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Eco-contamination Assessment of Heavy Metals from Auto-mechanic Activities in Akure Metropolis, Nigeria

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Abstract: Five (5) Pollution index was used to assess the eco-contamination of heavy metals in an area associated with auto-mechanic activities in order to determine the impact of improper automobile waste oil discharge in the research area. The total digestion and fractionation of the analyzed heavy metals was performed using standard methods, while quantification of heavy metals was carried out using atomic absorption spectroscopy. Risk assessment coded reveal that Fe and Cd have a low probability of been release to the environment due their low concentrations in the exchangeable and carbonate fractions. The ecological risk index revealed that with the exception of Cd and Cu, the analyzed heavy metals does not pose risk to the environment, while the geoaccumulation index revealed that only Cu fell in a class above 4, thereby suggesting Cu is strongly geo-accumulated in the study area. The enrichment factor revealed that none of the analyzed heavy metals in high enriched in the study area, while the contaminator factor suggested that with the exception of Cd, Cu and Pb, the heavy metals have a low degree of contamination. Finally, the total concentration of the analyzed heavy metals in the soil samples collected from auto-mechanic site was higher than those obtained from the control site. This indicated that anthropogenic conditions such as auto-mechanic activities are responsible for these results.

Keywords: auto-mechanic; heavy metals; anthropogenic; eco-contamination; risk assessment.

1. Introduction

Heavy metals are known as high density metallic chemical elements or stable metals with density greater than 5.00 to 6.00 g/cm³, which may have hazardous effects on plants, animals and the ecosystems when present in higher concentrations than found naturally. The daily accumulation of heavy metals in our environment has intensified in recent years due to population growth, industrialization and new technological developments.[1,2] Heavy metals from anthropogenic sources such as the improper disposal of waste oil from automobile engines are regarded as one of the most dangerous environmental pollutants due to their toxic and non-biodegradable nature which results in their persistence in the environment and tendency to accumulate in living organisms, thereby affecting the food chain and leading to serious ecological problems which results to a significant concern in the sustainability of the environment.[3-5]

Globally, the problem of soil contamination due to heavy metals has begun to raise concern in most cities since this may lead to geoaccumulation, bioaccumulation and biomagnifications in ecosystem.[6,7] The known fatal effects of heavy metal toxicity include damaged or reduced mental and central nervous functions and lower energy level. They also cause irregularity in blood composition, badly effect vital organs such as kidneys and liver. The long term exposure to toxic metals result in physical, muscular, and neurological degenerative processes that cause Alzheimer's disease (brain disorder), Parkinson's disease (degenerative disease of the brain), muscular dystrophy (progressive skeletal muscle weakness), and multiple sclerosis (a nervous system disease that affects brain and spinal cord), heavy metals are also toxic to the aquatic life.[8,9] Previous study in the research area revealed that auto-mechanic activities contribute to the release of heavy metals into the environment.[10] However, this study is aimed at using pollution index to assess the eco-contamination profile of heavy metals as a result of auto-mechanic activities in Akure metropolis.

2. Materials and Methods

2.1. The Study Area

Akure is a metropolitan city in south-western Nigeria and it lies about 7.0°15'N of the equator and 5.0°15'E of the Meridian. The city is situated in the tropic rainforest zone in Nigeria.

2.2. Preparation of Sample Containers

Polythene bags were used for the collection of soil samples. These bags were previously soaked in 14% HNO_3 for 24 hours to remove all entrained metals, washed with detergents and rinsed with deionized water.

2.3. Collection of Soil Samples

Soil hugger was used to collect six soil samples from auto-mechanic garage and control site (FUTA residential staff quarters) in Akure metropolis. The soil samples were kept in labelled polythene bags and taken to the laboratory for analysis. All soil samples were air dried ground and sieved through a 2 mm sieve mesh before chemical analysis was carried out.

2.4. Fractionation and total concentration of Heavy metals in Soil

The exchangeable (F1) and carbonate fractions (F2) of heavy metals was done by using the sequential extraction procedure,[3-5,11] while the total concentration of heavy metals in soil was done by using Aqua Ragia to digest 2 g of the air-dried soil samples. The quantification of heavy metals in the soil samples was determined by using atomic absorption spectroscopy.

2.5. Assessment Indices for Heavy Metal Contamination

Five (5) risk assessment indices, fractionation studies and comparative analysis of the total concentration of the analyzed heavy metal with USEPA maximum permissible limit and world shale background values were carried out in order to access the contamination levels of heavy metals in the soil samples.[12,13]

2.5.1. Risk Assessment Code (RAC)

The total concentration of heavy metals in soil and sediment matrixes is inadequate to provide information on the toxicity of heavy metals in the environment, because the mobility and bioavailability which is a function of the toxicity of heavy metals depends on the chemical fractions of heavy metals. RAC is defined as:

$$RAC = Exc\% + Carb\%$$

Exc% and Carb% are percentages of metals in exchangeable and carbonate fractions. According to RAC values: RAC≤1% (no risk), 1%<RAC≤10% (low risk), 10%<RAC≤30% (medium risk), 30%<RAC ≤50% (high risk) and 50%≤RAC (very high risk).

2.5.2. Contamination Factor (CF)

The contamination level of a particular toxic substance can be illustrated by using the contamination factor (CF). A high CF indicates anthropogenic impact on the environment while a low CF indicates no considerable anthropogenic impact on the environment, contamination factor is determined using the following index: CF <1 (low CF), 1 ≤ CF < 3 (moderate CF), 3 ≤ CF < 6 (considerable CF), CF ≥ 6 (very high CF).[3-5]

CF = Co/Cb where Co = concentration of metal in soil, Cb = background concentration of metal.[12-15]

2.5.3. Ecological Risk Index (RI)

Potential ecological risk index from a sedimentology perspective was used to access the toxicity of heavy metal contaminants in soil matrixes. The potential risk index method gives a relationship between the concentration of heavy metals in the sample and the background value of the analyzed heavy metals. Ecological risk index comprises a single contamination coefficient, a comprehensive contamination measure, the toxic response factor for heavy metals, and a potential ecological risk index.[15,16] The mathematical expression of Risk Index can be shown as:

$$E_i = T_i \times \frac{Ci}{Co}$$

Where T_i is the toxic response factor for a given substance (e.g., Cd = 30, Hg= 40, As= 10, Pb = Ni = Cu = 5, Cr = 2, Zn = 1), C_i represents metal concentration in soil and C_0 is the regional background value of heavy metals. As the regional background values of measured heavy metals were unavailable, the metal concentrations for the world shale average were chosen as the background value.[3-5]

The categorization of Ecological risk index for values E_i <40, 40≤ E_i <80, 80 ≤ E_i <160, 160 ≤ E_i < 320 and 320 ≤ E_i indicate low (slightly), moderately, strongly, very strongly and extremely toxic in designation to the soil.[3-5]

2.5.4. Geoaccumulation Index (I_{geo})

The geoaccumulation Index (I_{geo}) is a widely used empirical relationship for evaluating the degree of metal contamination or pollution in soil or sediment samples of terrestrial or aquatic environments.[3-5] The geoaccumulation index can be mathematically expressed as follows:

$$I_{geo} = \log_2\left(\frac{Cn}{1.5Bn}\right)$$

Where Cn is the measured concentration of heavy metal (n) in the sediment, Bn is the geochemical background value of heavy metal (n), and 1.5 is the background matrix correction factor due to lithogenic effects. In the present study, Bn was selected from the control site average of heavy metals.[3-5] Categorization of Geo-accumulation index for I_{geo} values of >5, 4-5, 3-4, 2-3, 0-1 and 0 indicate an I_{geo} class of 6, 5, 4, 3, 2 and 1 which has soil quality designation of extremely contaminated, strongly to extremely contaminated, strongly contaminated, moderately to strongly contaminated, uncontaminated to moderately contaminated and uncontaminated respectively.

2.5.5. Enrichment Factor (EF)

The enrichment factor (EF) is an analytical measure of geochemical trends of heavy metals; it is a useful contamination index in determining the degree of anthropogenic heavy metal pollution. The enrichment factor of heavy metals in soil and sediment matrixes helps to understand whether certain heavy metals were present in high concentrations relative to the concentrations in the earth's crust by using the relevant equation.[17-23]

Table 1. The results of total metal concentration in soil (mg/kg)

Site/heavy metals	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Auto-mechanic Garage	7.50±0.01	22.00±0.07	33.25±0.35	6475.00±0.35	5.00±0.02	60.00±0.01	48.50±0.31
Control site	0.10±0.02	0.40±0.066	18.36±0.02	3546.00±0.35	0.19±0.03	22.90±0.05	22.42±0.07
MPL	3.00	400.00	50.00	NL	50.00	300.00	200.00

MPL= maximum permissible limit,[13] NL= No limit

Table 2. Assessment indices for the analyzed heavy metals in the soil samples

Assessment index/heavy metals	RAC (%)	E_i	I_{geo}	CF	EF
Cd	0.80	225.00	2.32	7.50	4.96
Cr	10.73	1.26	-1.25	0.63	0.95
Cu	12.24	116.25	4.47	33.25	21.97
Fe	0.09	1.00	-1.18	0.66	1.00
Ni	20.75	12.5	0.74	2.50	3.78
Pb	31.11	42.85	2.51	8.57	12.97
Zn	21.12	3.03	1.02	3.03	4.59

RAC = Risk assessment code, E_i = Ecological Risk index, I_{geo} = Geoaccumulation index, CF = Contamination Factor, EF = Enrichment factor

In this study, iron was considered as a reference element for geochemical normalization, the background value was selected from the world shale average of heavy metals.[3-5] The EF for each of the heavy metals was calculated in order to evaluate the anthropogenic influence on heavy metals in the soil using the formula:

$$\mathbf{EF} = \frac{\left[\frac{Cx}{CFe}\right]\mathbf{sample}}{\left[\frac{Cx}{CFe}\right]\mathbf{background}}$$

CX = Concentration of heavy metals, CFE = Concentration of iron

Categorization of Enrichment factor (EF) values of < 0.5, 0.5-1.5, 1.5-2, 2-5, 5-20, 20-40 and > 40 indicate an EF Class of 0, 1, 2, 3, 4, 5 and 6 which corresponds to enrichment from point and non-point source, enrichment entirely from crustal materials, minimal enrichment, moderately enrichment, significant enrichment, very high enrichment and extremely high enrichment respectively.

3. Results and Discussions

3.1. Eco-contamination based on the total concentration of heavy metals in soil

The total concentration of heavy metals in the research areas are summarized in table 1.

From table 1, it can be deduce that the total concentration of the heavy metals from auto-mechanic activity sites exceeded that of the control site as a result of the release of auto-mechanic waste which contains heavy metals. Moreover, the concentration of cadmium in the auto-mechanic sites was observed to exceed the maximum permissible limit.[10]

3.2. Eco-contamination based on pollution indices

The assessment indices for the analyzed heavy metals in the soil samples from auto-mechanic activity sites are summarized in table 2.

The values for the risk assessment index for the analyzed heavy metals in the soil samples collected from auto-mechanic activities is depicted in Table 2. The calculated RAC values indicated that Cd and Fe fell below 1, thereby posing no risk to the environment, while Cr, Cu, Ni, Pb and Zn metals fell in the region of medium risk category to the environment. This result is contrary to the report on assessment of heavy metals in the sediments of Xiawan Port.[24] However, with the exception of Cd, the total concentration of the analyzed heavy metals in the soil samples fell below the USEPA maximum permissible limit.[13,24] The ecological index revealed that Cd and Cu which fell in the region of strongly and very strongly toxic to the environment, in contrast, other metals fell in the region of slightly toxic to the environment. This result is in concord with the previous research on heavy metals in road deposit in Suleja.[25] The geoaccumulation index revealed that Cr, Ni and Fe fell in the unpolluted class, while Cd, Cu and Pb fell in the region from moderately to strongly polluted, this result indicate that the accumulation of Cd, Cu and Pb in the research may have resulted the auto-mechanic activities. This result is in agreement with the research on heavy metal distribution in Calabar.[26] The contamination factor revealed that with the exception of Cu, Cd and Pb, other metals have CF which varied from low to moderate. This report agrees with previous study on heavy metal pollution in tropical lagoons.[27] Table 2 revealed that the enrichment factor (EF) values were lesser than 40 for all the analyzed heavy metals. This result indicated that the analyzed heavy metals are not highly enriched in the study area. This agrees with the research on geochemical fractionation of heavy metals in sediment of Tapi estuary.[14]

4. Conclusions

This study investigated the eco-contamination assessments of heavy metal in auto-mechanic activities from Akure metropolis, the findings can be summarized in the following ways as stated below:

1. Risk assessment based on the levels of heavy metals revealed that the total concentration of the analyzed heavy metals in the soil samples collected from auto-mechanic sites were reportedly higher than those collected from the control sites, this indicated that anthropogenic activities such as auto-mechanic activities are responsible for these results

2. Risk assessment on the basis of risk assessment indices is stated as follows:

(a) According to RAC, the analyzed heavy metals fell in the category of medium risk except Cd and Fe which fell in the category of low risk, thereby suggesting a low probability of posing risk to the environment due to its low percentages in the exchangeable and carbonate fractions, which means they cannot be easily leach into the environment.

(b) According to risk index, Cd and Cu has high risk index, while the other metals have at a low risk to the environment because the risk index values of the investigated heavy metals are less than 40.

(c) According to geoaccumulation index, the analyzed heavy metals fell below class 5, except Cu which fell in class 5

(d) According to contamination factor, the analyzed heavy metals had a low contamination factor, except Cd, Cu and Pb which has a contamination factor value above 6

(e) According to enrichment factor, the analyzed heavy metals fell below EF class 6, thereby suggesting that the analyzed heavy metals are not high enriched in the study area.

3. Finally, it is of uttermost important for auto-mechanic workers to make use of efficient methods which will prevent the improper discharge of auto-mechanic waste into the environment.

Conflicts of Interest

The authors declare no conflict of interest.

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