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Mining Effluent Impact on Selected Soil Physical Quality Parameters in Agricultural Land Daba, Kwara State, Nigeria

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ABSTRACT

The study examined soils' physical, chemical, and selected soil water transmission properties in an unregistered mining community in Moro Local Government Area, Kwara State, North-Central Nigeria. The assessed agricultural lands based on the reconnaissance survey were 400 m and 800 m away from the mine site, and 1200 m (forested area) away from the mine site. A 25 m x 25 m plot was demarcated and replicated three times in each farmland and mining site. Soil samples were obtained from 0 to 15 cm soil layer at 5 m x 5 m subplot level and analyzed for particle size distribution, pH, organic C, total N, available P, exchangeable Ca^{2+}, Mg^{2+}, K^+ and Na^+, total acidity and selected heavy metals (Zn and Cu). Infiltration tests were run using the double-ring infiltrometer. Sixty soil core samples were collected from the study area to determine the water-holding capacity, bulk density, and hydraulic conductivity. The study showed that soil particles at mining sites were loamier and contained a significantly higher concentration of heavy metals but lesser concentrations of some soil nutrients than in the farmlands and the forested areas. The study also revealed that hydraulic conductivity and bulk density trends vary between 400 and 800 m from the mining site but within the recommended range of the soil-water transmission pathway. As a result, the mining effluent seems to have little impact on the water retention capacity of the soil's water transmission system, and plants growing in that region will not suffer a distorted soil water flow.

Keywords*: Heavy metals, hydraulic conductivity, loam, mining effluents, soil water transmission, soil nutrients*

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INTRODUCTION

Good plant growth and development depends on the soil's mineral and nutrient content and structure. Soil can be defined as the unconsolidated mineral or organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants (Soil Science of America, 2007). Soils are teeming with life such as microorganisms: bacteria and fungus many of which inhabitants and feed on plants and animals remains, breaking down their tissues. In the process, they create pore space and release nutrients needed by the plants (Hudson, 1995). Soil holds a considerable amount of water through these pores until it has reached its total capacity or until the rate at which it can transmit water into and through the pores is exceeded.

Some water will steadily drain through the soil, but much of it will be retained (Vlotman *et al.*, 2020). Generally, the soil's ability to retain water is strongly related to particle size; water molecules hold more tightly to the fine particles of clay soil than to coarser particles of sandy soil, so clays generally retain more water. Clay type, organic content, and soil structure also influence soil water retention. Soils with smaller particles (silt and clay) have a larger surface than those with larger sand particles, and a large surface area allows the soil to hold more water. In other words, soil with a high percentage of silt and clay particles, which describes fine soil, has a higher water-holding capacity than soil with larger particles (Elliot *et al*., 2003).

The transmission of effluent from the mining site to nearby agricultural land causes environmental problems arising due to mining activities resulting in natural land degradation, air and water pollution with heavy metals, organic and inorganic waste, and negative impact on terrestrial. Additionally, effluent discharge to surface soils and waters may not always be appropriate for agricultural use of the effluent. It might lead to distortion of soil water transmission due to pore blockage from soil structure destruction. The process can be linked to metal smelting to separate minerals during mining that introduced many pollutants and several granules into the soil (Alloway, 2013). Mining is the extraction of naturally occurring materials from the earth's crust; it is considered the world's second oldest and most significant industry after agriculture.

According to Ogundele *et al*. (2017), mining and smelting facilities release vast quantities of heavy metals and other toxic elements into the environment. These persist for long periods, long after the end of these activities. Toxic mining wastes might be left in the soil, mainly formed by fine particles with different concentrations of heavy metals. These polluted particles can be dispersed by wind and water erosion, sometimes reaching soils. These wastes are regarded as mining effluent. However, due to a lack of proper planning and negligence of mining regulations in Nigeria, the discharge from the mining site seems to be a source of pollution, forming an appreciable amount of environmental degradation and ecological damage to the soil and water (Makinde *et al*., 2013).

Emel *et al*. (2011) reported that informal mining activities are characterized by low productivity, a lack of capital, poor technology, hazardous working conditions, land degradation, and pollution. However, mining and farming activities are sources of income for individual and corporate bodies. The continuous existence of either of the two often limits the effectiveness and proliferation of the other. Nevertheless, farming is usually the primary recipient of the hazard associated with the efficiency and spread of mining activity. Mining has some degree of impact on the environment regardless of the level of operation. Despite the numerous benefits derived from the industry, small-scale mining has been implicated in recent times as a source of pollution to soil and water systems. However, the extent of damage varies and depends on the scale of mining and processing methods adopted (Aryee *et al*., 2003). The African continent contains about 30% of the world's mineral resources and possesses the largest known reserves of strategically essential minerals, including gold (Darimani *et al*., 2013).

Mining practices are common in Africa, and many researchers have investigated their attributes. For example, Hilson (2001) provides information about the workings of the small-scale mining industry in Ghana and argues that initiatives have recently been taken to regularize and formalize the industry's activities to reduce the associated environmental impacts and land-use conflicts. Except for the recent efforts by the Ministry of Mine and Steel Development, gold mining in Nigeria is mainly uncontrolled, and the majority of the operators are unlicensed (Oramah *et al*., 2015). Studies have indicated mine sites are around farmlands where chemicals may accumulate in fruits and leaves of arable and cash crops, and that soil contamination in mine sites and surrounding areas can cause severe heavy metal contamination of water sources and poisoning of humans and animals if ingested (Bartrem *et al*., 2014; Oramah *et al*., 2015). Poisoning by materials associated with mining has been associated with increased cases of kidney pain, respiratory problems, dizziness, miscarriages in women, cancer, and deaths in many residents of communities where mining activities are carried out (Twerefou *et al.*, 2015).

There is little understanding of the effect of the mining effluent that contains particles that serve as a blockage to soil water transmission due to mining effluent from the gold mining sites. Existing studies have focused on the economic and vegetal consequences of the mining activities on the people and the impact of the mining effluent by enumerating and amending soils and the environment of the mining site. Therefore, there is a need to evaluate the discharge tag as mining effluent containing particles that can cause blockage to soil water transmission on agricultural soil, especially the nearby agricultural land. This research intends to evaluate the effect of mining effluent on soil water transmission near agricultural land.

MATERIALS AND METHODS

Study area

The study area is located at Daba Village, Moro Local Government Area (LGA), Kwara State. It is mainly populated by the Hausa and Yoruba people. The primary source of living for the people in the community is farming.

The area has a large expanse of land used for farming by the people living in that community. The area is a typical rural area with high records of migrants that work in the minefields (most of the migrants are core northerners). Moro LGA is famed for its yam, corn, rice, groundnut and cassava farms. It also has large deposits of mineral resources such as granite, talc, dolomite, tin, stone, marble, and silica sand. In the study area, the major minerals mined are dolomite, marble, and talc (Silas and Jimoh, 2018).

Based on the on-site field assessment, the farmlands around the mining site are approximately 400 m and 800 m away from the mining site, while the forested area is 1200 m away. The area is located within latitude 8^0 47' 25" N and longitude 4^0 31' 1" E, 316 m above sea level. The climate is characterized by the tropical wet and dry climate in the Guinea savanna ecological region. The mean annual temperature of the area typically varies from 18°C to 35°C, rarely below 14°C or above 38°C, and relative humidity ranges between 45% and 95%.

Experimental layout and design

The design for the experiment was a randomized complete block design. The agricultural farmland at 400 m, 800 m, and 1200 m and the mining site formed the area of interest. On each of the four land areas, plots of 25 m x 25 m were marked and replicated three times. The total number of plots was 12. Soil samples were collected in each plot to run the field and laboratory analysis.

Procedure for Infiltration test and Moisture content (MC) measurement

Infiltration rates were determined by using a double-ring infiltrometer. The inner and outer ring diameters were 10 cm and 20 cm, respectively, and both have equal heights of 16 cm each. Both rings were driven into the marked spot on each plot soil surface uniformly through a hammer to 8 cm deep. Soil samples for estimating MC were collected before the infiltration test from the field using a soil auger at a depth of 15 cm, and MC was determined using the oven drying method, that is, keeping soil samples at 105°C for 24 h (Patle *et al.*, 2019).

The formula used to calculate the MC:

$$MC = \frac{(\mathrm{M2} - \mathrm{M1}) - (M3 - M1)}{\mathrm{M2} - \mathrm{M1}}\ X\ 100$$

Where, MC: moisture content (%); M1: weight of dish (g); M2: weight of wet soil sample with the dish (g); M3: weight of dried soil sample with the dish (g).

Procedure for water holding capacity, Bulk density (BD) and Hydraulic Conductivity

60 core samplers with soil were collected from the study area to determine the water-holding capacity, bulk density, and hydraulic conductivity. The BD of soil samples was measured using a cylindrical core sampler of 4.5 cm diameter and 6 cm length. The volume and weight of the core sampler were determined. The core sampler was hammered down into the soil with a hammer. The weight of the soil with core was determined. The BD was calculated by:

$$BD = \frac{W2 - W1}{\mathrm{V}}$$

Where; BD: Bulk density (g/cm³); W_1: weight of core sampler (g); W_2: weight of core sampler and soil (g); V: volume of core sampler (cm³)

Laboratory analysis

Soil samples were obtained from the study area using a multistage procedure. A 25 m x 25 m sample plot was carved out of each classified area and further divided into a subplot of 5 m x 5 m systematically mapped out in each plot. Soil samples were then randomly taken, at 0–15 cm soil depth, using a soil auger from each subplot and then bulked in a black polythene bag and labelled for analysis in the laboratory. The soil samples were air-dried and allowed to pass through a 2-mm sieve before being analyzed. Particle size distribution was analyzed using the hydrometer method (Huluka and Muller, 2014), while pH was determined with a glass electrode pH meter. Organic matter content was determined with the chromic acid oxidation method, while total N was determined by the Kjeldahl digestion method (Pansu & Gautheyrou, 2006). Furthermore, available P was determined by the Bray No. 1 method; concentrations of K^+, Ca^{2+}, and Na^+ were determined with a flame photometer, and the concentration of Mg^+ and selected heavy metals were determined using an atomic absorption spectrophotometer at their respective wavelengths. Also, exchangeable acidity was determined by the titration method.

Data analysis

All data were analyzed using the GenStat Release 8.1 statistical package, 2005. The differences in the mean were separated using the least significant differences (LSD) at a 5% probability level ($p < 0.05$).

Table 1: Effect of mining effluents on pH in water and KCl, organic carbon, organic matter, and N of surrounding farmland.

Location (m)	pH H_2O	pH KCl	Organic carbon (%)	Organic matter (%)	Total N (%)
400	6.53	5.65	0.21	0.36	6.02
800	6.85	5.45	0.31	0.54	4.98
1200	6.95	4.86	0.32	0.74	5.44
Mining Site	7.09	7.01	0.69	1.16	6.27
Lsd (p<0.05)	0.52	1.07	0.16	0.28	1.74

pH (H_2O and KCl)= water and potassium chloride acidity in the soil; Total N= Total Nitrogen

Table 2: Effect of mining effluents on available P, K, Na, Fe and Mg of surrounding farmland.

Location (m)	Available P	K cmol/kg	Na	Fe	Mg
400	1.38	0.50	0.22	0.11	1.11
800	1.20	0.49	0.12	0.10	1.34
1200	1.23	0.52	0.54	0.10	1.57
Mining site	1.04	0.56	0.11	0.17	1.24
Lsd(p<0.05)	0.88	0.10	0.30	0.03	0.33

Available P=Available Phosphorus; K=Potassium; Na=Sodium; Fe=Iron; Mg=Magnesium

RESULTS

Tables 1, 2, and 3 show the influence of mining effluent on selected soil chemical characteristics in the region that surrounds and at the mining site. Except for soil pH in water, there is a substantial variation in mining site soil pH in KCl, organic carbon, organic matter, and total N when compared to 400, 800 and 1200 m (forested area) soils. However, (Table 2) shows that there is no significant distinction between phosphorus and potassium in the four sites. Forested soils included much more salt and magnesium than the remaining three locations, but mining soil contained significantly more iron (Fe) (Table 2). The mining site was only significantly different from 400 m of agricultural farmland away. This revealed various anthropogenic activities in the study area (the mining and surrounding environment), which is typically a heavily disturbed area with evidence of cultivation around the mining site, known to reduce soil pH and cause significant variation in major and micro crop nutrients, which is in line with findings from Estrada-Lillegas *et al*. (2020) on the impact of mining activities and soil reaction. Soil pH in water and KCl at the mining site, which is 7.09 and 7.01, seems to have neutral pH values, indicating that soil reaction to crop cultivation is neutral compared to slightly acidic soil reaction in the agricultural farmland and forested area (1200 m). However, in the forested area, the pH is close to 7, signifying that soils in that area are undergoing significant rest to regain some stability, as deduced by Lemmenih *et al*. (2004). This fact agrees with Estrada-Lillegas *et al*. (2020) and Dansa Marfo *et al*. (2019) findings that most uncultivated soils reaction tends toward neutral with the increase in the uncropped period. However, for the 1200 m from the mining site, the pH KCl is 4.86, the lowest, indicating a strongly acidic soil characteristic of a typical forest area (Marfo *et al*., 2019).

As shown in (Table 1), the soil's organic carbon content is higher (0.69%) and significantly distinct from the other locations. This might be ascribed to the use of carbon-rich products such as oil, waste materials, and food eaten by workers, which may have been decomposed to form part of mining soil components, rather than 400, 800, and 1200 m away from the mine site. At 400 m, its low content (0.211%) could be attributed to continuous cultivation crops such as maize, cassava, and yam, which are heavy nutrient feeders (Fageria *et al*., 2008), implying that the majority of the mineralized organic matter has been utilized for the crop life cycle and that little or no management technique exists.

The primary nitrogen source in the soil is organic matter which plays a critical role in soil ecosystem functions. Lehmann and Kleber (2015) and Lal (2005) reported that the soil nitrogen content depends on the organic matter's humification and relates significantly with the carbon: nitrogen ratio (C: N). However, there is no significant difference in the mean of total N for the four locations, but the mining site is higher (6.07%). The 400 m away had higher nitrogen content than the 800 and 1200 m from the mining site. Their high nitrogen content could be traced to nitrogen-rich inorganic materials such as cyanide and mercury (Fashola *et al*., 2016) used in the resources refinery and inorganic fertilizers on cultivated farmland, typical of rural farmers.

Also, the 400 m away, which is the highest (6.32), is a cultivated area, and most likely inorganic fertilizer is used to increase the nitrogen in the soil, compared to the 800 m, which is the lowest (4.98), indicates that it could be a new open area where farmers grow crops without adding inorganic fertilizers or soil amendments. At 1200 m, which is 5.4, it could be linked to a nitrogen regeneration, building up nitrogen to its natural condition.

The impact of mining effluents on the soils' acidity, base saturation, zinc, and copper is presented in (Table 3) for the sites of interest. In comparison to the mining site

Table 3: Effect of mining effluents on acidity, base saturation, Zn, and Cu of surrounding farmland.

Location (m)	Acidity	Base saturation cmol/kg	Zn	Cu
400	0.80	86.52	0.049	0.087
800	0.40	92.73	0.049	0.062
1200	0.36	91.53	0.053	0.064
Mining site	1.73	68.46	0.070	0.133
lsd (p<0.05)	0.41	5.47	0.001	0.017

Zn= Zinc; Cu=Copper.

Table 4: Effect of mining effluents on selected soil physical properties of the surrounding farmland.

Location (m)	Clay%	Gravel%	Sand%	Silt%	Texture
400	19.18	4.79	56.16	24.89	SL
800	13.58	2.27	63.08	23.33	SL
1200	16.47	8.96	64.20	19.33	SL
Mining Site	15.36	20.19	47.31	37.33	L
lsd (p<0.05)	1.521	2.475	5.005	5.560	

SL: sandy loam, L: loam

(1.16%), the organic matter concentration of the farmlands at 1200 m (0.74), 800 m (0.54), and 400 m (0.40) is more acidic. Therefore, contamination with untethered overburdened materials that include a large quantity of carbonates known as acidic radicals may be the source of the pH increase (Bihain *et al*., 2023). Compared to the mining site, the three farmlands have higher base saturation. An essential soil chemical characteristic that influences soil fertility and taxonomy categorization is base saturation. For soils to be productive, base saturation has to be higher than 80%. A soil that has a base saturation of less than 40% will develop problems relating to nutrient release and retention, and it will be difficult for such a field to produce a crop (Osman, 2018), such as the one recorded in this study mining site. This is a measurement of a soil's energy level. The mining sites have more Zn and Cu, which is likely due to the continuous mining activities that might have led to the deposit of hazardous heavy metals.

The effects of the mining effluent on selected soil physical characteristics are presented in (Table 4). Forested areas serve as control or baseline sites in this studies to examining soil degradation due to mining. They are characterized by high porosity, low bulk density, and superior hydraulic conductivity, as highlighted in the 1200 m site's characteristics in the research in line with Widyastuti *et al*. (2022) study. In contrast to the mining site, which is loam, the farmlands, 400 m and 800 m, which are cultivated areas, and 1200 m, which is a forest area, are characterized by sandy loam. This means that the three distinct components of the soil—sand, silt, and clay—did not have a significantly dominant effect on the soil's characteristics concerning the availability of water and nutrients. This is because the natural soil texture may have been disturbed by the mining operations. According to Worlanyo and Jiangfeng (2021) findings on the evaluation and economic impact of post-mining, it could be linked to topsoil extraction, blasting, and the breakdown of significant soil particles like sand using heavy machinery. Thus, sandy loam soils characterized the community before mining activities, which resulted in the change of the soil texture at the mining site. According to the results, the mining site had the lowest percentage of sand compared to the three locations; for example, the farmland 400 m from the mining site had 56.16% sand, whereas the percentages at the farmland, 800 m from the mining site, and a forested area averaged 63.08% and 64.20%, respectively. Additionally, there was 20.19% gravel at the mine site, with farmlands 200 and 500 m away, and 4.79, 2.27 and 8.96% gravel in the woodland area.

Table 5 shows the effects of mining effluent on the selected soil water transmission properties. The bulk density, whose unit is in g/cm³, 1200 m away from the mining site, is the lowest, 1.189, typically characterized as a value for forest area (Huang *et al*., 2011). The mining site with the highest bulk density (1.45 g/cm^3) could be linked to the weight of particles, which are majorly smaller but in higher portions and have higher gravel content. This indicates a fairly compacted soil due to the current mining activities in just five years. However, the long-term mining effect with continuous excavation and heavy-duty equipment was reported to cause soil structural damage and grossly contaminated soil (Bell and Donnelly, 2006).

The hydraulic conductivity of the soil at the mining site is low (0.0075 cm/h), indicating that the volume of water that can percolate into the soil of the mining site is low as a result of the soil structural damage. The infiltration rate is low in the mining site because the soils are highly compacted, allowing little or no water volume. According to Patle *et al*. (2019), the infiltration rate plays a critical

Table 5: Effect of mining effluents on soil water transmission parameters of the surrounding farmland.

Location (m)	Bulk density (g/cm^3)	Ksat (cm/min)	Moist 001 bar	Moist 006 bar	Moist 01 bar	Moist 10 bar	Moist 15 bar	Moist -1 bar
400	1.23	0.11	0.42	0.41	0.39	0.38	0.37	0.37
800	1.21	0.12	0.40	0.39	0.37	0.36	0.35	0.35
1200	1.19	0.10	0.37	0.36	0.34	0.32	0.31	0.31
Mining Site	1.45	0.01	0.19	0.19	0.19	0.25	0.17	0.18
lsd (p<0.05)	0.11	0.05	0.12	0.10	0.14	0.11	0.10	0.11

Table 6: Effect of mining effluents on soil water transmission parameters of the surrounding farmland.

Location (m)	Moist sat	TP%	Void ratio	Ksat (cm/h)
400	0.45	53.57	1.17	6.34
800	0.55	54.33	1.23	7.05
1200	0.41	55.13	1.27	6.29
Mining site	0.23	45.19	0.85	0.45
Lsd(p<0.05)	0.10	4.18	0.20	0.86

part in irrigation and drainage efficiency, optimizing plants' water availability, and crop yield, and reducing erosion. Also, the infiltration rate is significantly impacted by land use, vegetation covers, seasons, and soil physical properties. Although a higher bulk density indicates a highly compacted soil concerning poorly structured soil, the 800 m farmland away from mining sites shows the highest hydraulic conductivity (ksat) to be 7.05 cm/h, indicating a relatively high volume of water (100 cm^3/m^2) percolating into the soil. Hydraulic conductivity is a critical indicator of a soil's ability to transmit water. Bulk density is a measure of soil compaction and is inversely related to soil porosity and water infiltration. Studies have shown that mining activities significantly increase soil compaction due to heavy machinery, reduced vegetative cover, and alteration of soil structure. Higher bulk density values are often observed near mining sites compared to undisturbed areas, which corroborates the finding that the crop-cultivating sites (400 m and 800 m) can exhibit lower compaction and better hydraulic conductivity than areas closer to the mine (Zhao *et al*., 2020; Li *et al*., 2021). However, the study on post-mining land reported by Liu *et al*. (2022) indicated bulk density values up to 1.8 g/cm^3, which significantly reduces soil aeration and water movement compared to less-disturbed soils with bulk density values around 1.2–1.4 g/cm^3.

Additionally, the soil structure is probably less disrupted 800 m from the mining site, which improves water percolation. Because of soil compaction, decreased organic matter, and disturbed pore connection, areas near mining operations often have poorer hydraulic conductivity (Sun *et al*., 2020). According to research by Adhikari and Hartemink (2018), compacted soils in mining zones have much lower hydraulic conductivity than soils in undisturbed or vegetated areas (such as forests). The mining site has the lowest overall porosity, which suggests that the micro and macro pores are not as good as those found in other soils. The bulk density of the soil and the distribution of macro and micro pores have a direct impact on porosity. These findings aligned with Liu *et al*. (2022) on soil degradation patterns that because of compaction and the breakdown of soil aggregates, mining operations lower overall porosity. However, compared to 400 m, 800 m and 1200 m, the mined soil has typically worsened soil water transmission; the forest area at 1200 m has the maximum porosity; also, operations in the 200 m may have resulted in compaction, which has greatly reduced soil water flow into the soil. Forest areas (like the 1200 m site) typically exhibit higher porosity due to minimal anthropogenic disturbance, higher organic matter, and natural vegetation processes. This aligns with findings that forested areas have better soil water infiltration and retention capacity compared to degraded soils near mines.

The moist sat in the moist condition and percolation rate/s, at the mining site it has the lowest moist sat at 0.23 and highest moist sat at 800 m which is 0.45, 400 and 1200 m away from the mining site 0.45, 0.41 respectively. In agreement with the finding, the 0.23 moisture saturation at the mining site indicates significant degradation of soil structure (Liu *et al*., 2022). The Void ratio is the ratio of the pore volume that contains air and water to the volume of solids. At the mining site, the void ratio is the lowest (0.85), while at 1200 m, it is the highest, which is 1.27. The void ratios at 400 m and 800 m are 1.17 and 1.23, respectively. A study by Zhao *et al*. (2020) demonstrated that mining-compacted soils show void ratios as low as 0.80–0.90, consistent with the mining site's 0.85 void ratios in the quoted findings.

DISCUSSION

Mining generally involves non-regulated practices and is a common mineral exploitation approach in many developing countries (Mason, 2014). In the study area, resource mining started approximately five years ago. However, the government and town leaders seems to overlook the significance of this mining due to the poor condition of the access road and the severely inadequate infrastructure in the area. Bordo and Flandreau (2003) noticed that resource bases in communities hosting mining sites are generally degraded due to the ecosystem disruptions that are often occasioned by the unsustainable exploitation of resources. In the study area, resources that have been disrupted are soil and the environment. Apart from the fact that the soils are deliberately excavated during the mining process, once mined, the opened land portions are rarely filled up, causing them to be dangerous as they serve as accident spots to an unsuspecting user or serve as habitats for reptiles and dangerous animals. Pollutants from the site may be absorbed by shallow-rooted plants or washed into surface water, from where they may contaminate the food chain.

The data on the field of interest (Mining site, near mining site cultivated area, and forested area) demonstrate substantial variations in soil pH in KCl, organic carbon, organic matter, and total nitrogen. However, phosphorus and potassium levels remain consistent across the four sites. Forested soils are characterized by significantly higher concentrations of salt and magnesium than the other locations, while the mining site shows a significant difference only from the agricultural farmland with higher iron content, organic matter, and bulk density. This reveals the profound impact of various anthropogenic activities in the study area, particularly in the heavily disturbed mining and surrounding environments. Such disturbances undoubtedly contribute to a decline in soil pH and result in considerable variations in key macro and micronutrients. These findings align with the research conducted by Estrada-Lillegas *et al*. (2020), which highlights the significant impacts of mining activities on soil reactions. Understanding these effects can guide us in developing more sustainable practices in mining to mitigate harm to the environment.

The primary nitrogen source in the soil is organic matter which plays a critical role in soil ecosystem functions. Lehmann and Kleber (2015) and Lal (2005) reported that the soil nitrogen content depends on the organic matter's humification and relates significantly with the carbon: nitrogen ratio (C: N). However, there is no significant difference in the mean of total N for the four locations, but the mining site is higher (6.07%). The 400 m away had higher nitrogen content than the 800 and 1200 m from the mining site. Their high nitrogen content could be traced to nitrogen-rich inorganic materials such as cyanide and mercury (Fashola *et al*., 2016) used in the resources refinery and inorganic fertilizers on cultivated farmland, typical of rural farmers. Due to smaller macropore spaces that prevent water penetration and movement, compacted soils close to mining operations typically have poor soil water transfer. On the other hand, because of improved soil structure and reduced disturbance, soil water transfer improves with increasing distance from the mining site (Liu *et al*., 2022).

In comparison to soils farther away, activities close to the 400 m location (such as vehicle or mining-related movements) probably resulted in more compaction, which decreased water penetration as revealed in the studies by Feng *et al*. (2021) examining the gradient impacts of human activity on soil characteristics to which the tendency was noted. Mining activities often lead to soil compaction, reducing soil porosity and the soil's ability to retain and transmit water. This results in lower moisture saturation values near mining sites. Compacted soils have fewer macropores, which decreases water infiltration and increases runoff (Sun *et al*., 2020). The void ratio represents the volume of voids (air and water) relative to the volume of soil solids, serving as an indicator of soil aeration and water storage capacity. Soils near mining sites typically exhibit lower void ratios due to compaction and loss of soil structure.

Furthermore, agricultural productivity is likely to decrease with increased mining activities, especially in countries with low coping strategies based on relatively poor access to improved agricultural facilities. Research should be done to observe the plant component of the area of interest with hazardous heavy metals. Also, farmers should be advised on a safer area for planting crops.

Conclusion and Recommendation

The mining site has a poor infiltration rate, indicating more compacted soils than agriculture and woodland regions. According to the study, the soils in the mining site were loamier than those in other locations. The primary farming region in that community is within the range of the proposed soil water transmission channel, since the hydraulic conductivity and bulk density vary distinctly between 400 and 800 m from the mining site, respectively. The water transmission of the soil in the existing agricultural area associated with the mining site has not been impacted by mining effluent, thus plants growing in that region will not have challenges with soil water flow. Research on the concentration of dangerous heavy metals and cancer-causing substances in the plant component of the present agricultural area should be conducted, thereby advising farmers on a safer crop-planting location in order to improve community health.

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