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A GIS-based analysis of heavy metals around Otukpo rice mill in Benue state

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Abstract

Heavy metals are primarily sourced from natural pedo-geochemical backgrounds and anthropogenic occurrences like composting, sewage sludge, aerosol deposition, and waste animal manure. The study aims to determine the heavy metals within the rice mill in Otukpo to understand the spatial distribution with the objectives to examine the heavy metals within the identified activity areas in the Otukpo rice mill, to determine the spatial distribution of heavy metals within the study area and to compare heavy metal values with the acceptable limits. Soil samples were collected from ten locations at Otukpo Rice Mill to analyze heavy metal concentrations. The samples were collected using sterile bottles and a stainless trowel, and the soil samples were analyzed for the concentrations of Cadmium, Copper, Lead, Nickel, Zinc, Mercury, Iron, Arsenic, and Chromium using the Atomic Absorption Spectrophotometry method. The result was analyzed using interpolation to see the variation of the Heavy metals within the various activity areas. The result of the study reveals that Iron has the highest concentration at the Entrance point and lowest at the Generator house with a range value of 3.92 – 1.12mg/kg respectively. The highest concentration of Zinc was recorded at the Mechanic workshop while the lowest is at the Drying point with a range value of 0.135 – 0.872mg/kg respectively. The Husk dumpsite recorded the highest concentration of Copper (0.666mg/kg) with the Drying point recording the least (0.088 mg/kg). The study reveals uneven concentrations and highlights the effectiveness of the Geographic Information System in mapping heavy metal concentrations.

Keywords: Heavy Metal; Soil; Rice Mill; Spatial Distribution; Concentration; Industrial Areas

1. Introduction

1.1. Background of study

Soil is a major sink for metals released from various anthropogenic activities, including transport, agriculture, and waste disposal. [1] [2] [3]. Heavy metals are primarily sourced from natural pedo-geochemical backgrounds and anthropogenic occurrences like composting, sewage sludge, aerosol deposition, and waste animal manure. [4] Other anthropogenic routes include industrial emissions, waste generation, agricultural activities, metalliferous mining, energy production, and vehicle emissions.

Heavy metals pose an environmental burden, causing toxic effects on living organisms when concentrations exceed certain water, soil, and food levels. [5]

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[6] Heavy metal accumulation in surface soils is influenced by environmental factors, soil properties, and human activities. Researchers emphasize continuous monitoring of soil heavy metal concentration, particularly in industrial areas, as a significant problem. [7]

The study aims to determine the heavy metals within the rice mill in Otukpo to understand the spatial distribution with the objectives to examine the heavy metals within the identified activity areas in the Otukpo rice mill, to determine the spatial distribution of heavy metals within the study area and to compare heavy metal values with the acceptable limits.

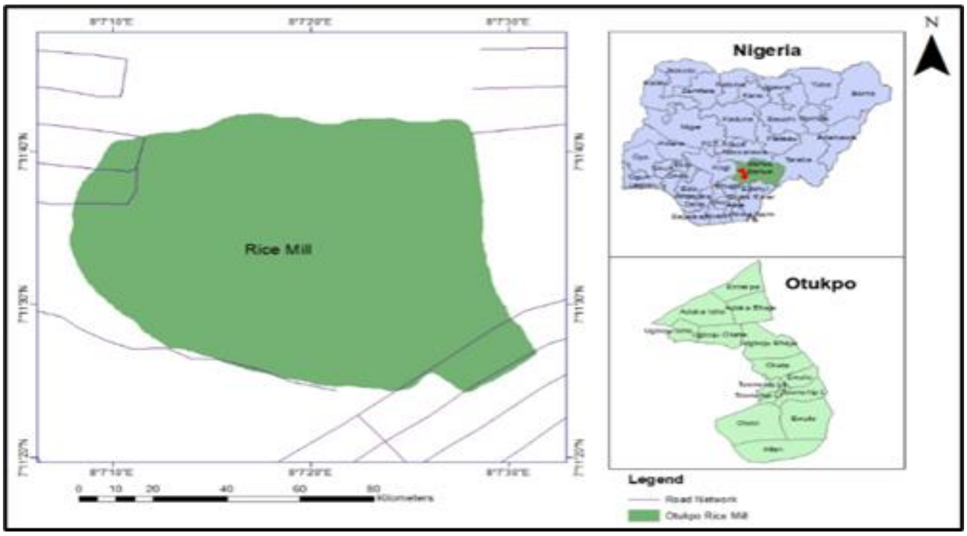

Figure 1 Study area map

Figure 2 Satellite view of the study area

2. Research methodology

2.1. Materials and Methods

Soil samples were collected from ten locations at Otukpo Rice Mill to analyze heavy metal concentrations. The samples were collected using sterile bottles and a stainless trowel, and the soil samples were analyzed for the concentrations of

Cadmium, Copper, Lead, Nickel, Zinc, Mercury, Iron, Arsenic, and Chromium using the Atomic Absorption Spectrophotometry method. The research aimed to cover different levels of activities within the mill.

2.2. Soil Samples Analysis

Soil samples were mixed, air-dried, and crushed to remove moisture. Crushed samples were sieved for pH, organic carbon, and total metal content, and pulverized to a fine powder.

2.3. Spatial Analysis and Mapping Soil Concentration

The study mapped metal concentrations in soil samples using spatial interpolation, a statistical method that predicts attribute values at unsampled sites. Descriptive statistics determined data range, mean, and standard deviation. This study employed the use of an interpolation known as ordinary kriging.

2.4. Data Analysis

The rice milling factory activity area consists of various sections, which include; an entrance, dumpsite, warehouse, generator house, parboiling, green vegetation, drying, and mechanic workshop. Descriptive statistics were used to represent heavy metal dispersion and element activity.

3. Results and discussion

3.1. Soil Physiochemical Properties

Table 1 Summary of heavy metal levels in Otukpo Rice Mill soil, including range, mean, and standard deviation. According to World Health Organization Table 2, there are permissible limits for heavy metals in soil.

Cadmium		**Copper**	**Lead**	**Nickel**	**Zinc**	**Iron**	**Mercury**	**Arsenic**
1	0.037	0.582	0.027	0.466	0.743	3.92	0.006	0.05
2	0.048	0.66	0.333	0.562	0.386	1.23	0.003	0.042
3	0.032	0.592	0.016	0.43	0.664	3.36	0.005	0.055
4	0.039	0.513	0.023	0.447	0.648	2.24	0.003	0.037
5	0.033	0.428	0.022	0.483	0.582	1.12	0.003	0.04
6	0.032	0.428	0.016	0.43	0.386	1.12	0.006	0.037
7	0.048	0.666	0.033	0.562	0.743	3.92	0.003	0.058
8	0.038	0.555	0.024	0.478	0.605	2.23	0.002	0.046
9	0.006	0.088	0.016	0.051	0.135	1.25	0.004	0.009
10	0.033	0.153	0.023	0.562	0.872	1.12	0.003	0.05
Minimum	0.006	0.088	0.016	0.051	0.135	1.12	0.002	0.009
Maximium	0.048	0.666	0.333	0.562	0.872	3.92	0.006	0.058
Mean	0.035	0.467	0.053	0.447	0.576	2.15	0.004	0.042
S.D	0.011	0.227	0.0934	0.141	0.203	1.122	0.001	0.012

Table 2 Elevated heavy metal concentrations in Otukpo Rice Mill.

Heavy metals	Target value of soil(mg/kg) by world health organisation
Iron	-
Zinc	12 – 60
Mercury	0.001 – 0.04
Copper	1 – 12
Cadmium	0.002 – 0.5
Chromium	0.002 – 0.2
Lead	0.3 – 10
Nickel	0.1 – 5

3.2. Heavy Metal Distribution in Soil Within Otukpo Rice Mill

3.2.1. Iron Concentration

Iron is the most abundant metal in heavy metal concentration analysis around Otukpo Rice Mill, with concentrations ranging from 1.12-3.92mg/kg. Iron (Fe) concentrations in other areas range from 1746.4-2839.4mg/kg. [8] Iron may be attributed to motor vehicle scraps and leaching from iron melting. The entrance point has the highest Iron concentration, while the generator house, mechanic workshop, and warehouse points have the lowest. [9]

3.2.2. Zinc Concentration

Zinc is the second most abundant heavy metal in the study, with concentrations ranging from 0.135mg/kg to 0.872mg/kg. The permissible limit is 12-60mg/kg. [10] Industrial sources and motor vehicle tyres contribute to zinc concentrations. The mechanic workshop has the highest concentration, while drying points, untampered land, and husk dumpsite have the lowest.

3.2.3. Copper Concentration

Copper is the third most abundant heavy metal in the study area, with values ranging from 0.088mg/kg to 0.666mg/kg. The WHO recommends a permissible limit of 1-12mg/kg for soil. [11] However, the concentration observed is lower than waste dumpsite concentrations reported for soil dumpsites. Long-term exposure to copper can cause irritation, headaches, stomachaches, dizziness, vomiting, and diarrhea. [12].

3.2.4. Nickel Concentration

Nickel is the fourth most abundant heavy metal in Nigeria, with values ranging from 0.051mg/kg to 0.562mg/kg. The WHO recommends a permissible limit of 0.1-5mg/kg. However, the values of Nickel obtained from the study area were lower than the level found in urban soils in Nigeria [13]. The highest concentrations are found in mechanic houses, green vegetation, untampered land husk dumpsites, and entrance, indicating that nickel is found in trace amounts in the environment.

3.2.5. Chromium Concentration

The study found chromium concentrations ranging from 0.015mg/kg to 0.163mg/kg in various sites, with an average mean of 0.12mg/kg. The permissible limit is 0.002-0.2mg/kg. Similarly low levels of chromium have been observed in surface soils under waste dumps in Onitsha, Nigeria [14] and soils along foam manufacturing industries [15]. The highest concentration was found at dumpsites, while the lowest was at dry points and mechanic workshops. Adverse effects include ulcerations, dermatitis, and allergic skin reactions.

3.2.6. Lead Concentration

Low levels of lead were found in soil samples from study sites, with concentrations ranging from 0.016mg/kg to 0.333mg/kg. The WHO recommends a permissible limit of 0.3-10mg/kg. [12] Lead concentrations in large quantities can be toxic and have adverse effects on humans and animals.

3.2.7. Arsenic Concentration

Arsenic concentrations in the site ranged from 0.009mg/kg to 0.058mg/kg, with untampered land, husk dumpsite, mechanic workshop, entrance point, and dumpsite having the highest concentrations. High inorganic form poses a significant public health threat, with long-term exposure causing cancer and skin lesions.

3.2.8. Cadmium Concentration

The soil concentration of cadmium in the site was found to be lower than WHO's permissible limit of 0.002 - 0.5mg/kg. [16] This could be due to vulcanization in car tires or lubricating oils in old tires. Untampered land and husk dumpsites had the highest cadmium concentration while drying points had the lowest. Human exposure to cadmium occurs through inhalation or ingestion.

3.2.9. Mercury Concentration

The site had mercury concentrations ranging from 0.002mg/kg to 0.006mg/kg, with a mean of 0.004mg/kg. The WHO recommends a permissible limit of 0.001-0.04mg/kg. Mercury poisoning can cause diseases like acrodynia, Hunter-Russell syndrome, and Minamata disease. Heavy metal concentrations are shown in Figures 4.1- 4.10.

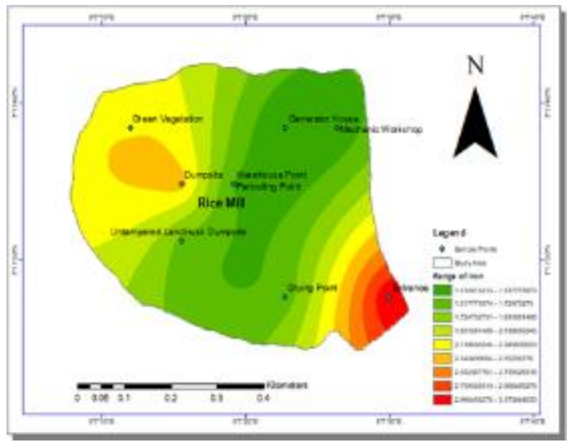

Figure 3 Concentration of Iron

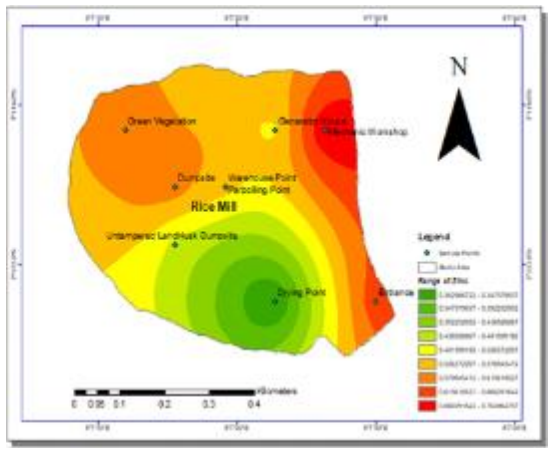

Figure 4 Concentration of Zinc

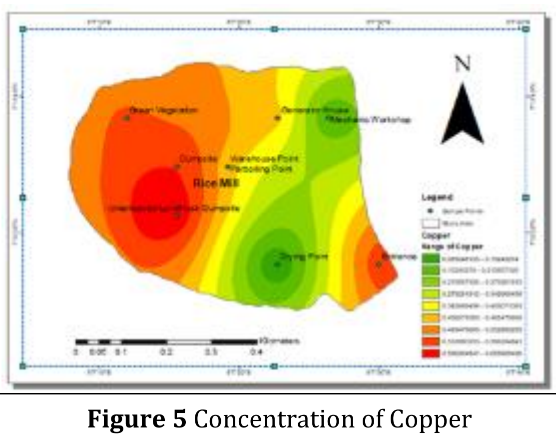

Figure 5 Concentration of Copper

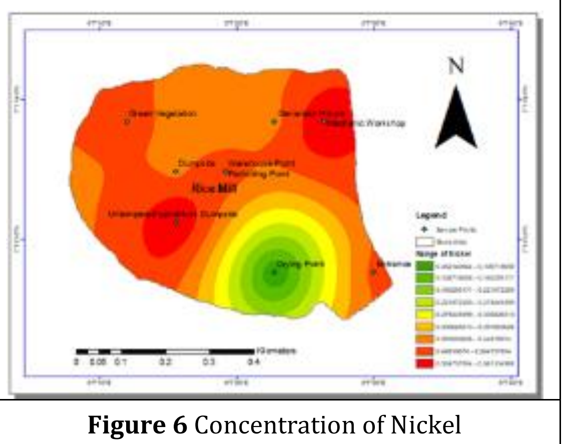

Figure 6 Concentration of Nickel

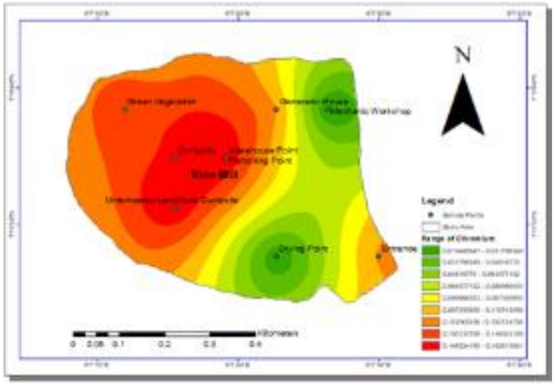

Figure 7 Concentration of Chromium

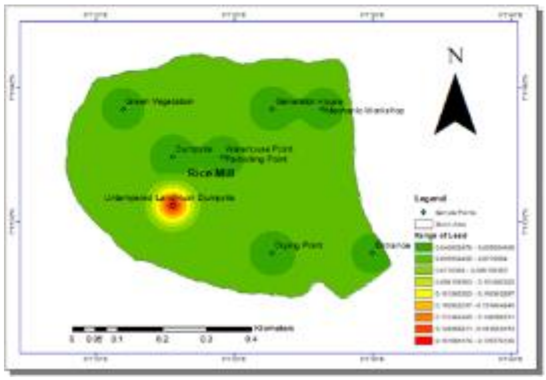

Figure 8 Concentration of Lead

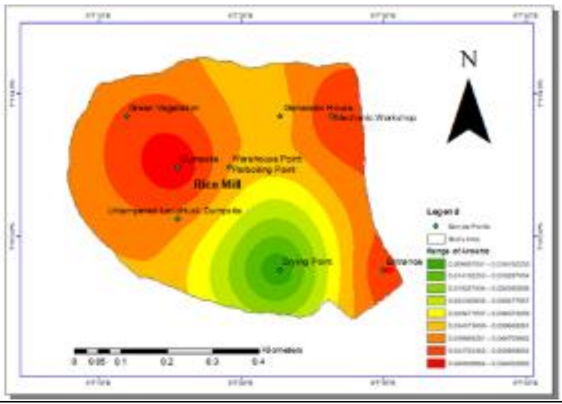

Figure 9 Concentration of Arsenic

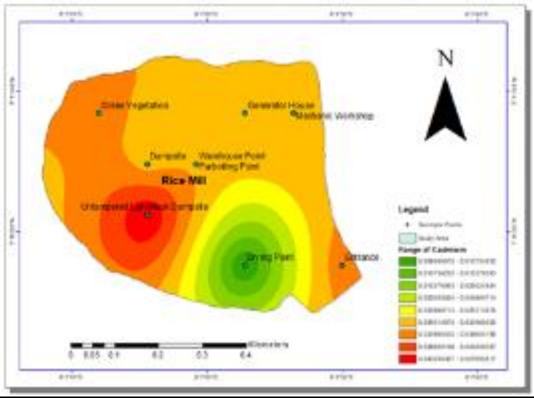

Figure 10 Concentration of Cadmium

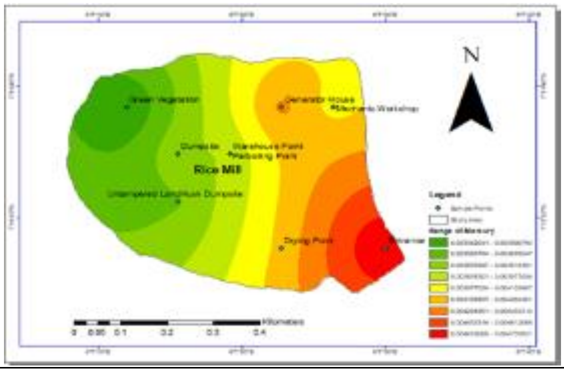

Figure 11 Concentration of Mercury

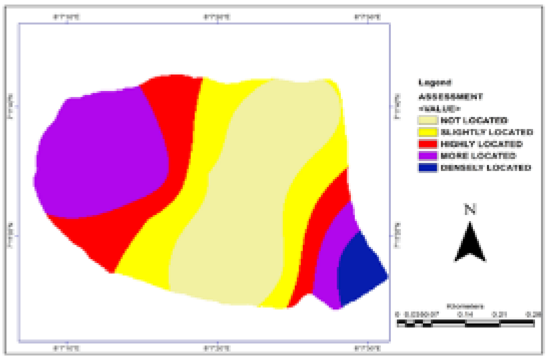

Figure 12 Assessment of Concentration

4. Conclusion and recommendations

The study examines heavy metal concentrations in the Otukpo rice mill, focusing on their spatial variation. The factory is classified into activity areas, with iron having the highest concentration at the entrance point and zinc at the mechanic workshop. The study reveals uneven concentrations and shows the Geographic Information System's ability to map heavy metal concentrations. To reduce health implications, programs should be organized, sanitation practices should be improved, health screenings conducted, and drainage channels constructed to enhance soil aeration and oxidize heavy metals.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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