Faculty of Natural and Applied Sciences Journal of Applied Chemical Science Research
Print ISSN: 3027-0359
www.fnasjournals.com
Volume 2; Issue 1; September 2024; Page No. 48-51.

Investigation of Heavy Metal Presence and Concentration in Soils Around Selected Quarries in the FCT, Abuja

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Abstract
This paper investigates the presence and concentration of heavy metals in the soils around selected quarry of the Federal Capital Territory (FCT), Abuja, Nigeria. Investigation of soils around quarry sites was carried out to assess the presence and concentrations of some heavy metals in the soils. It involves the collection of soil samples between the depth of 15-30cm. the soil samples were digested, and a Thermo Scientific Atomic Absorption Spectrophotometer (AAS) was used to measure the concentrations of Cadmium, chromium, zinc, copper and lead metals. The result shows the presence of Lead (Pb), Chromium (Cr), Cadmium (Cd), Zinc (Zn) and Copper (Cu) heavy metals in quarry soils; at significant concentration levels within the quarry site at 0.05 percent level of probability, using one-way ANOVA. The heavy metals were at higher concentrations in the soils around the quarry sites while the control site recorded lower concentrations. Heavy metals concentration at the quarry sites falls within the acceptable limit of World Health Organization standards except for Cadmium (Cd) and Zinc (Zn). The study recommends the need for proper regulation of quarrying activities especially as it relates to the establishment of quarries in areas of predominant existence of economic trees, especially the edible ones, amongst other recommendations.

Keywords: Quarrying activities, Heavy Metals, Economic trees, Federal Capital Territory (FCT)

Introduction

Heavy metals are high-density metallic chemical elements that are toxic at low concentrations (Lentech, 2020). Examples of these metals include Mercury (Hg), Cadmium (Cd), Arsenic (As) Chromium (Cr), and Lead (Pb). According to Lentech (2020), heavy metals are natural components of the earth's crust. They cannot be destroyed, and they can enter our bodies via food, drinking water and air. Some heavy metals, like Copper, Selenium and Zinc are essential to maintain the metabolism of the human body (Lentech, 2020). However, they can lead to poisoning at higher concentrations. Heavy metals exhibit bioaccumulation (Lentech, 2020). This is the increase in the concentration of a chemical in a biological organism over time, in comparison with the environmental concentration. Elements with high density and high atomic weight showing metallic properties are known as Potential Toxic Elements (Om, 2018). Cobalt, Copper, Iron, Manganese, Molybdenum, Nickel and Zinc, which are PTE can be beneficial to the biological human system, at permissible amounts (Om, 2018). Pb, Cd, Hg and AS which are soil potentially toxic elements are harmful to crops, humans and animals (Om, 2018). Anthropogenic activities add PTE to soils, even though they can naturally be found in soils. In metallic mines and serpentinite quarries, soils formed have high levels of heavy metals, among other unfavourable features (Lago-Vila et al., 2017). They can cause surface and subsurface water contamination when released into the environment. Their uptake by plants and an accumulation in the food chain have adverse effects on living organisms.

According to Okafor (2006), rock quarrying and stone crushing happen globally, and it is a cause for concern. Quarrying activities provide materials used in hard flooring. These materials include granite, limestone, marble and slate (Okafor, 2006). These activities have a significant impact on the environment. Vegetation is often under intense human pressure in mining (quarrying) areas where surface mining activities are prevalent. These results in changes in land use/land cover of mine areas (Adewoye, 2005; David & Mark, 2005). Some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations, they can lead to poisoning (Lentech, 2020). Heavy metal poisoning could result, for instance, from drinking-water contamination (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food chain (Lentech, 2020). Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment (Lentech, 2020). Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted (Lentech, 2020). Sources of heavy metal poisoning include Mining (which includes quarrying), industrial wastes, treated timbers, etc (Lentech, 2020).

Potentially toxic elements are elements with high density and high atomic weight, showing metallic properties such as ductility, malleability, conductivity, and ligand specificity (Om, 2018). Some potentially toxic elements such as Co, Cu, Fe, Mn, Mo, Ni and Zn are beneficial to the biological system when present in permissible amounts but damage the biological system if present in excess (Om, 2018). Soil potentially toxic elements such as Pb, Cd, Hg and As (a metalloid but generally referred to as a potentially toxic element) are harmful to crops, humans and animals. Potentially toxic elements are added to the soil naturally and by anthropogenic activities (Om, 2018). Soils formed in metallic mines and serpentinite quarries, among other unfavourable features, have high levels of heavy metals. They can be released into the environment causing surface and subsurface water contamination, uptake by plants, their accumulation in the food chain and adverse effects on living organisms (Lago-Vila et al., 2017). Rock quarrying and stone crushing is a global phenomena and have been the cause of concern everywhere, including the advanced countries (Okafor, 2006). Quarrying activity is a necessity that provides much of the materials used in traditional hard flooring, such as granite, limestone, marble, sandstone, slate and even just clay to make ceramic tiles. However, like many other man-made activities, quarrying activities have a significant impact on the environment (Okafor, 2006). Although vegetation is of high environmental and biological importance, it is often under intense human pressure in mining (quarrying) areas especially where surface mining and illegal small-scale mining activities are prevalent, resulting in changes in land-use/land-cover of mine areas (Adewoye, 2005; David & Mark, 2005).

Quarrying activities facilitate the supply of raw materials to meet some of the society's needs. However, they can have negative effects on the environment, and local communities, including the soil (Osha,2006). Several studies (Anand, 2006; Aigbedion, 2005; Adekoya, 2003) have shown that quarrying activities harm the environment. Therefore, this research paper aims to determine the impact of quarrying activities on the presence and concentration of heavy metals in the soils of some selected quarries in the Federal Capital Territory (FCT), Abuja.

Materials and Methods

The research was carried out in two selected quarry sites: CCECC quarry located at the Idu industrial area of AMAC, and Zeberced quarry located along the Kubwa/Bwari area of the FCT.

Table 1: GPS of sampling points

Sampling locations	latitude	Longitude
1. CCECC quarry	9$^{o.}$ 0048’	7^{o} .4109’
2. Zeberced quarry	9$^{o.}$ 1631’	7^{o} ·3093’
3. Control site	9^{o}. 0108’	7^{o}. 4134’

Soils from the two quarry sites and the control site were taken to the laboratory for analysis. Cadmium, chromium, lead, zinc and copper were analyzed in all the soil samples. Thermo Scientific Atomic Absorption Spectrophotometer (AAS) was used to measure the concentrations of Cadmium, chromium, zinc, copper and lead metals. About 2g of each perfume sample was acidified with 1 ml of nitric acid (HNO_3) and 0.5 ml of tetra-oxo-sulphate IV acid (H_2SO_4). The mixture was digested in a fume cupboard for 30 minutes at 100 ºC until a clear solution was seen. The mixture was transferred to 100 ml volumetric flask and diluted with deionized water and the mixture made up to 100 ml mark. The mixture was filtered with Whatmann No. 1 filter paper after cooling and analyzed for lead, chromium and cadmium using the Atomic Absorption Spectrophotometer (Chauhan et al., 2014). Standard solutions were prepared with the salts of the various metals analyzed. The amount dissolved in 1 litre of distilled water was calculated by dividing the molecular weight by the atomic mass. Copper sulphate has a molecular weight of 249.68 and copper has an atomic mass of 63.55. Therefore 249.68/ 63.55= 3.93g of copper sulphate was dissolved in 1 litre of distilled water. The same was done for all the salts. The following salts were used for the heavy metals and they were of Analar R grade BDH chemical Ltd Poole England. Cadmium sulphate ($CdSO_4$), lead nitrate ($(PbNO_3)_2$, and chromium sulphate ($CrSO_4$) was used for lead, cadmium and chromium respectively. The standard solutions were prepared and analyzed in the Atomic Absorption Spectrometer (AAS) (Model Thermo Scientific AAS iCE 3000 series) to get the absorbance and to prepare a calibration curve, from which the concentration of the heavy metal was read directly. Distilled water was used as the blanks.

Cite this article as:
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Results

The results of the investigation of the presence and concentration of heavy metals in some selected quarries are shown in Table 2.

Table 2: Summary of Heavy Metals Actual Mean Concentrations at Quarry Sites and Control Site

Samples	**Mean Concentrations in mg/kg**				
	Pb	Cr	Cd	Zn	Cu
Q1	12.2600±0.0	30.5900±0.0	4.7800±0.0	54.4000±0.0	4.6950±0.0
Q2	10.8250±0.0	58.6450±0.0	4.2400±0.0	52.0800±0.0	5.9900±0.0
Control	08.6750±0.0	29.2150±0.0	3.6500±0.0	28.4400±0.0	3.5250±0.0
Acceptable Limit	85	100	0.8	50	36

Each value represents mean ± standard deviations of triplicate values

Key

Q1	Quarry site 1
Q2	Quarry site 2

The result from Table 2 shows the presence and concentrations of Lead (Pb), Chromium (Cr), Cadmium (Cd), Zinc (Zn) and Copper (Cu) in soils around the quarry sites investigated (Q1, Q2 and the Control Site). It was observed that the actual mean concentration of Lead (Pb) in the sampled soil was 12.26 mg/kg for Q1, 10.83 mg/kg for Q2 while the control site was 8.68 mg/kg. This shows that the highest concentration level of Lead (Pb) was recorded in the soil around site Q1 and the lowest concentration was recorded at the control sites. The standard threshold or acceptable limit of lead (Pb) is 85 mg/kg. It was observed that the mean concentration of Chromium (Cr) in the sampled soil was 30.59 mg/kg for Q1, 58.65 mg/kg for Q2 while the control site was 29.22 mg/kg. This shows that the highest Chromium (Cr) concentration was recorded in the soil around site Q2 and the lowest concentration was recorded at the control sites. The standard threshold or acceptable limit of Chromium (Cr) is 100 mg/kg. It was observed that the mean concentration of Cadmium (Cd) in the sampled soil was 4.78 mg/kg for the soil around Q1, 4.24 mg/kg for the soil around Q2 while the control site was 3.65 mg/kg. This shows that the highest Cadmium (Cd) concentration was recorded in the soil around site Q1 and the lowest concentration was recorded at the control sites. The standard threshold or acceptable limit of Cadmium (Cd) is 0.8 mg/kg. It was observed that the mean concentration of Zinc (Zn) in the sampled soil was 54.4 mg/kg for Q1, 52.08 mg/kg for Q2 while the control site was 28.44 mg/kg. This shows that the highest concentration level of Zinc (Zn) was recorded in the soil around site Q1 and the lowest concentration was recorded at the control sites. The standard threshold or acceptable limit of Zinc (Zn) is 50 mg/kg. It was observed that the mean concentration of Copper (Cu) in the sampled soil was 4.70 mg/kg for Q1, 5.99 mg/kg for Q2 while the control site was 3.53 mg/kg. This shows that the highest concentration level of Copper (Cu) was recorded in the soil around site Q2 and the lowest concentration was recorded at the control sites. The standard threshold or acceptable limit of Copper (Cu) is 36 mg/kg.

Discussion

From the research study, using ANOVA at 0.05 level of probability, there is a significant difference in the concentration of heavy metal elements in the soil samples. It was observed that the concentration levels of all the investigated heavy metals were higher in the soils around quarry sites than at the control site. They all equally fall within the WHO acceptable limits except Cadmium and Zinc that has a higher concentration level above the WHO permissible limit (4.78 mg/kg for Q1, 4.24 mg/kg for Q2, control site was 3.65 mg/kg, all above the acceptable limit of 0.8 mg/kg for Cadmium. For Zinc, 54.4 mg/kg for Q1 and 52.08 mg/kg for Q2 are above the permissible 50 mg/kg). The presence of heavy metals at the quarry sites agrees with most research studies which have shown the presence of heavy metals in soils around quarry and mining sites. However, there are varying concentrations of these heavy metals at respective or various soils around quarry and mining sites. The natural zinc content of soils is estimated to be 30mg/kg. The presence of zinc in the environment is associated with mining and smelting which pollutes the air, water and soil with fine particles, which ultimately undergo oxidation to release Zn^{2+} (Tiimub et al., 2015). The higher concentration of the Zinc metal in the study sites even above the WHO acceptable limit may be attributed to the quarrying activities. Also, in a research study carried out by Lago-Vila et al. (2017), severe Cadmium contamination was observed in the Serpentine quarry soils. This goes further to affirm the findings of this research study. Furthermore, Oyeyemi et al. (2019) observed the presence and contamination of Cadmium in the soil and the possible interference in the biochemical pathways, in their research work on the Geospatial Distribution of Heavy Metal Contamination. This equally has lent credence to the findings of this research study. It is good to note that caution needs to be taken on the higher concentrations of Cadmium and Zinc in the soils above the standard threshold limits.

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Conclusion

The presence and concentration levels of lead (Pb), Chromium (Cr), Cadmium (Cd), Zinc (Zn) and Copper (Cu) were carried out. The presence of heavy metals was established and the mean concentration levels were recorded. The heavy metals concentration levels were compared with the WHO standard threshold limits and their threats to life were clarified. It was observed that Cadmium and Zinc in the soils around both quarry sites were above the WHO standard threshold. Hence caution should be taken on the consumption of edible fruit trees and other edible economic trees within the quarry sites as this may be injurious to health.

Recommendations

1. Heavy metals have been established to be harmful to health even in low quantities, and when they are above a certain threshold.
2. Heavy metals have been established in this research study, and the concentrations of Cadmium and Zinc are high above the WHO threshold. Therefore, caution should be taken when consuming fruits from edible trees within these quarry sites.
3. Further studies should be carried out to establish the uptake and concentration levels of these heavy metals in the economic/edible trees within the quarry sites. And also, to determine the presence and concentrations of other heavy metals within the quarry sites.

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