



# Rainy Season Microbiological and Physicochemical Quality of Soil and Water in Udege Mining Area, Nasarawa State, Nigeria

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## ABSTRACT

Seasonal rainfall strongly influences contaminant transport and microbial dynamics in mining-impacted environments. This study evaluated the microbiological and physicochemical quality of soil and water during the rainy season in the Udege mining area of Nasarawa State, Nigeria. Soil microbial analysis revealed elevated total heterotrophic bacterial counts ( $4.29 \times 10^2 \pm 4.51$  cfu/g), alongside the presence of *Escherichia coli*, *Salmonella* spp., *Staphylococcus* spp., *Micrococcus* spp., *Bacillus* spp., and heterotrophic fungi. Water samples exhibited increased microbial loads, reflecting enhanced runoff and hydrological mixing during rainfall. Physicochemical assessment showed slightly acidic soil (pH 6.63–6.68) and water (pH 5.72–5.95), with increased nutrient availability and moderate conductivity. Heavy metals such as iron, copper, cadmium, lead, and chromium were detected in both soil and water, indicating mobilization of mining-derived contaminants during rainfall events. The rainy season was characterized by increased microbial abundance and wider dispersal of contaminants compared to dry-season conditions. These findings demonstrate that rainfall intensifies contaminant redistribution and microbial proliferation in mining environments, posing potential ecological and public health risks. The study provides critical rainy season baseline data for environmental monitoring and supports the need for improved mining regulation and water resource protection.

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## INTRODUCTION

Mining activities constitute a major source of environmental disturbance in mineral-rich regions, particularly where artisanal and small-scale mining predominates. Such activities disrupt soil structure, alter hydrological pathways, and introduce chemical and biological contaminants into surrounding ecosystems. Seasonal variation plays a critical role in shaping the magnitude and distribution of these impacts. During the rainy season, increased precipitation enhances surface runoff, soil erosion, and leaching processes, facilitating the transport of pollutants from mining sites into adjacent soils and water bodies.

In tropical mining regions such as Udege in Nasarawa State, rainfall events act as powerful drivers of contaminant mobilization. Heavy metals deposited in mine tailings and disturbed soils are readily washed into surface waters, while organic matter and nutrients released during rainfall promote microbial growth and redistribution. Studies have shown that rainy seasons are often associated with elevated microbial counts, increased turbidity, and fluctuating physicochemical parameters in mining-impacted waters (Edokpayi et al., 2016; Chapman, 1997).

Microbial communities respond rapidly to these seasonal changes. Increased moisture, nutrient input, and organic debris during rainfall create favorable conditions for bacterial and fungal proliferation. Indicator organisms such as *Escherichia coli* and *Salmonella* spp. frequently increase during the rainy season due to runoff from surrounding settlements, animal grazing areas, and disturbed soils (Florini et al., 2020). At the same time, heavy metals exert selective pressure on microbial populations, promoting the persistence of tolerant and adaptive species (Gadd, 2010).

Heavy metal contamination remains a defining feature of mining environments. Metals such as iron, manganese, copper, lead, cadmium, and chromium are released during ore extraction and processing and may persist long after mining activities cease. Rainfall enhances their mobility through dissolution and sediment transport, increasing the risk of contamination of surface waters used for domestic and agricultural purposes (Eisler, 2004).

Given the environmental and public health implications associated with rainy season contamination, this study aimed to assess the microbiological and physicochemical characteristics of soil and water during the rainy season in the Udege mining area. By focusing on peak rainfall conditions, the study provides insight into periods of heightened ecological vulnerability and supports informed environmental management and policy development.

## MATERIALS AND METHODS

### Sample Collection

Soil and water samples were collected during the rainy season from active and abandoned mining locations within the Udege mining area of Nasarawa State, Nigeria. Soil samples were obtained at a depth of 0–15 cm using a sterile soil auger and transferred into clean, sterile containers. Water samples were collected from surface water bodies and mining pits using sterile 500 mL bottles. All samples were transported to the laboratory in cold storage containers and analyzed within 24 hours.

### Microbiological Analysis

Microbial populations in soil and water were determined using standard spread plate techniques. One gram of soil was suspended in sterile distilled water and serially diluted, while water samples were analyzed directly following serial dilution. Aliquots were inoculated onto Nutrient Agar for total heterotrophic bacteria, selective media for indicator organisms, and Sabouraud Dextrose Agar for fungi. Plates were incubated at  $30 \pm 2^\circ\text{C}$  for 24–72 hours. Microbial counts were expressed as colony-forming units per gram (cfu/g) for soil and per milliliter (cfu/mL) for water (Cheesbrough., 2006).

Indicator organisms including *Escherichia coli*, *Salmonella* spp., *Staphylococcus* spp., *Micrococcus* spp., *Bacillus* spp., and total coliforms were isolated using appropriate selective and differential media.

### Physicochemical Analysis

Physicochemical parameters of soil and water were analyzed following standard procedures. Soil parameters included temperature, pH, moisture content, porosity, bulk density, organic carbon, nitrate, sulphate, and particle size distribution. Water parameters included temperature, pH, electrical conductivity, total dissolved solids, total hardness, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, nitrate, chloride, and sulphate. All analyses were performed in triplicate.

### Heavy Metal Analysis

Heavy metal concentrations in soil and water were determined using atomic absorption spectrophotometry (AAS) after acid digestion. Metals analyzed included iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), cadmium (Cd), lead (Pb), nickel (Ni), and chromium (Cr). Results were expressed as mg/kg for soil and mg/L for water.

### Statistical Analysis

All data were analyzed using descriptive statistics and presented as mean  $\pm$  standard deviation.

## RESULTS AND DATA PRESENTATION

### Microbiological Quality of Soil and Water Samples During the Rainy Season

**Table 1** summarizes the microbiological quality of soil and water samples during the rainy season. Microbial counts were generally higher in soil than in water, indicating greater microbial retention and activity in the soil matrix. *Gluconobacter* recorded the highest soil count ( $1.29 \times 10^2 \pm 1.15$  cfu/g), followed closely by total heterotrophic fungal counts ( $1.25 \times 10^2 \pm 3.2$  cfu/g), reflecting favorable moisture conditions for microbial growth.

Pathogenic indicators such as *Escherichia coli*, *Salmonella* spp., and *Staphylococcus* spp. were present in both soil and water, with higher values in soil samples. Total coliforms were detected only in water ( $1.82 \times 10^1 \pm 4.3$  cfu/mL), suggesting fecal contamination and surface runoff influence during rainfall. The observed microbial distribution highlights the role of rainfall in enhancing microbial transport and proliferation.

**Table 1 Microbiological Quality of Soil and Water Samples During the Rainy Season**

Isolates	Soil (cfu/g)	Water (cfu/mL)
Micrococcus	$4.29 \times 10^1 \pm 1.44$	$1.68 \times 10^1 \pm 3.7$
<i>Escherichia coli</i>	$9.5 \times 10^1 \pm 3.1$	$2.96 \times 10^1 \pm 5.7$
<i>Salmonella</i> spp.	$5.4 \times 10^1 \pm 1.8$	$3.27 \times 10^1 \pm 5.0$
<i>Bacillus</i> spp.	$1.58 \times 10^1 \pm 5.03$	$5.87 \times 10^1 \pm 10.76$
<i>Staphylococcus</i> spp.	$8.7 \times 10^1 \pm 3.0$	$2.15 \times 10^1 \pm 4.4$
<i>Gluconobacter</i>	$1.29 \times 10^2 \pm 1.15$	$8.38 \times 10^1 \pm 1.54$
Total heterotrophic fungal count	$1.25 \times 10^2 \pm 3.2$	$2.1 \times 10^1 \pm 4.8$

### Physicochemical Properties of Soil During the Rainy Season

**Table 2** presents the physicochemical characteristics of soil samples during the rainy season. The soil exhibited a slightly acidic pH ( $6.68 \pm 0.08$ ) and moderate temperature ( $26.07 \pm 0.68$  °C), conditions suitable for microbial activity. The textural composition was dominated by silt and sand fractions, indicating relatively good permeability. Moisture content and porosity were moderately high, supporting increased biological processes. Total organic carbon and nutrient parameters such as sulphate and nitrate were present at measurable levels, reflecting enhanced organic matter decomposition and nutrient availability during rainfall.

**Table 2: Physicochemical Properties of Soil Samples During the Rainy Season**

Parameter	Value
Temperature (°C)	$26.07 \pm 0.68$
Sand (%)	$38.86 \pm 2.16$
Silt (%)	$42.51 \pm 3.05$
Clay (%)	$17.86 \pm 1.95$
pH	$6.68 \pm 0.08$
Moisture content (%)	$0.62 \pm 0.04$
Soil porosity (%)	$43.34 \pm 6.68$
Wet density (g/cm <sup>3</sup> )	$0.94 \pm 0.04$
Dry density (g/cm <sup>3</sup> )	$0.94 \pm 0.04$
Bulk density (g/cm <sup>3</sup> )	$0.93 \pm 0.04$
Total organic carbon (mg/kg)	$2.45 \pm 0.13$
Sulphate (mg/kg)	$35.89 \pm 1.70$
Nitrate (mg/kg)	$5.08 \pm 1.17$

### Physicochemical Properties of Water During the Rainy Season

**Table 3** shows the physicochemical properties of water samples collected during the rainy season. The water was slightly acidic (pH  $5.95 \pm 0.10$ ) with moderate conductivity, indicating dilution effects from rainfall combined with dissolved ionic inputs. Dissolved oxygen levels were moderate, while biochemical oxygen demand values suggest the presence of biodegradable organic matter. Nutrients and ions such as nitrate, sulphate, and total hardness were detected at appreciable levels, reflecting runoff-induced mobilization of dissolved substances into the aquatic environment.

**Table 3: Physicochemical Properties of Water Samples During the Rainy Season**

Parameter	Value
Temperature (°C)	$23.90 \pm 0.55$
pH	$5.95 \pm 0.10$
Conductivity (µS/cm)	$75.40 \pm 6.20$
Dissolved Oxygen (mg/L)	$4.60 \pm 0.40$
Total Dissolved Solids (mg/L)	$45.20 \pm 3.90$
Total Suspended Solids (mg/L)	$0.13 \pm 0.015$
Total Hardness (mg/L)	$238.60 \pm 13.40$
Nitrate (mg/L)	$1.95 \pm 0.32$
Total Chlorine (mg/L)	$3.52 \pm 0.28$
Sulphate (mg/L)	$21.90 \pm 0.90$
COD (mg/L)	$9.80 \pm 0.84$
BOD (mg/L)	$2.45 \pm 0.27$

## Heavy Metal Concentrations in Soil During the Rainy Season

**Table 4** presents the concentrations of heavy metals in soil samples during the rainy season. Essential elements such as potassium, magnesium, calcium, and iron were detected at relatively higher concentrations, reflecting their natural abundance and possible contribution from mining activities. Trace metals including cadmium, lead, nickel, and chromium were present at low levels, indicating limited accumulation but active mobilization within the soil system during rainfall. The presence of these metals suggests ongoing geochemical interactions influenced by mining disturbance and seasonal runoff.

**Table 4: Heavy Metal Concentrations of Soil Samples During the Rainy Season**

Trace Metal	Concentration (mg/kg)
Calcium	6.40 ± 0.48
Magnesium	7.80 ± 0.28
Potassium	10.61 ± 0.38
Manganese	0.86 ± 0.06
Copper	3.66 ± 0.15
Iron	3.84 ± 0.18
Zinc	0.86 ± 0.06
Cadmium	0.02 ± 0.00
Lead	0.03 ± 0.01
Nickel	0.07 ± 0.01
Chromium	0.41 ± 0.01

## Heavy Metal Concentrations in Water During the Rainy Season

**Table 5** shows the heavy metal concentrations in water samples during the rainy season. Iron recorded the highest concentration (0.60 ± 0.17 mg/L), followed by manganese and zinc, indicating leaching and transport of metals from surrounding soils and mining substrates. Other trace metals such as copper, lead, nickel, and chromium were detected at low concentrations, suggesting minimal but continuous metal input into the water system. These findings demonstrate the influence of rainfall on the mobilization and dispersion of heavy metals into surface waters.

**Table 5: Heavy Metal Concentrations of Water Samples During the Rainy Season**

Metal	Concentration (mg/L)
Manganese	0.14 ± 0.02
Iron	0.60 ± 0.17
Zinc	0.14 ± 0.01
Copper	0.01 ± 0.00
Lead	0.02 ± 0.00
Nickel	0.01 ± 0.00
Chromium	0.06 ± 0.01

## DISCUSSION

The rainy season assessment of soil and water in the Udege mining area demonstrated a clear intensification of microbial activity and contaminant redistribution. Increased rainfall enhances soil moisture, nutrient availability, and surface runoff, creating favorable conditions for microbial growth and transport.

The elevated counts of *E. coli* and *Salmonella* spp. observed during the rainy season highlight the role of runoff in introducing fecal and anthropogenic contaminants into mining environments. Similar seasonal patterns have been reported in other mining and agricultural regions, where rainfall events significantly increase microbial loads in surface waters (Florini et al., 2020).

Physicochemical parameters further supported these observations. Slightly acidic conditions and increased nutrient availability during the rainy season promoted microbial proliferation, while rainfall-driven dilution and leaching influenced water chemistry. The detection of heavy metals during the rainy season reflects their mobilization through erosion and dissolution processes, consistent with findings from other tropical mining regions (Eisler, 2004).

Overall, the rainy season represents a period of heightened environmental vulnerability, characterized by increased microbial contamination and wider dispersion of mining-derived pollutants.

## CONCLUSION

This study demonstrates that mining activities significantly influence the microbiological and physicochemical quality of soil and water during the rainy season in the Udege mining area. Rainfall enhances microbial proliferation, contaminant transport, and heavy metal mobilization, increasing ecological and public health risks. The findings provide essential rainy-season baseline data and underscore the need for effective environmental monitoring, improved mining regulation, and targeted remediation strategies, particularly during periods of high rainfall.

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