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# Evaluation of Heavy Metal Levels and its Applications in Risk Assessment Indices in the Soils of Some Communities in Gokhana Local Government Area, Rivers State, Nigeria

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**Abstract** Soil samples were collected at a depth of 0-40cm from four communities (Yeghe, Bodo, B-Dere and K-Dere) in Gokana Local Government Area of Rivers State, Nigeria to evaluate the concentration of some (Cd, Pb, Cr, Cu, Fe and Ni) within the locality. The levels of heavy metals in the soils were determined using Atomic Absorption Spectrophotometer. The levels of the studied heavy metals were below the values allowed as limit for heavy metals in agricultural soil. The results showed that the mean concentrations (mg/kg) of the heavy metals were in the order Fe (174.926) >Cr (4.119)>Cu (4.030) > Ni (3.810) >Pb (2.687) > Cd (1.501). The contamination level in the investigated communities of Gokhana were in the order Yeghe > Bodo > K-Dere > B-Dere. The pollution evaluation indices applied in the assessment of the anthropogenic influence on the soils' quality in the Gokhana communities using the DPR approved limit as the criteria of judgement were, Geo-accumulation index (Igeo), enrichment factor, potential ecological risk coefficient ($E^i_r$) and potential ecological risk index (RI). These indices indicated that the soils of the communities were not yet contaminated nor polluted to the level that will pose any ecological risks by heavy metals as the values obtained were far lower than the DPR acceptable limits. The government and relevant agencies should therefore protect and regulate the soil environment of Gokhana local Government Area so that the levels of heavy metals will not increase in other to preserve the health status of the inhabitants.

**Keywords** heavy metals, soil, Gokhana, geo-accumulation, enrichment factor, contamination, ecological risk

## Introduction

Soil is the organic and inorganic part of the earth that cover the rocky part of the earth. The decayed parts of plants and animals which is mostly found on the uppermost part of the soil is the organic part while the fragments of rocks formed due to the chemical and physical wearing away of the bedrock formed thousand years ago make up the inorganic part of the soil. The soil is important for the production of crops and animals (agriculture) in order to supply the world food, it requires [1]. The soil is subject to environmental changes and is sensitive to variations that take place within the soil environment [2]. The soil is the major reservoir for heavy metals and of primary importance in the natural cycle of heavy metals [3-4].

Heavy metals are natural components of the soil and mostly exist combined in nature. Heavy metals are being added daily to the soil directly or indirectly due to human activities such as industrialization, agriculture and waste disposal [5]. The accumulation of heavy metals in the soil is being transferred to plants and through the consumption of the contaminated plant in the form of food which is being transferred to animals and man. The transfer of heavy metals is as a result of the interface between the soil and the roots of plants. Heavy metals are persistent, non-degradable and harmful to the environment and as a result of that becomes very important in the life of humans [6-7].

The contamination and pollution of the soil by heavy metals due to high concentrations affects the functions of the soil, growth of microbes and the composition of microbes within the environment [8]. The pollution of the soil, through the food chain processes can affect the health status of humans; heavy metals have been associated with human diseases such as nervous disorder, cancer and others which affect the various organs or parts of the body [9]. The contamination of the soil can come from acid precipitation, waste disposal, radioactive decay, aerial deposition, agricultural chemicals, gasoline, paints and petrochemicals spill [10-11].

The concentrations of heavy metals at high levels has negative effects on the ecosystem, agriculture and human health. The high levels of heavy metals such as Cd, Cu, Pb, Hg and As possesses potential human health hazards [12]. There is therefore the need to emphasize the health risk associated with heavy metals as reported by certain authors [13]. The application of certain indices will enable the understanding of the ecological risks and health risks associated with heavy metals and the impacts heavy metals creates in the soil [14].

This work investigated the level of heavy metals in the soils of five communities in Gokhana with particular reference to Cd, Pb, Cr, Cu, Fe and Ni. The study also made use of ecological risk evaluation indices such as; geo-accumulation index (Igeo), Enrichment factor ($E_f$), ecological risk factor ($E^i_r$) and potential ecological risk index (RI) to assess the degree of pollution by these heavy metals and also ascertain the level of anthropogenic influence on the soils of these communities in Gokhana Local Government Area of Rivers State, Nigeria.

## Materials and Methods

### Collection of Soil Samples

Soil samples from four communities (Yeghe, Bodo, B-Dere and K-Dere) in Gokana Local Government Area were randomly collected with the help of soil auger. A composite sample was formed by the combination of samples collected from three different points in a sampling station. Soils samples from the different communities in Gokhana were collected in March and November of 2020. The soil auger was washed thoroughly after the collection of samples from any particular location and allowed to dry in order that samples from one station/location will not interfere or influence that from another location/station. The collected samples were kept in polythene bags which were labelled according to where they were collected. The polythene bags were used for the preservation of the samples and then transferred to the laboratory for pretreatment, digestion and analysis for the determination of the levels of different heavy metals in the soil.

### Sample Pretreatment and Soil Digestion

The collected soil samples were then dried overnight using an oven under regulated temperature of 105°C in order that there will be a separation between the heavy metals and the soil particles. The already dried samples were then mechanically sieved using a 0.5mm sieve and then pulverized about 0.063mm size after it has been homogenized according to the pattern used by Madrid *et al*., [15], and Sherbiny *et al*., [16]. The ground soil particles were weighed to 1.00g±0.01 accuracy and the digestion of the soil was performed by adding a mixture of nitric acid and perchloric acid ($HNO_3/HClO_4$) using the ratio 4:1 in a previously cleaned beaker. The already digested samples were then heated at a regulated temperature of 40°C for a period of one hour and then increased to 140-170°C for an interval of 4 hours till a clear solution was obtained. The clear solution was filtered and then diluted to 50ml by adding deionized water.

### Determination of Heavy Metals

Atomic Absorption Spetrophotometer (SG71906 Model) was used in the analysis of the level of heavy metals in the studied soils of the communities of Gokhana according to the pattern adopted by APHA-AWWA-WPCF [8]. The digested sample was aspirated directly into a nitrous oxide/acetylene flame which was generated by a cathode lamp at a specified wavelength for any given heavy metal to be determined. For each of the metals investigated, calibration curves were obtained first for blank samples and standards set before sample aspiration. The concentrations of each of the heavy metals were then displayed by the system monitor at a specific absorbance. The levels of the heavy metals were recorded in mg/Kg for the soil sample under a detection limit of <0.001mg/Kg. The heavy metals analyzed were Fe, Pb, Cu, Cd, Cr and Ni.

**Pollution Assessment Indices**

These are pollution indices that indicates the degree of pollution and the level of intensity as a result of anthropogenic activities that has influenced the metal concentration of the soil. The indices applied in this study were; geo-accumulation index (Igeo), enrichment factor (EF), potential ecological risk coefficient ($E^i_r$), and potential toxicity response (RI). The background values of heavy metals used in this work were limits allowed by Directorate of Petroleum Resources (DPR) [17].

**Geo-accumulation Index (Igeo)**

The index compares the contamination of the level of heavy metals at present and pre-industrial (original) level of the soils under examination or study. The method of computation used by Muller [18] was applied in this work.

$Igeo = Log_2 [(Cn)/(1.5Bn)]$

Where, Cn is the recorded concentration of metal investigated, Bn is the background value of metal investigated recorded by DPR, 1.5 is a constant which minimizes the effect of variation on the background level as a result of lithologic processes.

The classification interval used in interpreting the geo-accumulation index used by Odewande and Abimbola [19] and was adopted in this study is Igeo < 0, not contaminated, 0 < Igeo < 1, not contaminated to moderately contaminated, 1 < Igeo < 2, moderately contaminated, 2 < Igeo < 3, moderately to strongly contaminated, 3 < Igeo < 4, strongly contaminated, 4 < Igeo < 5, strongly to extremely contaminated and Igeo > 5, extremely contaminated.

**Potential Ecological Risk Coefficient ($E^i_r$)**

The$E^i_r$index was calculated by applying the equation of Hakanson [20] which is mathematically expressed as,

$E^i_r = T^i_r \times C^i_r = T^i_r \times C^i_s / C^i_n$

Where, $T^i_r$is the toxic response factor of the heavy metal, $C^i_r$ is the contamination factor of the heavy metal, $C^i_s$ is the recorded concentration of heavy metals in the studied soil and $C^i_n$ is the background concentration value for the investigated heavy metals. The response factors for the investigated heavy metals are Cd; 30, Pb; 5, Cu; 5, Cr; 2 and Ni = 5.

The classification interval or categories of interpretation of potential ecological risk coefficient are given as; $E^i_r < 40$; low level of risk, $40 \leq E^i_r < 80$; moderate level of risk, $80 \leq E^i_r < 160$; considerable level of risk, $160 \leq E^i_r < 320$; high level risk and $E^i_r \leq 320$; very high-risk level.

**Potential Ecological Risk Index (RI)**

The RI index is mathematical expressed with the relation

$RI = \Sigma E^i_r$

This index is a multiple index used in the calculation of the total sum of various risk factors and in assessing the level of toxicity of the various heavy metals that was investigated in the soil. The terms of interval of classification applied in estimating the degree of potential ecological risk index are RI < 150; low ecological risk, 150 ≤ RI < 300; moderate (reasonable) ecological risk, 300 ≤ RI < 600; considerable ecological risk and RI > 600; very high (excessive) ecological risk.

**Enrichment Factor**

The mathematical expression of the enrichment factor index is given as;

$EF = [(C_n/C_{ref}) \text{ sample}/B_n/B_{ref}]$

Where, $C_n$ (sample) is the concentration of the investigated heavy metal, $C_{ref}$ is the concentration of the referenced heavy metal in the environment which is Fe in this study, $B_n$is the reference heavy metal's background value and $B_{ref}$ is the value of the background reference heavy metal (Fe) in the environment referenced in average value in shale's as first used by Turekian and Wedepohl [21]

The enrichment factor index assesses the geochemical changes among regions and forecasts the probableorigin and sourceof heavy metals' spread within the environment [22].

The categories for the enrichment factor and interpretations are given as; EF < 2; minimally enriched, 2 ≤ EF < 5; moderately enriched, 5 ≤ EF < 20; significantly enriched, 20 ≤ EF < 40; very highly enriched and EF > 40; extremely enriched.

## Results and Discussion

### Heavy Metals Levels in the Communities of Gokhana Local Government Area

The results for the concentrations of heavy metals in the soils of the selected communities of Gokhana Local Government Area are presented in Tables 1 and 2 while the average concentrations of the heavy metals are presented in Table 3 and the mean concentrations of each of the studied heavy metals in the communities of the local government area are provided in Figure 1. The mean concentrations of heavy metals occurred in the communities in the order, Bodo> Yeghe > B-Dere > K-Dere with an average value of 1.501mg/Kg for Cd, Bodo > Yeghe >B-Dere > K-Dere with an average of 2.687mg/Kg for Pb, Bodo > B-Dere >Yeghe >K-Dere with an average of 4.030mg/Kg for Cu, Yeghe >Bodo > K-Dere > B-Dere with an average of 174.926mg/Kg for Fe and Yeghe > Bodo >B-Dere > K-Dere with an average of 3.810mg/Kg for Ni, for the local government area. The average level of contamination by the heavy metals within the communities of the local government area as shown in Figure 1 followed the order Fe > Cr > Cu > Ni > Pb > Cd.

The values obtained in this research were lower than that recorded in the investigation carried out by Gbarako and Konne [23], Boisa and Bekee [24]. The level of heavy metals recorded were lower than the approved limit by the Directorate of Petroleum Resources (DPR) [17] and the mean values obtained in this study were lower than NOAA acceptable values (world soil reference) [25] which are given as; Cr; 37, Ni; 13, Pb; 16 and Cd; 1.6.The results of heavy metals concentrations obtained in the soils of the different communities of Gokhana showed very slight variations. This result may be a revelation that similar activities take place within the soil environment of these communities and that the distribution, geologic formations and the source of the heavy metals in the agricultural farmlands of these communities are similar or the same. The results obtained for heavy metals concentrations in the Gokhana communities might be due to the low levels of contaminants let out into the environment and the rate at which these heavy metals are being deposited [26].

**Table 1:** Heavy Metals Concentration in Soils of Selected Communities in Gokhana Local Government Area in March

| **Heavy Metals (mg/Kg)** | **Stations** | | | |
|---|---|---|---|---|
| | **Yeghe** | **Bodo** | **B-Dere** | **K-Dere** |
| Cd | 1.493 | 1.698 | 1.421 | 1.410 |
| Pb | 2.720 | 3.210 | 2.709 | 2.121 |
| Cr | 4.121 | 4.984 | 4.738 | 3.017 |
| Cu | 3.312 | 4.335 | 4716. | 3.720 |
| Fe | 215.115 | 184.116 | 139.800 | 159.618 |
| Ni | 4.709 | 3.776 | 3.713 | 3.036 |

**Table 2:** Heavy Metals Concentration in Soils of Selected Communities in Gokhana Local Government Area in November

| Heavy Metals (mg/Kg) | Stations | | | |
|---|---|---|---|---|
| | Yeghe | Bodo | B-Dere | K-Dere |
| Cd | 1.435 | 1.772 | 1.432 | 1.395 |
| Pb | 2.713 | 3.186 | 2.720 | 2.116 |
| Cr | 4.101 | 4.879 | 4.741 | 3.005 |
| Cu | 3.311 | 4.332 | 4.710 | 3.800 |
| Fe | 217.115 | 183.211 | 139.812 | 159.620 |
| Ni | 4.721 | 3.781 | 3.701 | 3.041 |

**Table 3:** Mean Concentrations of Heavy Metals in Soils of Selected Communities in Gokana Local Government Area

| Heavy Metals (mg/Kg) | Stations | | | |
|---|---|---|---|---|
| | Yeghe | Bodo | B-Dere | K-Dere |
| Cd | 1.437 | 1.735 | 1.427 | 1.403 |
| Pb | 2.717 | 3.198 | 2.715 | 2.119 |
| Cr | 4.111 | 4.932 | 4.740 | 3.011 |
| Cu | 3.312 | 4.334 | 4.713 | 3.760 |
| Fe | 216.615 | 183.665 | 139.806 | 159.619 |
| Ni | 4.715 | 3.779 | 3.707 | 3.039 |

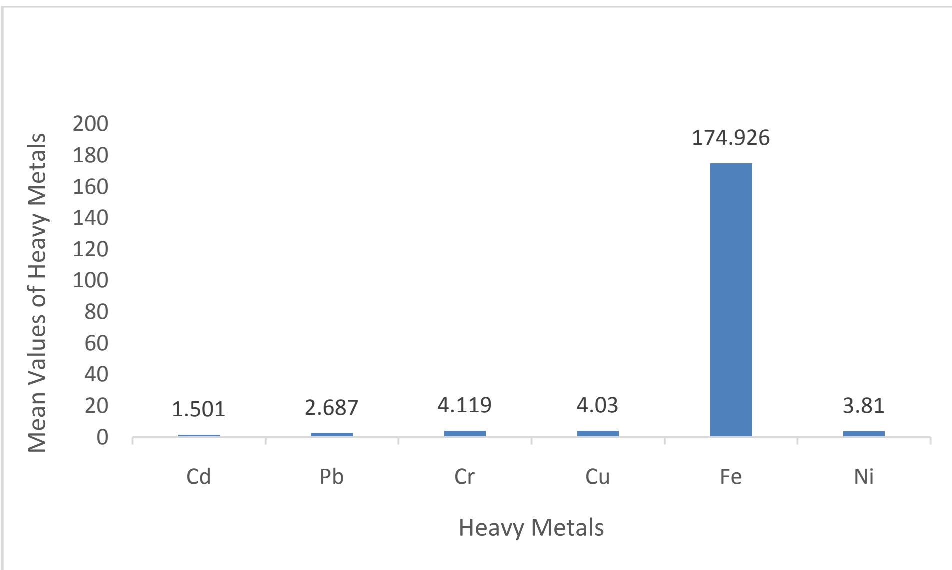


*Figure 1: Mean Concentrations of Heavy Metals (mg/Kg) in Soils of Selected Communities in Gokhana*

**Geo-accumulation Index (Igeo)**

Table 4provided the results for the geo-accumulation index of heavy metals in the soil of selected communities of Gokana Local Government Area. The results obtained for geo-accumulation index of the studied heavy metals were Cd; 1.189, Pb; 0.021, Cr; 0.027, Cu; 0.061, Ni; 0.090 and Fe; 0.001 for Yeghe, Cd; 1.446, Pb; 0.025, Cr; 0.033, Cu; 0.080, Ni; 0.072 and Fe; 0.001 for Bodo,Cd;1.189, Pb; 0.021; Cr;0.032, Cu; 0.080, Ni; 0.071 and Fe; 0.001 for B-Dere and Cd; 1.169, Pb; 0.017, Cr; 0.020; Cu; 0.070, Ni; 0.058 and Fe; 0.001 for K-Dere. The average values recorded for the geo-accumulation of the heavy metals in the local government area were Cd; 1.251, Pb; 0.021, Cr; 0.028, Cu; 0.075, Ni; 0.073 and Fe; 0.001. The results obtained for all the heavy metals in the soils of the different communities were greater than zero but lower than one which fall into the range of no contamination to moderate contamination except Cd that was greater than one in all the soils in the communities studied in Gokhana but was less than 2 which revealed that Cd was in the range of moderate contamination. The geo-accumulation of the heavy metals in this region was low possibly due to the absence of industries that directly influence the input of heavy metals into the soil. The predominant occupation of the Gokhana people is farming and the non-usage of inorganic fertilizers to boost agricultural produce must also have accounted for the record of heavy metals in the area.

**Table 4:** Analysis of Heavy Metals Geo-Accumulation Indexin the Soils of Selected Communities in Gokhana Local Government Area

| Heavy Metals | Stations | | | | Mean |
|---|---|---|---|---|---|
| | Yeghe | Bodo | B-Dere | K-Dere | |
| Cd | 1.189 | 1.446 | 1.189 | 1.169 | 1.251 |
| Pb | 0.021 | 0.025 | 0.021 | 0.017 | 0.021 |
| Cr | 0.027 | 0.033 | 0.032 | 0.020 | 0.028 |
| Fe | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Cu | 0.061 | 0.080 | 0.080 | 0.070 | 0.075 |
| Ni | 0.090 | 0.072 | 0.071 | 0.058 | 0.073 |

**Enrichment Factor (EF)**

The results obtained for the enrichment factors of the heavy metals studied in selected communities of Gokhana are provided in Table 5. The results obtained from Yeghe soil were Cd; 315.104 which fall in the classification of EF > 40, Pb, Cr and Cu were 5.607, 7.212 and 16.139 which is classified under 5 ≤ EF < 20 category, while Ni; 23.632 fall into the category 20 ≤ EF < 40. The results of enrichment factor in Yeghe soil showed that Cd was extremely enriched, Pb, Cr, and Cu were significantly enriched while Ni had very high enrichment. In Bodo, Cd was 448.703, Pb was 7.784, Cr was 10.204, Cu was 24.908 and Ni was 22.339. The results from Bodo indicated that Cd was extremely enriched, Pb and Cr were significantly enriched while Cu and Ni very highly enriched. The results from B-Dere were Cd; 484.824, Pb; 8.682, Cr; 12.884, Cu; 35.584 and Ni; 20.671, which clearly showed that Cd was extremely enriched, Pb and Cr were significantly enriched while Cu and Ni were enriched very highly. The results from K-Dere indicated Cd; 417.503, Pb; 5.935, Cr; 7.168, Cu; 24.865 and Ni; 20.671 which revealed that Cd was enriched extremely, Pb and Cr were enriched significantly while Cu and Ni were enriched very highly. Observation from the mean values obtained indicated that enrichment of the soils of the various communities of Gokhana by the heavy metals follow the order Cd > Cu > Ni > Cr > Pb. The order of enrichment of the soils from the Gokana communities follow the order B-Dere > Bodo > K-Dere > Yeghe. The source of enrichment of the soil might possibly be from anthropogenic sources since the enrichment factors obtained in all the communities of Gokhana were above 1.5, for Zhang and Liu [27] recorded that enrichment factors greater 1.5 has source of anthropogenic origin while those below and within 1.5 had their source from geogenic and diagenic origin.

**Table 5:** Analysis of Heavy Metals Enrichment Factor ($E_F$) in the Soils of Selected Communities in Gokana Local Government Area

| Heavy Metals | Stations | | | | Mean |
|---|---|---|---|---|---|
| | Yeghe | Bodo | B-Dere | K-Dere | |
| Cd | 315.104 | 448.703 | 484.824 | 417.503 | 416.534 |
| Pb | 5.607 | 7.784 | 8.682 | 5.935 | 7.002 |
| Cr | 7.212 | 10.204 | 12.884 | 7.168 | 9.367 |
| Cu | 16.139 | 24.908 | 35.584 | 24.865 | 25.374 |
| Ni | 23.632 | 22.339 | 28.788 | 20.671 | 23.858 |

**Potential Ecological Risk Coefficient ($E^i_r$) and Potential Ecological Risk Index (RI)**

The results for $E^i_r$and RI are provided in Table 6. The mean values obtained for $E^i_r$in the Gokhana communities for the investigated heavy metals appeared in the order Cd >Cu> Ni > Cu > Pb >Cr. The mean values obtained were Cd; 56.269, Pb; 0.158, Cr; 0.084, Cu; 0.560and Ni; 0.545. The $E^i_r$ values obtained for Cd ranged between 53.513 to 65.063, Pb; 0.125 to 0.188, Cr; 0.060 to 0.099, Cu; 0.460 to 0.655 and Ni; 0.434 to 0.674, within the soils of the investigated communities in Gokhana Local Government Area. The values for potential ecological risk coefficients for the heavy metals investigated in the selected communities of Gokana Local Government Area were far less than 40 apart from Cd which was between 53.513 to 65.063. The obtained results indicated that all the heavy metals investigated were low in ecological riskwhile Cd was at moderate ecological risk.

The results for Potential Ecological Risk Index (RI) for the soils of the different communities of Gokhana were Yeghe; 55.263, Bodo; 66.492, B-Dere; 54.953 and K-Dere; 53.500 with an average of 57.616 for the local government area. The results indicated that Bodo > Yeghe > B-Dere > K-Dere. Considering the interval of classification, the values obtained in all the communities were in the zoneof potential ecological risk index RI < 150, therefore the soils of the Gokhana communities were at very low level of ecological risk.

**Table 6:** Ecological Risk Coefficient ($E^i_r$) and Potential Ecological Risk Index (RI) of Heavy Metals in Soils of Selected Communities in Gokhana Local Government Area

| Heavy Metals | Stations | | | | Mean |
|---|---|---|---|---|---|
| | Yeghe | Bodo | B-Dere | K-Dere | |
| Cd | 53.887 | 65.063 | 53.513 | 52.613 | 56.269 |
| Pb | 0.160 | 0.188 | 0.160 | 0.125 | 0.158 |
| Cr | 0.082 | 0.099 | 0.095 | 0.060 | 0.084 |
| Cu | 0.460 | 0.602 | 0.655 | 0.522 | 0.560 |
| Ni | 0.674 | 0.540 | 0.530 | 0.434 | 0.545 |
| RI | 55.263 | 66.492 | 54.953 | 53.500 | 57.616 |

## Conclusion

The contamination of heavy metals (Cd, Pb, Cr, Cu, Fe and Ni) in the soils of the selected communities in Gokhana Local Government Area, Rivers State, Nigeria indicated no contamination to moderate contamination. The low concentration of heavy metals was possibly due to the low industrial activities in the area, since the inhabitants are mostly farmers. The application of certain pollution indices such as Igeo, $E^i_r$, RI, and EFto evaluate the degree to which the soils of the different communities have been contaminated revealed that the soils were still at low level of contamination, low enrichment level and therefore at low health risk by heavy metals. The soils of the Gokhana communities have not been greatly influenced by anthropogenic activities. The government and other relevant agencies should therefore keep in adequate check and monitor the activities within the area so that there will not be a sudden increase in the concentrations of heavy metals in the area and the health of the inhabitants will not be affected.

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