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Enrichment factor and ecological risk assessment of heavy metals in selected steel welding workshop's soil in Port Harcourt, southern Nigeria

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Abstract
Human activity is a notable component of environmental pollution. Soil samples were collected from soils in three different workshops within the Rumuolumeni/Akpor axis of Obio/Akpor Local Government area of Rivers State. The soil samples were treated to laboratory conditions and finally digested using a combination of acids. The final productof the digestion was analyzed for heavy metals using atomic absorption spectrophotometer (AAS) to determine their concentrations. The results of the heavy metals showed a variation of 842.30±10.68-1324.69±31.26 mg/kg for iron (Fe), 9.33±2.10-13.70±4.53 mg/kg for lead (Pb), 10.70±2.64-16.35±3.81 mg/Kg for copper (Cu), 0.74±0.00-1.43±0.02 mg/kg for cadmium (Cd), 9.11±1.96-19.20±5.38 mg/kg for chromium (Cr), 2.69±1.01-4.65±1.13 mg/kg for nickel (Ni) and 1.31±0.07-2.42±0.21 mg/kg for arsenic (As). The result further revealed that the most abundant metal in the workshop soils was Fe > Cr > Cu > Pb > Ni > As > Cd. Contamination factor evaluation showed that all the metals in the stations were at the level of contamination except Fe in all the stations which was uncontaminated in all stations and Cd with Ni that are at level of pollution with Cd and Ni at the some of the stations and As in all the stations. Enrichment factor evaluation of the soils from the stations revealed that the soils were enriched by all the metals through human influence. The ecological risk assessment of the heavy metals in the soils showed their levels are at low ecological risk to the environment except the values of Cd obtained at Elioparanwo and Chinwota stations.

Keywords: enrichment factor**,** ecological risk, welding workshop, heavy metals, pollution

Introduction

Although the progress of systematic and engineering expertise and the building of sophisticated equipment to enhance human life on earth has immense advantages, yet they are accompanied with numerous unwanted ecological substances which pollute the environment (El-Sherbiny *et al*., 2019) [9]. Heavy metals are associated with diverse human activities, whether in the industry or at home and some of these metal are directly discharge to the nearby soil environment without following proper discharge regulations. The content of heavy metals discharged into the environment, varies from one industry to the other and the nature of the release is dependent on the type of products processed or manufactured by the industry (Chopra *et al*., 2009) [3].

The alteration of the human surrounding is a world-wide problem which has culminated in different ecological and human health issues**.** Urbanization is accompanied with human drifts and heavy industrial presence which has precipitated into several ecological pollution within and around such heavily populated areas (Babandi *et al*., 2012; Dibofori-Orji and Edori, 2018) [1, 4]. The exposure of humans, plants and animals to environmental chemical is on a yearly rise. The processes of treatment of metals for human use such as mining, quarrying, handling, production and melting are collective anthropogenic activities which is negatively consequential on atmospheric locations and directly contribute to individual health risks and environmental pollution (He *et al*., 2015; Edori and Iyama, 2021) [11, 6]. The extraction and processing of metals which are of known economic importance help to concentrate of heavy metals and metalloids at such sites (Onyedikach *et al*., 2018) [17].

One of the most significant regular resource known to man is the soil. This is due to the fact that it has the capacity to act as a pool for the storage of contaminants. (Liu et al., 2014) [13]. It also possess the capacity to naturally buffer the dispersion of biochemical, organic and inorganic impurities in environmental surroundings such as air, water and living organisms (Lutts and Lefèvre, 2015) [14]. The natural ecosystem of the soil all over the world has been seriously altered through speedy growth of industries and human settlements. Some human activities which include building of infrastructures, production of electrical and mechanical energy, manufacturing, mining, burning of fossil fuel and discarding of generated wastes cause abnormal input of heavy metals in municipal soil subsequent in austere environmental toxic wastes (Taghipour *et al*., 2011) [24].

The issue of pollution of soils with heavy metals has generated serious concern because their presence in soil is difficult to be removed or reduced but gradually, they get increased over time and transferred to plants through absorption processes and so affect the food chain (Šmejkalová *et al*. 2003; Sipter *et al*. 2008) [22, 21].

The process of fabrication where parts of the same or different materials are fused together through the presence of heat and pressure and finally when cool forms a joint is referred to as welding. Welding is done on metals and thermoplastics and also on wood. Welding is basically divided into four, which are; gas metal arc welding, gas tungsten arc gas welding, shielded metal arc welding and flux cored arc welding. Welding of burglary proof materials is accompanied with other activities such as filing of the welded points, smoothing of the surface of the material with sandpaper and painting of garnishing of the edges that lead to the discharge of the steel materials on the surface of the soil within the working environment. Therefore this research examined the concentrations of some heavy metals in soils from selected metal welders' workshop.

Materials and Methods

Soil samples were collected from three different locations using soil auger. In each location, five samples were collected and mixed together to form composite sample. The soil samples were collected at a depth of 0 – 10cm. The sampled soils were immediately put into polythene bags and moved to the laboratory for preparation and analysis. The locations of welding workshops where samples were collected are Egbelu, Elioparanwo and Chinwota. The Egbelu and Chinwota welding workshops are situated along the St John's-Ogbogoro Road, while the Elioparanwo workshop is situated along Wimpey-Elioparanwo Road.

The soil samples were allowed to air dry freely in a clean well ventilated laboratory. Weight measurement of the soil samples were determined after seven days and then subsequent weight determination was done at two days interval until a constant weight was observed between the fourteenth and sixteenth day of drying. Thereafter, the soil was crushed in a ceramic mortar using pestle. The crushed soil was sieved with a 2mm stainless sieve. The finely divided soil samples were put into glass containers and covered firmly to prevent air from penetrating.

A 2g weight of the finely pulverized soil samples were measured into digestion containers which contains nitric acid (HNO_3) and hydrochloric acid (HCl) in the ratio of 3:1. The contents were heated on a hot plate at temperatures maintained between 100 –105 ^oC. The sample mixture was allowed to evaporate for one hour on the hot plate to reduce the initial volume to one third of the original content. Digestion was stopped when a clear digest was obtained. When the digestion was completed, the digestion containers were centrifuged. The containers were allowed to cool and the content transferred into a 50 ml volumetric flask and made to the mark with distilled water**.**

The concentrations of heavy metals in the soil samples were done by using atomic absorption spectrophotometer. The quality of the obtained values were checked through a comparative check on the determined values against those of standard reference constituents after every ten determinations of the samples.

The obtained values of heavy metals concentrations were evaluated using some pollution indices such as contamination factor, enrichment factor and ecological risk factor.

The contamination factor was gotten from the expression suggested by Lacatusu (2000) [12] as; Contamination Factor (Cf) = Cm/C_b This pollution parameter describes the extent to which a particular medium (water, sediment, land and air) has been contaminated or polluted based on the value obtained from the ration of the observed value against the natural or background value. The calculated values are interpreted based on ranges of values of contamination and pollution significance proposed (Lacatusu, 2000) [12]. The interpretation intervals are as follows; <0.1 is considered as very slight contamination, 0.10-0.25 is classified as slight contamination, 0.26-0.5 as moderate contamination, 0.51-0.75 is termed as severe contamination, 0.76-1.00 is classified as very severe contamination, 1.1-2.0 is slight pollution, 2.1-4.0 is categorized as moderate pollution is 4.1-8.0 as severe pollution and 8.0-16 is in the category of very severe to extremely severe pollution.

The application of data obtained for enrichment factor is used to evaluate developments in the soil geochemistry between different areas and further applied in the prediction of the origin and source of heavy metals distribution in environmental media (Pekey, 2006) [20]. The mathematical principle was first formulated by Buat-Menard and Chesselet (1979). This is stated arithmetically as:

$$EF = \frac{\left(\frac{Cn}{Cref}\right) sample}{Bn/Bref}$$

Where C_n (sample) = investigated metal concentration, C_{ref} (sample) = concentration of the investigated reference metal, B_n = is natural or standard value of the reference metal and B_{ref} = the value of the background reference metal (Turekian and Wedepohl, 1961) [25]. The value of 38000 mg/kg used for iron as the reference metal is taken from DPR (2000). The expressions for the interpretation of the different classifications of enrichment factor put forward by Sutherland *et al*. (2000) are as follows; EF < 2 (deficiently to minimal enrichment), 2 ≤ E F<5 (moderate enrichment), 5 ≤ EF < 20 (significant enrichment), 20 ≤ EF 40 (very high enrichment) and EF > 40 (extremely high enrichment).

Ecological risk factor (Er) shows the possible environmental threat of a specific heavy metal poison in soil or sediment environment (Håkanson, 1980). Arithmetically, it is given as;

Er = Tr x CF

Where Tr = toxic-response factor for the specific metal and Cf = the contamination factor of the specific metal. The terms applied for the interpretation of ecological risk factor (Er) are; low risk (Er<40), moderate (40≤Ef<80), considerable risk (80≤Ef<160), high risk (160≤Ef<320) and very high risk (Ef≥320).

Results and Discussion

The concentrations of the heavy metals observed in the soils from the different welding workshops are given in Table 1. The concentrations of Fe in the examined workshop varied from 842.30±10.68 to1324.69±31.26 mg/Kg. The values observed for Pb in the stations varied from 9.33±2.10 to 13.70±4.53 mg/Kg. The concentrations of Cu in the stations varied from 10.70±2.64 to 16.35±3.81 mg/Kg. The soil content of Cd varied from 0.74±0.00 to 1.43±0.02 mg/Kg. the values for Cr varied from 9.11±1.96 to 19.20±5.38 mg/Kg. the concentrations of Ni in the soil varied from 3.53±1.06 to 4.65±1.13 mg/Kg and that of As varied from 1.31±0.07 to 2.42±0.21 mg/Kg. All the concentrations of heavy metals observed at the various stations were lower than the DPR (2002) [5] values for soil, except Cd and As.

The result obtained from the stations revealed that all the metals were higher at the Chinwota station, followed by the Elioparanwo station and the lowest at Egbelu station. The stations variability in concentration is possibly due to the site position and topography (). At the Chinwota station, the roof is covered and therefore whatever was deposited on the floor of the workshop are not easily washed of by rainwater except when there is an overflow from the drainage. Moreover, it is situated on a flat land, but the other two stations are exposed, therefore rainwater can easily wash off deposit of metals on the floor of the workshop. Furthermore, the Egbelu station is on a slope, tilted towards the drainage, so deposits of metal from the welding activity can easily be washed down to the drain, which may the reason of lower values recorded at this station.

The concentrations of the heavy metals generally showed higher values than those of Nwoke and Edori (2020) [16] in soils from Rumuagholu waste dumps in Port Harcourt and those of Marcus *et al* (2017) [15] in ten different dumpsites all in Port Harcourt, Rivers State, Nigeria and also those of Edori and Kpee (2016) [7] in selected abattoirs within Port Harcourt metropolis. The observed values of metals in the present work is also higher than values obtained in soils elsewhere in Nigeria (Opaluwa *et al*., 2012; Ekwere *et al*., 2014) [18, 8] in soils from dumpsites within Lafia metropolis, Nasarawa State and Calabar, Cross Rivers State, Nigeria respectively. However, the observed values of individual heavy metals in the present work is lower than the values observed in contaminated soils from Daye, China (Yang *et al*., 2018) [26].

The higher concentrations of heavy metals observed in this work when compared to others in similar environment but with different activity is due to the specific metal welding activity carried out within the examined soils. This observation is in consonance with the observation of (Fazekašová and Fazekaš, 2020), that observed that mining and processing of metallic material is associated with heavy pollution issues. Welding is mostly associated with processing of metallic materials which cannot be done successfully without deposition of the metal components to the receiving soil.

Table 1: Concentrations of Heavy Metals in Soils from Selected Welding Workshops in Port Harcourt

Heavy Metals (mg/Kg)	Stations			DPR (2002)
	Egbelu	Elioparanwo	Chinwota	
Fe	842.30±10.68	1141.63±22.91	1324.69±31.26	38,000
Pb	9.33±2.10	11.61±2.83	13.70±4.53	85
Cu	10.70±2.64	12.84±3.02	16.35±3.81	36
Cd	0.74±0.00	1.37±0.02	1.43±0.02	0.8
Cr	9.11±1.96	14.83±4.28	19.20±5.38	100
Ni	3.53±1.06	2.69±1.01	4.65±1.13	35
As	1.31±0.07	1.31±0.11	2.42±0.21	1.0

The contamination factor of the individual heavy metals is shown in Table 2. The contamination factor values for the metals showed that Fe varied from 0.022-0.035, Pb varied from 0.11-0.161, Cu varied from 0.297-0.454 and Cd varied from 0.925-1.713. Other contamination factor values are Cr, 0.091-0.192, Ni, 0.077-0.133 and As, 1.310-2.420. The contamination factor values when juxtaposed with the intervals of contamination/pollution proposed by Lacatusu (2000) [12] showed that all the stations were uncontaminated with Fe, Cr at Egbelu station and Ni at the Elioparanwo station. All the stations were slightly contaminated with Pb, slightly contaminated with Cr at Elioparanwo and Chinwota stations and slightly contaminated with Ni at the Egbelu and Chinwota stations. All the stations were moderately contaminated with Cu. Egbelu station was very severely contaminated with Cd, while Elioparanwo and Chinwota stations were slightly polluted with Cd, Egbelu and Elioparanwo stations were polluted with Ni, but moderately polluted with Ni at the Chinwota station. All the stations were slightly polluted with As.

The contamination factor values for the present work are lower than the values observed for same metals in soils collected within a near vicinity of cement factory in Saudi Arabia (El-Sherbiny *et al*., 2019) [9] and also those of Oumenskou *et al*. (2018) in irrigated agricultural soils collected from Beni Amir, Tadla plain, Morocco. High contamination factor values of heavy metals in soil implies that soil is deteriorating (El-Sherbiny *et al*., 2019) [9]. However, the values of this research is yet to reach that situation, since the observed contamination status is within the level of slight pollution.

Table 2: Contamination Factor of Heavy Metals in Soils from Selected Workshops in Port Harcourt

Heavy Metals (mg/Kg)	Stations		
	Egbelu	Elioparanwo	Chinwota
Fe	0.022	0.030	0.035
Pb	0.110	0.137	0.161
Cu	0.297	0.357	0.454
Cd	0.925	1.713	1.788
Cr	0.091	0.148	0.192
Ni	0.101	0.077	0.133
As	1.310	1.310	2.420

The enrichment factor of the heavy metals in the different soils from the workshops are shown in Table 3. The enrichment factor values for Pb varied from 4.624 -10.735, those of Cu varied from 11.872-13.409, while the values for Cd varied from 41.731-57.002. The values for others metals ranged from 4.120-5.508 for Cr, 2.558-4.550 for Ni and 43.604-69.420. The interpretations of these values based on the terminologies proposed by Sutherland *et al*. (2000) indicated that the soils were moderately enriched with Pb at the Egbelu and Chinwota stations, but significantly enriched with Pb at the Elioparanwo station. All the soils from the stations were at the level of significant enrichment with Cu, moderately enriched with Cr and Ni in all the stations and are at the stages of extremely high enrichment with Cd and As in all the stations.

The observations on the levels of enrichment has shown that the geochemical developments within the examined soils has greatly been influenced with anthropogenic activities. Therefore, the spread of heavy metals within the experimental sites is due to human influence rather than natural occurrence (Pekey, 2006) [20]. This assertion could be observed from the enrichment factor values observed specifically for As, Cd and Cu in the soil samples.

Table 3: Enrichment Factor of Heavy Metals in Soils from Selected Workshops in Port Harcourt

Heavy Metals (mg/Kg)	Stations		
	Egbelu	Elioparanwo	Chinwota
Pb	4.95	10.735	4.624
Cu	13.409	11.872	13.028
Cd	41.731	57.002	51.276
Cr	4.120	4.936	5.508
Ni	4.550	2.558	3.811
As	59.100	43.604	69.420

The ecological risk factor of heavy metals in soils from selected workshops are given in Table 4. The various ecological risk factor values for the examined metals were; Pb (0.550-0.805), Cu (1.485-2.27), Cd (27.750-53.64), Cr (0.182-0.384), Ni (0.385-0.665) and As (13.100-24.200). The interpretations of the different values obtained from the ecological risk evaluation of the heavy metals based on Hakanson (1980) intervals, showed that all the metals in the different stations examined were at low level of ecological risk except Cd at Elioparanwo and Chinwota stations, which showed moderate risk. The ecological risk of the individual heavy metals in the examined soil were in the order Cd > As > Cu > Pb > Ni > Cr.

Table 4: Ecological Risk Factor of Heavy Metals in Soils from Selected Workshops in Port Harcourt

Heavy Metals (mg/Kg)	Stations		
	Egbelu	Elioparanwo	Chinwota
Pb	0.550	0.685	0.805
Cu	1.485	1.785	2.27
Cd	27.750	51.39	53.64
Cr	0.182	0.296	0.384
Ni	0.505	0.385	0.665
As	13.100	13.100	24.200

Conclusion

The concentrations of all the metals were below the DPR intervention value except cadmium and arsenic which exceeded their values. Contamination factor values showed that the soils were generally at contamination levels for most of the metals except Cd and Ni at some stations and As in all the stations the has reached pollution level. The values of the heavy metals in the examined soils showed anthropogenic enrichment. However, the observed concentrations of heavy metals do not pose risk to the environment presently, but if allowed to continue may portend danger to the environment.

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