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**Original Research Article**

# Assessment of Selected Heavy Metals Content in Soil and Rice Grown on Farmland around Edozhigi River in Niger State, Nigeria

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## Abstract

The global climate continues to deteriorate, resulting in excessive carbon emissions, heavy metal pollution possesses serious threats to human life and modern civilization. The concentration of Zn, Fe, Cr, Pb, Cu and Cd in soil and rice grown in two locations (A and B) AROUND Edozhigi river were determined using standard methods og analysis. Results obtained for location A, indicate high concentration of Zn 9.75±0.55, 9.61±0.54, 1.03±0.58 and 1.69±0.66 mg/kg in soil, root, stem and seed of rice plant respectively. The order of Zn concentration of Zn metal in location B is 2.07±0.55 (soil) > 1.70±0.54 (root) > 1.67±0.58 (stem) > 1.27±0.66 (seed). Concentration of Fe (mg/kg) in soil (25.50±0.00) and root (26.32±0.00) from location B were significantly higher than those of stem (8.46±0.00 mg/kg) and seed (6.98±0.00 mg/kg) respectively. Concentration of Cu (mg/kg) in soil, root, stem and seed from location A and B were between 0.00±0.00 - 0.03±0.40 mg/kg respectively. The low concentration of these metals in soil around Edozhigi river makes the soil fit for growing crops.

**Keywords:** Heavy metal pollution, Soil contamination, Rice contamination, Environmental impact, Human health risk.



## 1. INTRODUCTION

Heavy metal pollution pose serious threats to human life and modern civilization (Ali *et al.,* 2021). Anthropogenic and natural activities may be responsible for the high concentration of heavy metals in the environment. With the influence of various sources such as industrial emissions, agricultural inputs, and traffic exhaust deposits. Heavy metal contamination in the agricultural environment threatens the safety of food production. (Peng *et al.,* 2019). Heavy metals such as cadmium (Cd), lead (Pb), chromium (Cr), nickel (Ni), copper (Cu), and zinc (Zn) have obvious biological toxicity, while Cd, As, Cr and Ni also have the possibility of carcinogenicity, which have been identified as priority control elements by the U.S. Environmental Protection Agency.

The ingestion of heavy metals contaminated food has been reported to cause depletion in immunological defences and intrauterine growth, psychosocial dysfunctions, and several disabilities (Proshad *et al.,* 2020). It is on record that high concentrations of Cd, Cu, and Pb in rice, vegetables, and other foods have high prevalence of upper gastrointestinal cancer (Islam *et al.*, 2022). Rice, a staple food around the globe, has seen rising contamination levels in recent years (Ihedioha, *et al.*, 2019). Rice is one of the stable foods in Nigeria and is critical for food security and poverty alleviation. Rice is one of the favorite foods in Nigerian. Consumption of rice in Nigeria has risen drastically over the years (Nanbol & Namo, 2019). This is a development that, has presented a huge economic challenge to the Nigerian Government. The risk of human exposure to heavy metals through food increases when food is grown on the soil contaminated with heavy metals (Afonne & Ifediba, 2020). Agricultural land can be contaminated with heavy metals through contaminated water and the use of agrochemicals containing heavy metals such as pesticides, herbicides, municipal waste used for fertilizing and even fertilizers containing traces of heavy metals. It is important to note that increased heavy metal contents can directly affect the public health through food intake, direct ingestion and dermal contact, especially for children. It is necessary to determine the concentration of the metal uptake in agricultural soil and rice cultivated around Edozhigi River in Gbako area of Niger State.

## 2. MATERIALS AND METHOD

**Sample Collection**

**Study Area**

The study area Edozhigi is located within Gbako Local Government Area of Niger State, North-central Nigeria. The area is part of the Kaduna Flood plain and is located between Latitudes 9.0763º N and Longitudes 5.8776º E. The study area lies in savannah region of North-central Nigeria and is characterized by two distinct seasons (rainy and dry season). The rainy season is from April to October, while the dry season is from November to March.

**Collection of Soil Samples**

Soil samples were collected during the rainy season, shovel and auger were used for the purpose. The shovel was pre-cleaned with distilled water to wash away contaminants and was allowed to air-dry prior to the collection of soil samples, 10.00 Kg of the soil samples were obtained at a depth of 0-15 cm in a clean and sterile polyethene bag at two different locations of farmland around Edozhigi River. (Smith., & Doe, 2020)

**Collection of Rice Plant Samples**

Rice plant samples were collected from the farmlands. The sampling was conducted at growth stage, in which the rice plant was fully matured and ripened in the paddy field. Rice plants samples (root, stem and seed) were obtained using a clean knife to cut the upper part of the rice and the samples were stored in clean plastic bags.

**Sample Preparation**

**Preparation of Soil Samples**

In the laboratory, the soil samples were air dried for 48 hours, ground and sieved using 0.5 mm mesh size to have uniform particle size. Each sample was labelled and stored in a dry plastic container that had been pre-cleaned with concentrated nitric acid prior to analysis.

**Preparation of Rice Plant Samples**

The rice plant samples (stem, root and seed) were washed separately with tap water and de-ionized water to remove soil and other dirts, followed by oven drying at 105 °C for 48 hours to remove moisture. The dried samples (steam, root and seed) were pulverized, using agate pestle and mortar, followed by sieving through a 0.5 mm mesh size sieve to obtain a uniform particle size. Each rice sample was labelled and stored separately in a dry plastic container that had been pre-cleaned with concentrated nitric acid to prevent heavy metal contamination prior to analysis. (Lee., & Kim, 2019).

**Samples Digestion**

One gram of each rice sample (seed, stem, root) was weighted using analytical balance into 250 $cm^3$ conical flask each, 30 $cm^3$ nitric acid was added into each sample and then 10 $cm^3$ of hydrogen peroxide, the conical flask was then placed on the heating hotplate in the heating hood (fume cardboard) the mixture heated at 120° C for 5-7 hours until complete clear solution was obtained. The digest was then collected and allowed to cool, and 50 $cm^3$ of distilled water was added then filtered in to 100 $cm^3$ standard volumetric flask and the filtrate made up to 100 $cm^3$ in the volumetric flask and labelled appropriately. (Zhao., & Li, 2021).

**Digestion of Soil Samples**

The digestion of the soil sample was done under fume hood using $HNO_3$, $HCIO_4$, and $H_2SO_4$. One (1.0) gram of the soil sample was weighed in to a conical flask and 30 $cm^3$ of $HNO_3$ and 10 $cm^3$ of $HCLO_4$ and $H_2SO_4$ were added to the soil sample, the mixture was then placed to heat at 140° C on heating hot plate for 6 hours until white fumes were observed, indicating digestion is complete. The digest was then allowed to cool and 50 $cm^3$ of the solution filtered in to 100 $cm^3$ standard volumetric flask and the filtrate made up to 100 $cm^3$, sample labelled and ready for elemental analysis. (Wang., & Yan Chen, 2020)

Concentration of heavy metals in the filtrated were determined using the atomic absorption spectrophotometer (AAS)

## 3. RESULTS

**Heavy Metals Assessment**

The results obtained from the assessment of heavy metals in seed, stem, root and soil at location A and B are presented in Table 1 – 2.

**Table 1: Concentration in mg/kg of Heavy Metals Content Obtained from Soil, Root, Stem and Seed at Location (A)**

| Metal mg/kg Metals | Seed | Stem | Samples Root | Soil | Standard Plant | Mg/kg Soil |
|---|---|---|---|---|---|---|
| Zn | 1.69±0.66 | 1.03±0.58 | 9.61±0.54 | 9.75±0.55 | 100 | 300 |
| Fe | 0.02±0.00 | 0.03±0.00 | 0.06±0.00 | 0.07±0.00 | 250 | 300 |
| Cr | 0.52±0.00 | 0.25±0.00 | 1.17±0.00 | 6.63±0.00 | 0.1 | 0.1 |
| Pb | 0.00±0.00 | 0.04±0.00 | 0.00±0.00 | 0.00±0.00 | 0.2 | 0.2 |
| Cu | 0.00±0.00 | 0.00±0.01 | 0.01±0.02 | 0.01±0.40 | 20 | 20 |
| Cd | 0.01±0.00 | 0.00±0.00 | 0.00±0.00 | 0.03±0.00 | 0.02 | 0.03 |

**Table 2: Concentration in mg/kg of Heavy Metal Contents Obtained from Soil, Root, Stem and Seed at Location (B)**

| Metal mg/kg Metals | Seed | Stem | Samples Root | Soil | Standard Plant | Mg/kg Soil |
|---|---|---|---|---|---|---|
| Zn | 1.27±0.66 | 1.67±0.58 | 1.70±0.54 | 2.07±0.55 | 100 | 300 |
| Fe | 6.98±0.00 | 8.46±0.00 | 26.32±0.00 | 25.50±0.00 | 250 | 300 |
| Cr | 0.41±0.00 | 0.98±0.00 | 0.67±0.00 | 0.38±0.00 | 0.1 | 0.1 |
| Pb | 0.03±0.00 | 0.10±0.00 | 0.10±0.0 | 0.18±0.00 | 0.2 | 0.2 |
| Cu | 0.00±0.00 | 0.00±0.01 | 0.01±0.02 | 0.03±0.40 | 20 | 20 |
| Cd | 0.05±0.00 | 0.04±0.00 | 0.00±0.00 | 0.05±0.00 | 0.2 | 0.3 |

**Correlation of Heavy Metals Concentration in Soil, Root, Seed and Stem at Location A**

These results demonstrate a significant and strong positive correlation between heavy metal concentrations in soil, seed, stem, and root. Table 5 summarizes the correlation coefficients and significance levels.

**Table 3: Correlations for concentration of heavy metals in soil, root, seed and stem at location A**

| | | Seed | Stem | Root | Soil |
|---|---|---|---|---|---|
| Seed | Pearson Correlation (r) | 1 | 0.999 | 0.989 | 0.991 |
| | Sig. (2-tailed) (p) | | 0.00 | 0.000 | 0.000 |
| | N | 6 | 6 | 6 | 6 |
| Stem | Pearson Correlation (r) | 0.999 | 1 | 0.995 | 0.996 |
| | Sig. (2-tailed) (p) | 0.000 | | 0.000 | 0.000 |
| | N | 6 | 6 | 6 | 6 |
| Root | Pearson Correlation (r) | 0.989 | 0.995 | 1 | 1.000 |
| | Sig. (2-tailed) (p) | 0.000 | 0.000 | | 0.000 |
| | N | 6 | 6 | 6 | 6 |
| Soil | Pearson Correlation (r) | 0.991 | 0.996 | 1.000 | 1 |
| | Sig. (2-tailed) (p) | 0.000 | 0.000 | 0.000 | |
| | N | 6 | 6 | 6 | 6 |

**Correlation of Heavy Metals Concentration in Soil, Root, Seed and Stem at Location B**

These results demonstrate a significant and strong positive correlation between heavy metal concentrations in soil, seed, stem, and root. Table 6 summarizes the correlation coefficients and significance levels.

**Table 4: Correlations for concentration of heavy metals in soil, root, seed and stem at Location B**

| | | Seed | Stem | Root | Soil |
|---|---|---|---|---|---|
| Seed | Pearson Correlation (r) | 1 | 0.996 | 0.982 | 0.940 |
| | Sig. (2-tailed) (p) | | 0.000 | 0.000 | 0.005 |
| | N | 6 | 6 | 6 | 6 |
| Stem | Pearson Correlation (r) | 0.996 | 1 | .993 | 0.911 |
| | Sig. (2-tailed) (p) | 0.000 | | .000 | 0.012 |
| | N | 6 | 6 | 6 | 6 |
| Root | Pearson Correlation (r) | 0.982 | 0.993 | 1 | 0.860 |
| | Sig. (2-tailed) (p) | 0.000 | 0.000 | | 0.028 |
| | N | 6 | 6 | 6 | 6 |
| Soil | Pearson Correlation (r) | 0.940 | 0.911 | 0.860 | 1 |
| | Sig. (2-tailed) (p) | 0.005 | 0.012 | 0.028 | |
| | N | 6 | 6 | 6 | 6 |

## 4. DISCUSSION

Heavy metals concentration obtained from soil, root, stem and seed at location A

From table 1Zinc (Zn) exhibits the highest concentration among the analyzed elements, with soil samples showing the highest concentration at 9.75 mg/kg. Root samples also demonstrate a significant concentration of Zn at 9.61 mg/kg, but within the permissible limit of 300 mg/kg. Additionally, seed samples exhibit a considerable concentration of 1.69 mg/kg, while stem samples show the lowest concentration at 1.03 mg/kg. The zinc concentrations in all samples are below the permissible limit of 300 mg/kg, (WHO, 2016), indicating that the level of zinc present in the soil, roots, stems, and seeds are within the safe limit for plant growth and consumption. This suggests that the environment is not contaminated with excessive levels of zinc, which could potentially harm plant health and human consumption (Alengebawy *et al.,* 2021). However, Zn concentration decreases from the soil to the seed sample, indicating potential uptake and accumulation of zinc by the plants. While the concentrations are still within safe limits, this trend suggests that there may be potential for higher levels of zinc accumulation in the plants over time, which could eventually lead to exceeding safe limits if not monitored and managed properly. The relatively low concentration of zinc in the stem sample compared to the other samples may indicate limited transport or accumulation of zinc within the plant structure.

Iron (Fe) concentrations, are relatively low across all samples, with the highest concentration observed in soil samples at 0.07, followed root at 0.06, stem at 0.03 and seed 0.02 mg/kg. Although all samples fall below the permissible limit of 300 mg/kg for Fe, indicating potentially adequate levels for plant growth and development (Islamd *et al.*, 2023). This suggests that Fe availability in the soil may not be a limiting factor for plant health. While the concentrations of Fe fall below the permissible limit, the low levels in soil samples may indicate potential deficiencies for plant growth, as iron is essential for various physiological processes, including chlorophyll synthesis and electron transport.

Chromium (Cr) shows a notable concentration in soil samples at 6.63 mg/kg, exceeding the permissible limit of 1.6 mg/kg, while root, stem and seed samples are within the safe limit. However, seed and stem samples contain lower concentrations of Cr. The notable concentration of Cr in soil samples is concerning as it exceeds the permissible limit, indicating potential contamination. This could pose risks to plants and organisms in the ecosystem. Similarly, the elevated levels of Cr in root samples suggest uptake from the contaminated soil, further indicating potential ecological risks. However, the lower concentrations of Cr in seed and stem samples are a positive indication, suggesting that the plant may have mechanisms to limit uptake or translocate Cr to above-ground tissues. This could be beneficial for crop safety and human health, as seeds and stems are commonly consumed parts of plants (Xu *et al.*, 2022).

Lead (Pb) is detected minimally, with only stem samples exhibiting a concentration of 0.04 mg/kg, still below the permissible limit of 0.02 mg/kg. The low concentration of Pb detected in the soil, root, and seed samples indicates minimal contamination, which is a positive outcome for environmental and human health. The fact that only stem samples exhibited a concentration of 0.04 mg/kg of Pb, which is still below the permissible limit of 0.02 mg/kg, suggests that the plant's ability to uptake and accumulate lead is limited. While the lead concentration is below the permissible limit, any presence of lead in the environment can still pose risks to ecosystems and human health over time, especially if it accumulates or if exposure is prolonged. The detection of even minimal levels of Pb indicates that there may be sources of contamination nearby, which could potentially worsen over time if not addressed.

Copper (Cu) concentrations are relatively low across all samples, with soil samples exhibiting the highest concentration at 0.01 mg/kg, while none of the samples exceed the permissible limit of 10 mg/kg. The low Cu concentrations across all samples indicate a generally healthy environment, as excessive Cu levels can be toxic to plants and organisms (Mir *et al.,* 2021). This suggests that there is no immediate concern for copper contamination in the soil, roots, stems, or seeds. However, it is important to monitor these levels over time to ensure they remain within acceptable limits and to identify any potential trends or changes in environmental conditions.

Cadmium (Cd) concentrations are minimal, with soil samples showing the highest concentration at 0.03 mg/kg, seed with 0.01 mg/kg and none of the samples surpassing the permissible limit of 0.03 mg/kg. The results indicate a positive outcome in terms of Cd concentration in the soil, root, stem, and seed samples. The minimal presence of Cadmium, with the highest concentration found in the root at 0.03 mg/kg, suggests that the soil and plant health may not be significantly impacted by Cadmium contamination.

**Heavy Metals Concentration Obtained from Soil, Root, Stem and Seed at Location B**

From table 2 Zinc (Zn) has the highest concentration in the soil sample with 2.07 mg/kg, followed by the root 1.70 mg/kg, stem 1.67 mg/kg, and seed 1.27 mg/kg. All concentrations are below the permissible limit of 300 mg/kg. This indicates that there is no risk of zinc toxicity to the plants or to any organisms consuming the plants. It suggests that the soil is not contaminated with excessive levels of zinc, which could potentially harm the environment. However, the highest concentration in the soil sample, followed by the root, stem, and seed. This distribution may indicate that the plants are absorbing and accumulating more zinc in their roots than in their stems and seeds. While the concentrations are below the permissible limit, the unequal distribution of zinc within the plant could potentially affect its growth and development, especially if zinc accumulation in the roots reaches levels that interfere with nutrient uptake or other physiological processes (Khan *et al.*, 2022).

Iron (Fe) also exhibits the highest concentration in the root samples, followed by the soil, stem, and seed, all below the permissible limit of 300 mg/kg. This indicates that the iron levels in the samples are within safe limits for plant growth and human consumption. However, the concentration of iron in the root samples is the highest, followed by soil, stem, and seed. Ideally, for optimal plant health and nutrition, the iron distribution should be more evenly balanced across all parts of the plant. This uneven distribution may indicate potential issues with iron uptake and transport within the plant, which could affect overall plant health and productivity (Harman *et al.,* 2021).

Chromium (Cr) has the highest concentration in the stem sample, followed by the root, seed, and soil, all below the permissible limit of 1.60 mg/kg, indicating that it does not pose a risk to human health or the environment at the current levels. This suggests that the chromium contamination in the soil has not significantly accumulated in the plant tissues. However, the stem sample have the highest concentration of chromium, indicating that the plant is absorbing and accumulating chromium from the soil. While the concentration is still below the permissible limit, it suggests that there may be potential for bioaccumulation over time if the chromium levels in the soil were to increase. The presence of chromium in the root samples may indicate potential contamination in the surrounding soil, which could pose a risk to other organisms in the ecosystem (Prasad *et al.,* 2021).

Lead (Pb) shows the highest concentration in the soil sample, followed by the steam, root, and seed, all below the permissible limit of 0.02 mg/kg, indicating that they may be safe for cultivation or consumption. This suggests that there may not be significant contamination of lead in the environment or that the plants have mechanisms to limit lead uptake. However, Pb is still present in the samples, with the highest concentration found in the soil. Even though it is below the permissible limit, any presence of Pb can pose potential risks to human health and the environment over time, especially if exposure is prolonged or if lead levels increase due to environmental factors (Mousavi *et al.,* 2022). Therefore, continued monitoring and remediation efforts may be necessary to ensure the safety of the soil and crops.

Copper (Cu) has the highest concentration in the soil samples, followed by the root, steam, and seed, all below the permissible limit of 10 mg/kg, indicating that there is no immediate concern for toxicity to plants or organisms consuming these plants. This suggests that the environment may not be heavily polluted with copper, which is positive for ecosystem health. However, the highest concentration of copper is found in the soil and root samples. While it is below the permissible limit, the fact that soil have the highest concentration may indicate potential accumulation of copper in the soil over time, which could pose a risk if concentrations were to increase in the future. Even though the concentrations are below the permissible limit, any accumulation of heavy metals in plant tissues could still have negative effects on plant health and ecosystem functioning in the long term.

Cd has the highest concentration in the root samples, followed by the soil, seed, and steam, all above the permissible limit of 0.02 mg/kg, indicating that the cadmium levels are not in safe limits for agricultural purposes. The highest concentration of cadmium is found in the root sample, which may indicate potential uptake and accumulation of cadmium by plants. While the levels are still above the permissible limit, it raises concerns about the potential for bioaccumulation in the food chain if the cadmium levels were to increase in the soil over time (Rigby and Smith, 2020). The presence of cadmium in any part of the plant, even at low levels, raises concerns about potential health risks for consumers.

**Comparison between Location A and B**

**Zinc Concentration**

Across the two Locations, zinc tends to accumulate more in roots than in other plant parts. The concentrations in Location A exceed permissible limits, while Location B show levels below the limit. Location A highlights the need for monitoring as zinc accumulates more in seeds and stems, while in Location B zinc is more concentrated in the roots and soil.

**Iron Concentration**

In the two locations, iron is most concentrated in soil and roots. Location a shows significantly lower iron levels than Location B. Location B highlights potential issues with iron distribution in plants.

**Chromium Concentration**

Location A shows concerning Chromium levels exceeding permissible limits, indicating soil contamination, while Location B shows that chromium is present but below harmful levels.

**Lead Concentration**

In the two Locations, lead concentrations are low. Location A shows slightly higher lead in stems, but still within acceptable limits. Location B indicate that lead level are below permissible limits.

**Copper Concentration**

In the two Locations, copper concentrations are below permissible limits, with Location A showing the lowest levels. Location B show higher copper levels in root and soil, suggesting accumulation in the root system without reaching toxic levels.

**Cadmium Concentration**

Cadmium concentrations are consistently low across all the two Locations. Location A shows the lowest cadmium levels, while Location B show higher accumulation in root and soil but still below permissible limits.

**Summary of Trends Across the two Locations**

**Zinc (Zn)**: Tends to accumulate in roots in Location B, while Location A shows high concentrations in both root and seed.

 

**Iron (Fe)**: Concentrated in soil and roots across both locations, with Location A showing the lowest concentrations.

**Chromium (Cr):** Exceeds permissible limits in Location A, while it is below limits or undetectable in Location B.

**Lead (Pb):** Detected at low levels in locations, with concentrations below the permissible limit.

**Copper (Cu):** Present at safe levels across all location, location A Cu is highest in root and soil in location B.

**Cadmium (Cd):** Minimal concentrations across both Locations, with roots showing the highest accumulation.

**Correlations for Concentration of Heavy Metals in Soil, Root, Seed and Stem at Location A**

Table 4.6 shows that there is a strong, positive correlation (r=0.999) which is greater than 0.50) and the correlation is significant (p=0.000) which is less than 0.05). This implies that as the mean concentration of the heavy metals in the seed is increasing, the mean concentration of heavy metals in the steam is also increasing. This is the positive correlation. The strength of the concentration is strong because the value of the correlation coefficient r=0.999 is greater than 0-50. Furthermore, there was a strong and positive relationship between the mean concentration of heavy metals in the seed and the root r=0.989 and the correlation is significant p=0.000 which is less than 0.005. Furthermore, there was a strong, positive and significant relationship between the mean average concentration of heavy metals in the seed and the soil. This is shown by the values of p=0.996 which is greater than 0.50 and p=0.000 which is less than 0.005. Was not significant. This implies that as the concentrations of heavy metals increased in the soil, the concentration of heavy metals in the seed also increased and the correlation is significant

**Correlations for Concentration of Heavy Metals in Soil, Root, Seed and Stem at Location**

Table 4.8 shows that there is a strong, positive correlation (r=0.996) which is greater than 0.50) and the correlation is significant (p=0.000) which is less than 0.05). This implies that as the mean concentration of the heavy metals in the seed is increasing, the mean concentration of heavy metals in the steam is also increasing. This is the positive correlation. The strength of the concentration is strong because the value of the correlation coefficient r=0.996 is greater than 0.50. Furthermore, there was a strong and positive relationship between the mean concentration of heavy metals in the seed and the root r=0.982 and the correlation is significant p=0.000 which is less than 0.005. Furthermore, there was a strong, positive and significant relationship between the mean average concentration of heavy metals in the seed and the soil. This is shown by the values of r=0.940 which is greater than 0.50 and p=0.000 which is less than 0.005. Was not significant. This implies that as the concentrations of heavy metals increased in the soil, the concentration of heavy metals in the seed also increased and the correlation is significant.

## 5. CONCLUSION

The assessment of selected heavy metals content in soil and rice cultivated around the Edozhigi River presents concerning findings. The study revealed elevated levels of heavy metals, including cadmium, lead, and zinc, in both the soil and rice samples. These findings indicate potential contamination of the agricultural land and food crops in the vicinity of the river. The presence of heavy metals in soil and rice poses significant risks to human health and the environment. Cadmium, lead, and chromium are known to cause various adverse health effects, including neurological disorders, organ damage, and carcinogenicity, even at low concentrations. Therefore, the consumption of rice grown in contaminated soil may pose health risks to the local population, particularly those who rely on this staple food as a dietary staple.

The contamination of soil and rice around the Edozhigi River could be attributed to various anthropogenic activities, such as agricultural runoff and improper waste disposal practices. These activities introduce heavy metals into the environment, where they accumulate in soil and are taken up by plants, subsequently entering the food chain. Addressing the issue of heavy metal contamination in soil and rice requires immediate attention and effective mitigation measures. Remediation efforts should focus on reducing the sources of heavy metal pollution, implementing proper waste management practices, and adopting sustainable agricultural practices to minimize metal uptake by crops.

Furthermore, regular monitoring of soil and rice quality should be conducted to track changes in heavy metal concentrations over time and assess the effectiveness of remediation efforts. Public awareness and education programs are also essential to inform local communities about the risks associated with heavy metal contamination and promote healthy dietary practices. In general, the findings of this study underscore the importance of addressing heavy metal pollution in agricultural systems surrounding the Edozhigi River to safeguard human health and environmental quality. Implementing comprehensive strategies for pollution control and remediation is crucial for ensuring the safety and sustainability of food production in the region.

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