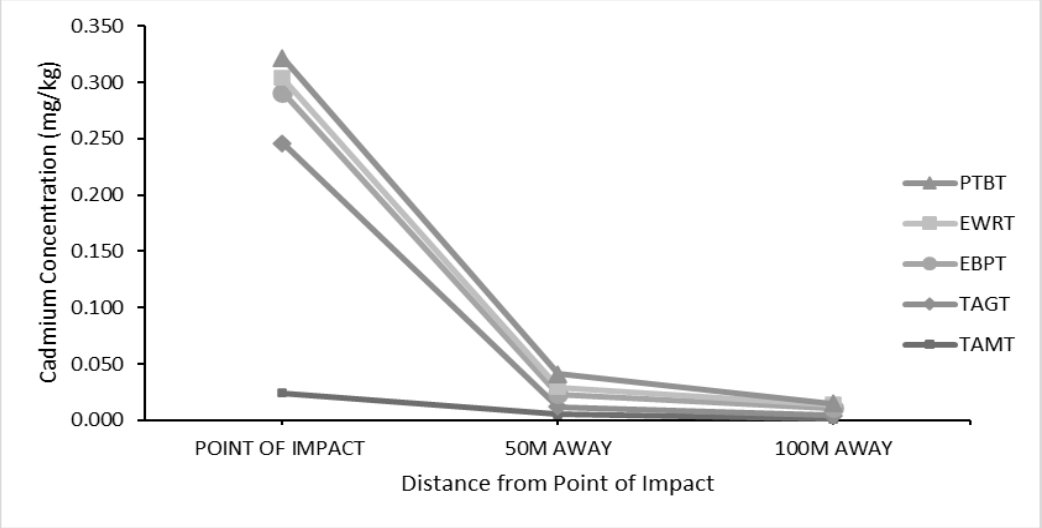

Fig. 10: The effect of distance from the impact point on the concentration of Cadmium

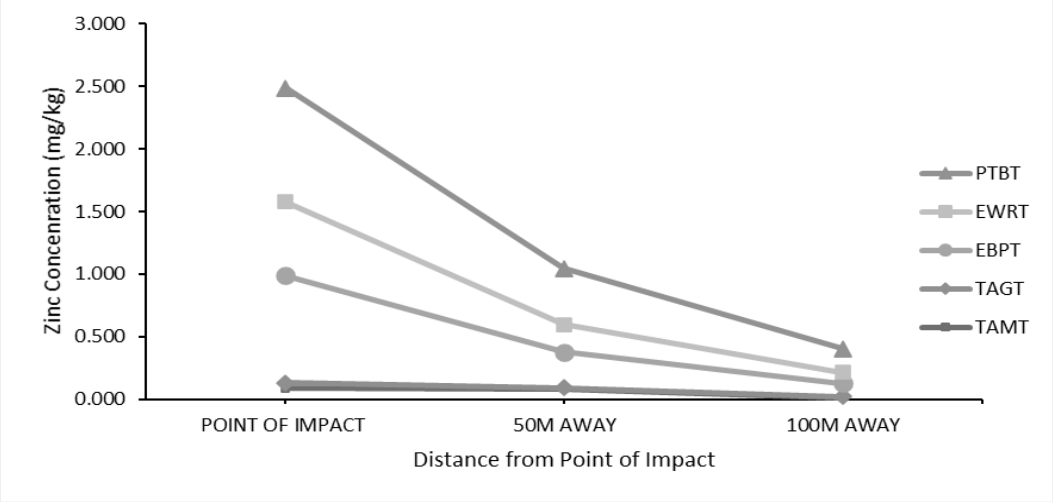

Fig. 11: The effect of distance from the impact point on the concentration of Zinc

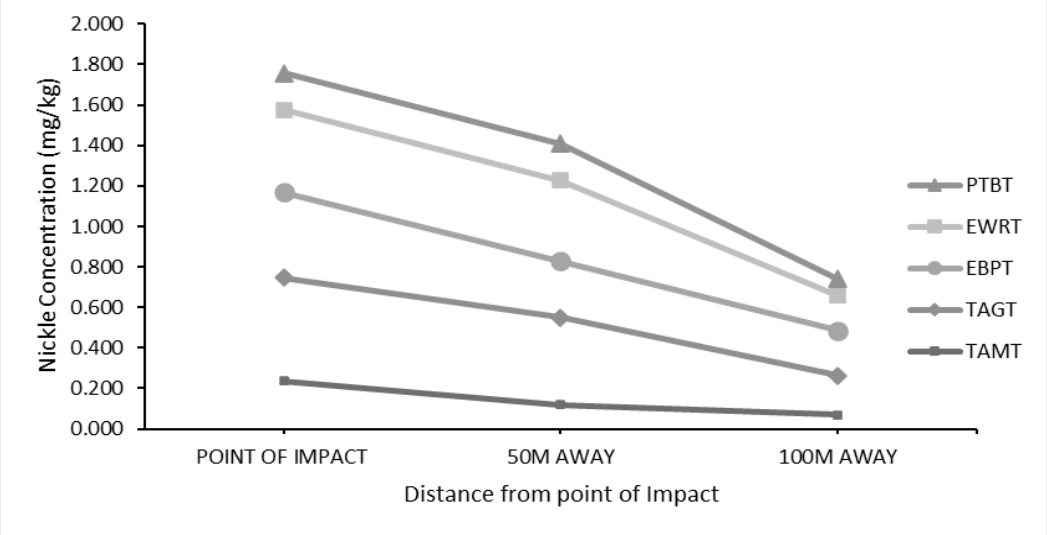

Fig. 12: The effect of distance from the impact point on the concentration of Nickel

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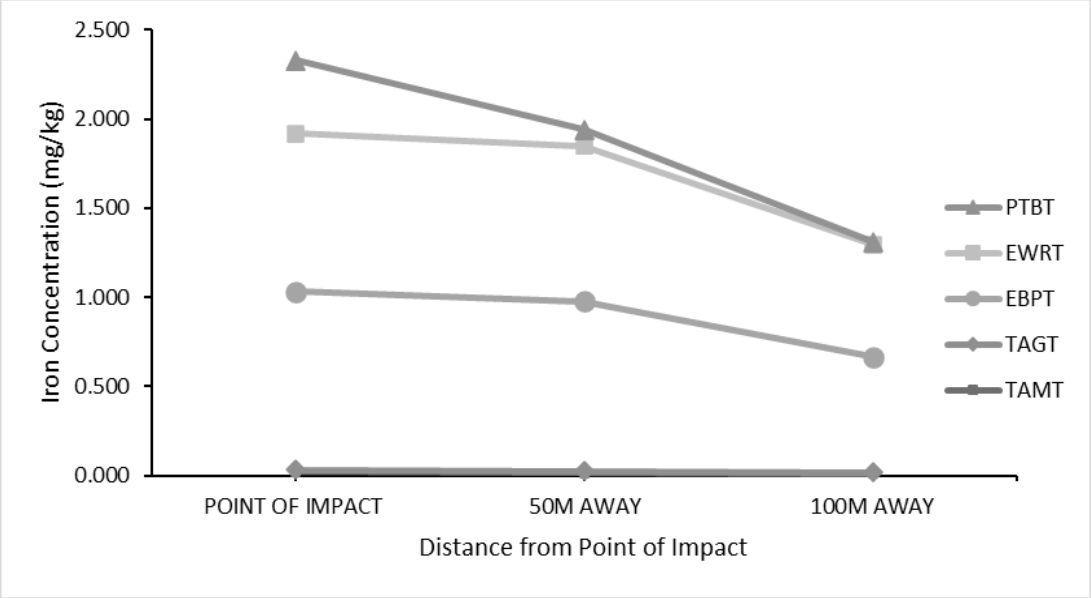

Fig. 13: The effect of distance from the impact point on the concentration of Iron

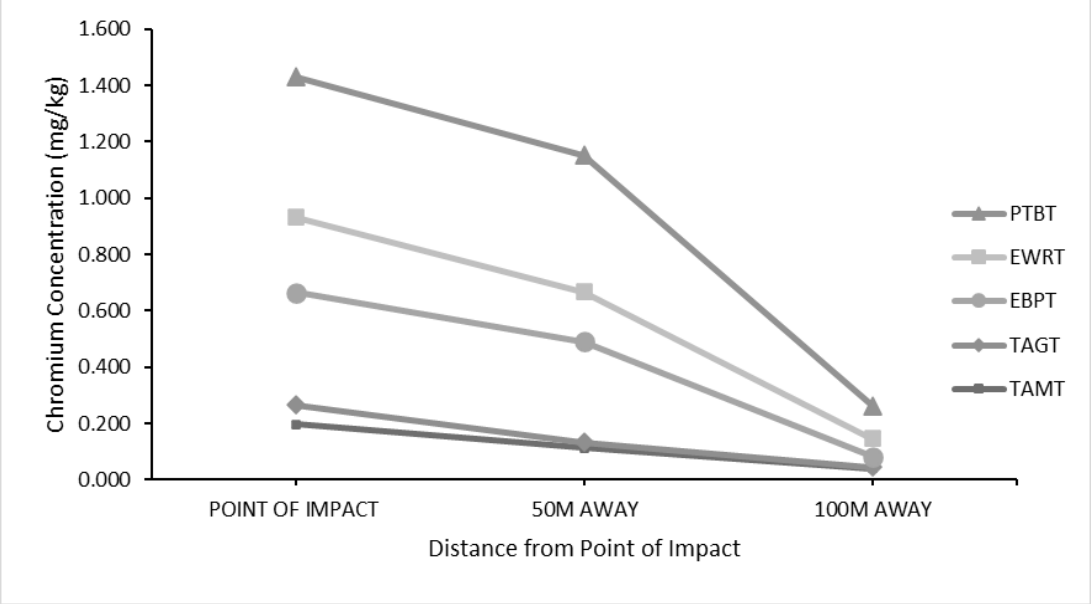

Fig. 14: The effect of distance from the impact point on the concentration of Chromium

4. CONCLUSION

Variations in the soil content of selected heavy metals analyzed show that metals concentration in the 5-30 cm soil samples reflected the concentrations in upper soil layers, but also appeared to be affected by the depth of the A1 horizon, which was quite variable between and within locations. Biological mixing within the A1 horizon and organic matter sorption of any soluble metals may tend to homogenize metals within the A1 horizon, but prevent movement out of this horizon. Concentrations of 30-60 cm soil samples, nearly devoid of organic matter, are near background levels for all metals and show little relation to the metal loading of the surface horizon. Elevated levels of heavy metals in soils may lead to uptake by nature and leaching to ground and surface waters. Movement of metals in soil profiles appeared to be minimal, as the litter layer and top-soil provide effective retention sites for the pollutants. Summarily, the results presented here indicates not only that the soils of Port Harcourt environment affected by industrial and municipal wastes are highly contaminated with Cd, Pb, Hg, Ni, Fe and Cr, but also that the extent of contamination is limited to the immediate industrialized area.

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