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Ecological Risk Assessment of Heavy Metals in Soils of Biseni, South-South Nigeria

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ABSTRACT

Heavy metals are natural constituents of the environment. However, when such heavy metals occur in significantly high concentrations exceeding acceptable limits, they become toxic and harmful to both human health and ecological balance. This study was aimed investigating the concentration levels and distribution patterns of selected heavy metals in soils around Biseni in Yenagoa. Five heavy metals – cadmium (Cd), copper (Cu), iron (Fe), nickel (Ni) and lead (Pb) – were the focus of the present study. Geochemical determination of heavy metals concentrations was carried out using the atomic absorption spectrophotometry (AAS) technique. The heavy metals were randomly distributed with the mean concentrations in the order of Cu > Ni > Cd > Fe >Pb. The specific ranges of the concentrations of the heavy metals in the soil are Cd (< 0.001 mg/kg – < 3.045mg/kg), Cu (0.946mg/kg – 4.680 mg/kg), Fe (o.542 mg.kg – 2.876 mg/kg), Ni (< 0.001 mg/kg – 3.849 mg/kg) and Pb (< 0.001 mg/kg – 0.008 mg/kg). The study revealed that heavy metals concentrations in some of the sampled soils exceed the World Health Organization (WHO) recommended maximum permissible limits of Cd, Ni and Cu whereas the observed Pb and Fe concentrations in the soils were well within the acceptable limits. It is inferred that the significantly high concentrations of Cd, Ni and Cu in the soils is as a result of human activities in the area, particularly hydrocarbons exploration and exploitation. In view of the observed random distribution relatively toxic concentrations of some of the heavy metals in the soils in Biseni, it is recommended that appropriate remediation efforts and strategies be adopted even as more detailed, periodic assessment and reassessment of heavy metals studies on the environment in the area are recommended.

1. INTRODUCTION

As population increases with the attendant urbanization and industrialization, there is often a corresponding rise in the rates and incidents of environmental degradation. Specifically, the rapid population growth and urbanization of Yenagoa over the last few decades has resulted in the significant increase in the amount of wastes – agricultural, domestic and industrial wastes – generated within the metropolis. These wastes occur in different forms and shapes (atmospheric, chemical, water-borne, organic and solid wastes). As a result of the rapid increase in population and the associatedurbanization, there has been

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severe social and demographic pressure on the environment (Ohwo, 2015; Imaitor-Uku*et al.,* 2021). According to Ekanem, Osabor&Ekpo (2019), automobile vehicles and workshops were such vehicles are repaired are a common source of soil pollutants, including polycyclic aromatic hydrocarbons and heavy metals. They opined that notwithstanding the numerous environmental pollutions resulting from mechanical workshops however, these forms of environmental degradation are often overlooked by researchers and policy makers.

Around Bayelsaand other parts of the Niger-Delta, heavy metals have been identified as common contaminants of soils and water (Iwegbue*et al.*, 2013; Fatoba*et al.*, 2015; Addey*et al*., 2018). Due to their toxicity and tendency for bioaccumulation in living organisms, heavy metals have been the subject of increasing environmental health concerns and research in recent years (Calmuc*et al*., 2021).

The soil, being a natural component of the ecosystem, acts as a reservoir for different pollutants, including heavy metals (Calmuc*et al.*, 2021). Food has been identified as one of the major exposure sources or entry routes for heavy metals into the human body (Kinuthia et al., 2020), making the need for proper and regular investigation of the concentration levels of heavy metals in soils extremely important. More so, given that the Niger Delta is a major hydrocarbons producing area, the need to regularly environmental integrity and quality in the region cannot be overemphasized. This is especially essential in view of the fact that the Niger Delta has been identified as a fragile ecosystem with a history of series of environmental pollutions (Nwankwoala&Mzaga, 2017; Ugboma, 2015; Ohimain, 2003). Therefore, the present study seeks to examine the distribution patterns of selected heavy metals in soils around Biseni in Yenagoa, South-South Nigeria.

Location and Accessibility

The present study was carried out around Biseni in Yenagoa, the capital of Bayelsa State in southern Nigeria (Figure1). Yenagoa occupies between latitude 4°48′00″ and 5°24′10″ north of the Equator and between longitude 6°12′00″ and 6°39′30″ east of the Greenwich Meridian (Imaitor-Uku*et al.,* 2021). A linear settlement, Biseni is situated along the coast of the Atlantic Ocean. Yenagoa is generally believed to have an average height not exceeding 15 metres above sea level, making vulnerable to flooding, both from sustained rainfall and the potential rise in sea level due to Global Warming and Climate Change (Imaitor-Uku*et al.,* 2021; Ohwo, 2015).

Yenagoa is surrounded by different states and local government areas. The city s bordered by Delta and Rivers states to the northwest and northeast respectively. It is bordered by Ogbia and Southern Ijaw local government areas to the southeast and southwest respectively (Imaitor-Uku*et al.*, 2021). As a state capital, the city of Yenagoa is one of the fast urbanizing settlements in contemporary Nigeria. Between 1988 and 2020, the built-in-areas in the city increased from 6.12% to 50.09% whereas there was a marked decrease in the amount of land occupied by vegetation cover from 89.67% to 45.76% (Imaitor-Uku et al., 2021). Culturally, Biseni and the entire Yenagoa area is occupied by the Izon (Ijaw) people of the Niger Delta and their language is Ijaw. The people of the area are predominantly fishermen, although urbanization and the presence of oil and gas companies in the area have brought about series of secondary and tertiary production activities.

Figure 1: Map of Yenagoa showing study area.

Justification for the Study

Findings from this research will provide insight into heavy metals concentrations and distribution patterns in Biseni and therefore, contribute towards the effective management of the environment in the area, providing useful too both for researchers and policy makers. The findings from the study will also provide a useful reference material for future research in the area of with regards to environmental pollution and as such, contributing to the existing body of knowledge on environmental pollution in the Niger Delta.

2. MATERIALS AND METHODS

For the purpose of this research, the under-listed materials were used for data collection and analysis: GERMIN 76 CSX Global

Positioning System (GPS), Sample bags, Auger, Field notebook, Masking Tape, Marker and Atomic Absorption Spectrophotometer (AAS).

Data Collection

A total of ten (10) soil samples were collected for this study. In order to ensure that the samples collected were truly representative of characteristics of the area of the study, the 10 samples were collected from different parts of Biseni. Sampling was concentrated on both residential and industrial areas. Also, to ensure that cross-contamination from external sources, the auger sample collector was thoroughly rinsed with distilled water before being used to collect soil samples. Soil samples were then collected at depth of about 15 cm. The samples were then put into the polyethylene bags and properly labeled using masking tape and permanent markers. Thereafter, the samples were taken the laboratory for analysis. The essence of using polyethylene bags instead of metallic cans for sample collection was to avoid contamination from such metallic containers.

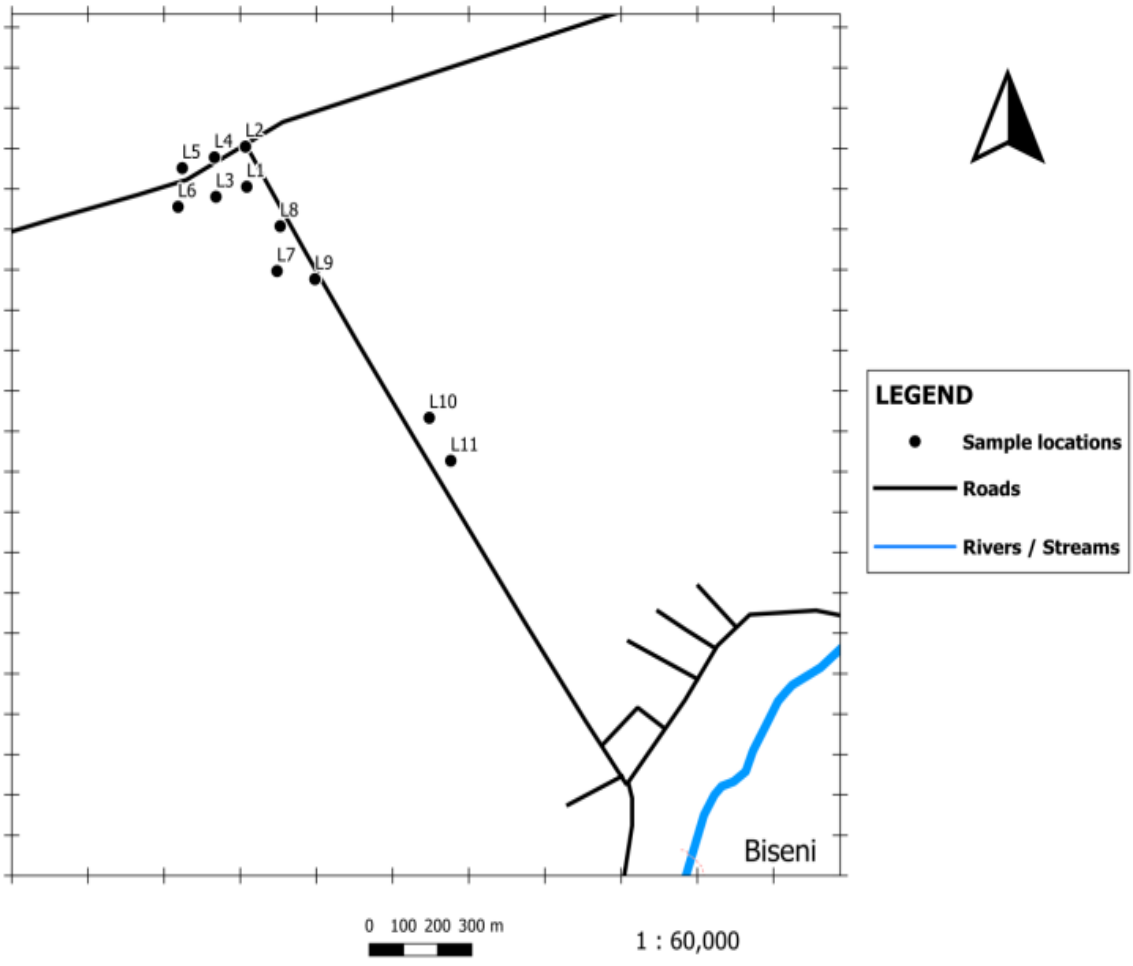

Figure 2: Location Map of the study area showing sampling points.

Plate1: Field data gathering

3. PRESENTATION OF RESULTS

The results of the laboratory analysis carried out to ascertain the heavy metals distribution in soils around Biseni are given in the table below.

Table 1: Concentration of heavy metals in the soil within the study area.

S/N	Sample Label	Cd (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
1	BS1	< 0.001	4.226	0.542	0.117	< 0.001
2	BS2	0.003	3.006	0.897	< 0.001	< 0.001
3	BS3	< 0.001	2.115	1.242	2.116	0.008
4	BS4	0.082	0.946	0.687	0.296	0.003
5	BS5	0.011	1.446	0.942	3.157	< 0.001
6	BS6	0.008	4.412	0.877	0.821	0.006
7	BS7	2.888	4.68	0.767	1.122	< 0.001
8	BS8	3.045	3.819	1.444	3.849	0.01
9	BS9	1.116	2.91	0.867	0.128	0.006
10	BS10	2.001	1.458	2.876	< 0.001	0.008
	Min.	0.003	0.946	0.542	0.117	0.003
	Max.	3.045	4.68	2.876	3.849	0.008
	Mean	1.144	2.902	1.114	1.451	0.007
	St. Dev.	1.3306	1.362	0.6711	1.4379	0.0024

The World Health Organization (WHO) limits for the analyzed heavy metals in soils are shown in the table below.

Table 2: WHO limits for analyzed parameters

S/N	Parameter	WHO Limit (mg/kg)	Source(s)
1	Cd	0.003	Kinuthia et al. (2020)
2	Cu	3.5	Vodyanitskii (2016)
3	Fe	300	Iyama et al. (2022)
4	Ni	0.05	Kinuthia et al. (2020)
5	Pb	0.1	Kinuthia et al. (2020)

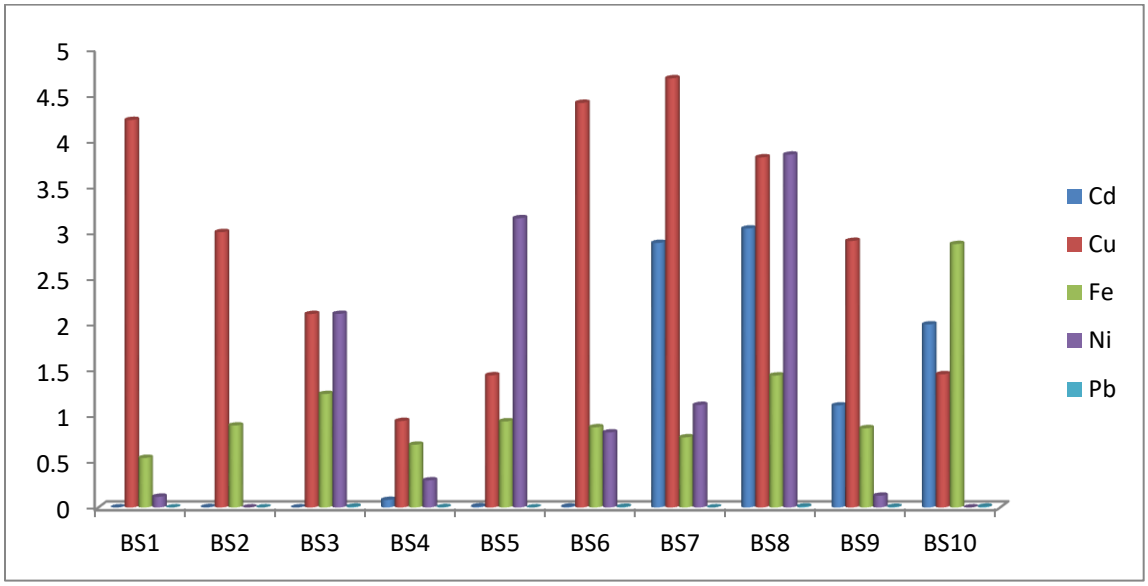

Figure 3: Histogram showing the gross concentrations of the selected heavy metals in soils in Biseni

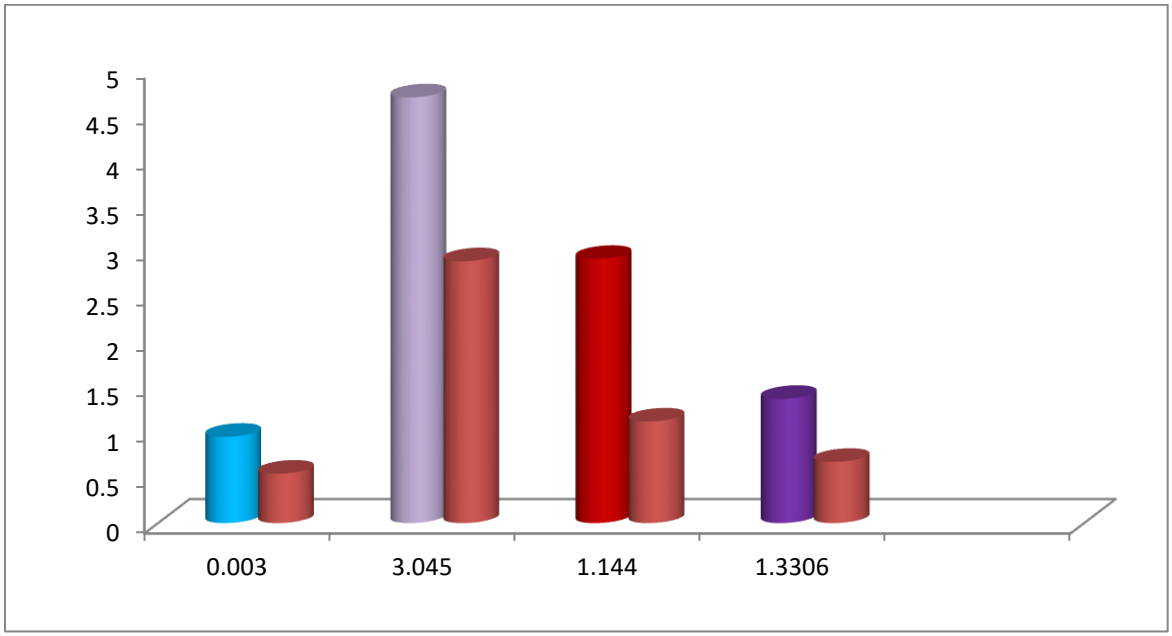

Figure 4: Histogram showing the mean concentrations of the selected heavy metals in soils in Biseni.

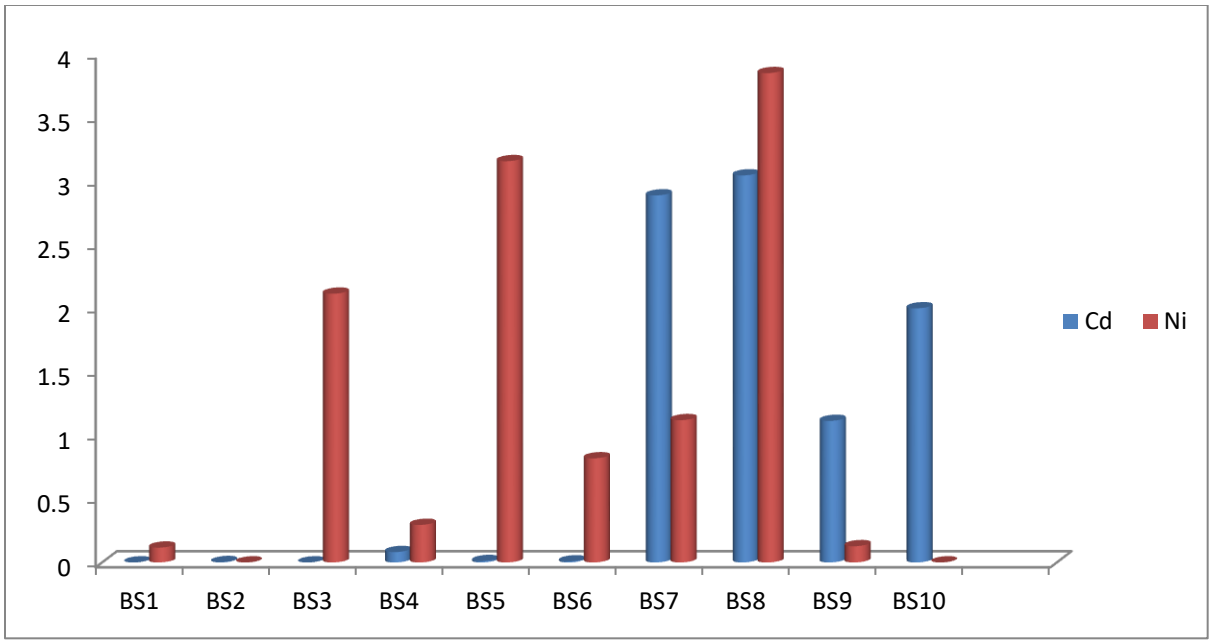

Figure 5: Histogram showing comparative distribution of Cd and Ni in soils around Biseni

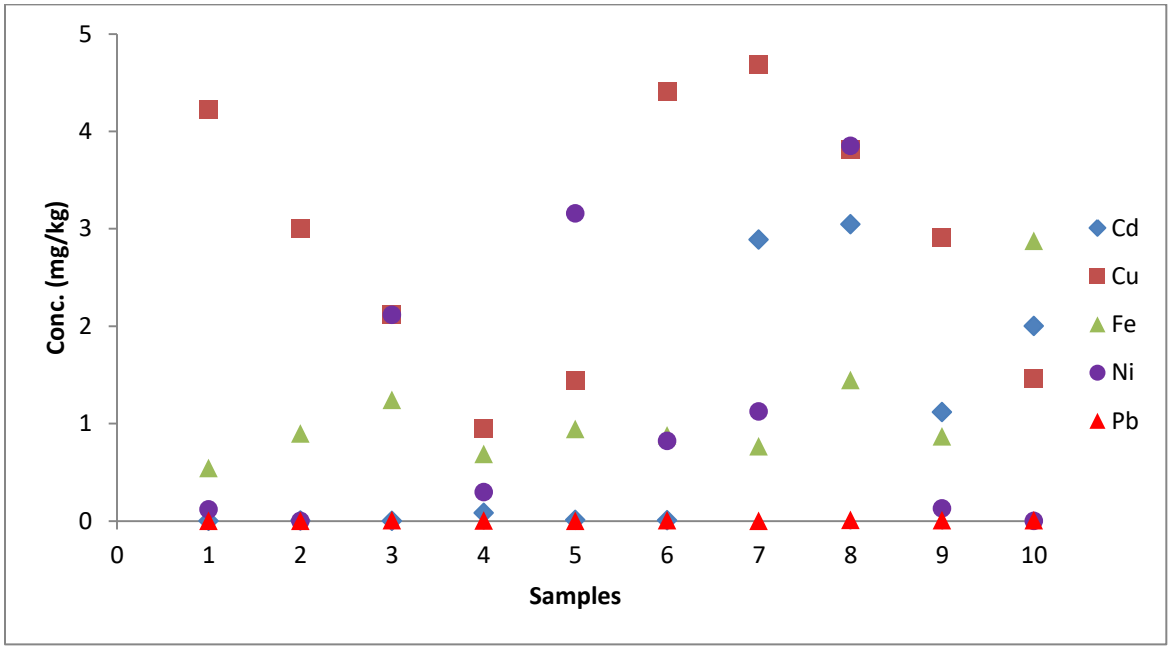

Figure 6: Plot of concentrations versus samples for the soils of the study area.

4. CONCLUSION

This study was carried out to investigate the distribution pattern of heavy metals in soils in Biseni in Yenagoa. Five (5) heavy metals of interest were selected for the study – Cd, Cu, Fe, Ni and Pb. A total of ten (10) soil samples were collected from the area of the study and taken to the laboratory for analysis to determine the concentrations of the aforementioned heavy metals in the soils in the area. Geochemical analysis to ascertain the heavy metals concentrations was carried out using the AAS technique.

Results from the geochemical analysis show that the concentrations of the selected heavy metals were randomly distributed in the soils within the area of the study. Whereas Pb and Fe were well within the WHO maximum permissible limits in soils, the concentrations of Cd, Ni and Cu exceeded the recommended allowable limits in many of the samples analyzed. In general, the mean distribution trend of the heavy metals in soils around Biseni as revealed from the geochemical analysis is Cu > Ni > Cd > Fe >Pb. The significant enrichment of Cd, Cu and Ni in the soils of the area of the study is believed to have resulted from anthropogenic activities, particularly oil and gas operations within the area. Similar heavy metals contaminations of soils have also been reported in other parts of the Niger Delta and are likewise considered to have been as a consequence of hydrocarbon exploration and exploitation within the region.

Arising from the findings from this study, the following conclusions have been made:

i. That anthropogenic activities, especially those related to oil and gas operations have adversely impacted the soils in Biseni in Yenagoa.

ii. That the environmental impacts of hydrocarbons exploration and exploitation vary from place to place as shown in the wide ranges of concentrations of heavy metals in soils in the area of the study. These random distributions can be local or regional but are largely dependent on the actual anthropogenic activities carried out and the intensity of such activities.

iii. If no mitigation and remediation activities are carried out, the observed toxic levels of heavy minerals in the soils in the area have the potentials for serious environmental health problems for the people of the area and the ecological balance in general, particularly when exposed to foods and animals produced from the area among others.

iv. Notwithstanding the relative similarity between the findings from this study and some previous studies from the area, the sample size of 10 is statistically small to make valid conclusions of regional importance. Consequently, it is advisable that findings from the study should be treated as tentative pending when more comprehensive studies confirm the outcomes reported here.

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