SOIL HEALTH AND METAL POLLUTION NEAR BARAPUKURIA COAL MINE

Md. Asif All Azad*[1], Md. Hafijur Rahman Sabbir[2]

[1] *Undergraduate student, Khulna University of Engineering & Technology, Bangladesh, e-mail: asif.che.kuet@gmail.com*
[2] *Undergraduate student, Khulna University of Engineering & Technology, Bangladesh, e-mail: sabbir.hafijur.rahman@gmail.com*

***Corresponding Author**

ABSTRACT

Bangladesh is experiencing a severe shortage of land as a result of its developing economy and burgeoning population. The coal exploitation sector in Bangladesh, notwithstanding its substantial industrial significance, exerts detrimental environmental impacts. The degradation of soil quality due to coal mining activities is a matter of concern in the Barapukuria Coal Mining Area (BCMA). This research aims to assess the fertility of the soil and the level of metal contamination in surface soil across three types of land use; soil near drainage areas, agricultural land irrigated with mine water and regular farmland. In May 2023, soil samples were sent to the Soil Resource Development Institute (SRDI) in Khulna for analysis. The concentrations of metals found in the surface soil near drainage areas are as follows: Copper (3.67 µg/g), Zinc (9.09 µg/g), Lead (1.08 µg/g), Cadmium (0.261 µg/g), and Iron (75.70 µg/g). These concentrations are within limits the Food and Agricultural Organization (FAO) and the Environment Agency (EA) set. Furthermore, both regular field and coal water-treated soil showed moderate acidity levels. The coal water-treated soil exhibited higher organic content compared to regular farmland. The Mn, Fe, and S levels showed an increase in the soil treated with coal water compared to the soil found in regular fields. The regular field soil had high levels of Cu and Mg, while Ca remained within the range. On the other hand, concentrations of K and P were relatively low. Conversely, the coal water-treated soil exhibited high Zn, Ca, Mg, and Cu concentrations, a low concentration of P, and a moderate amount of K. According to the study, agricultural area irrigated by mine water exhibited high soil fertility in various criteria. However, the continuous accumulation of heavy metals in the soil may pose a long-term risk to the soil resources and crop production in the BCMA.

Keywords: *Barapukuria coal mine, coal mining contamination, heavy metal, surface soil, irrigation suitability,*

1. INTRODUCTION

Agricultural productivity, ecosystems, and societal well-being are adversely affected by the dynamic relationship between soil fertility and heavy metal accumulation. The ongoing discussions increasingly recognize the consequences associated with coal extraction methods. The extensive problem of dispersal of metals and polycyclic hydrocarbons (PAHs) caused by coal mining and combustion poses risks, to both ecosystems and human communities (Hama Aziz et al., 2023). Studies indicate a link, between coal mining operations and the emission of chemical compounds containing PAHs and heavy metals into the atmosphere ultimately resulting in soil contamination. Additionally, the residues from coal combustion contribute to the distribution of chemicals in the environment resulting in their accumulation, in soil deposits. As a result, this particular process gives rise to the degradation of soil, disturbances in nutrient concentrations, and a decline in agricultural output (Ren et al., 2022). Air deposition, leaching from mine tailings, and runoff from nearby landscapes all contribute to the infiltration of heavy metals from coal and its associated waste into the soil. The Barapukuria coal mine serves as an exemplary case that exemplifies the difficulties associated with soil fertility loss and the contamination of heavy metals (Xu et al., 2023). Barapukuria, the exclusive commercial coal mine in Bangladesh, is under the management of Barapukuria Coal Mining Company Limited (BCMCL), which operates as a subsidiary of Petrobangla. The mine discovered in the early 1980s and began mining operations in 2005. The coal extracted from Barapukuria is predominantly employed for electricity production in a nearby thermal power plant with a capacity of 525 megawatts ("Barapukuria Coal Mine," 2023).

Coal is a naturally occurring mineral deposit that commonly displays a dark black or brownish-black coloration. The substance in question is derived from the decomposed residues of plant matter that may be traced back to a geological timeframe spanning around 100 to 400 million years. The substance under consideration is a multifaceted composite of various elements, including sulfur, elemental carbon, arsenic, residual ash, and a diverse assortment of heavy metals. In the specific context of Bangladesh, coal has the position of being the second most crucial resource in terms of its reserves. It accounts for 41.5 percent of global electricity output. The Barapukuria coal mine and its affiliated power station are crucial in mitigating Bangladesh's electricity deficit.

Nevertheless, the mining activities in this region have resulted in the dispersion of heavy metals and various pollutants into the surrounding ecosystems, particularly the soil. As a result, these changes have had an impact, on the quality, nutrient composition, and overall fertility of the soil. Unfortunately, this decline in soil fertility and the presence of metals have effects on agricultural productivity and can potentially pose health risks to humans. The extraction of coal whether it occurs underground or on the surface is an concern that significantly alters the physical, biological and chemical characteristics of the surrounding environment (Hossain et al., 2014). Human society and natural ecosystems are affected significantly and widely by this modification. The vicinity of coal mines is particularly vulnerable to contamination from several hazardous compounds, such as chromium (Cr), copper (Cu), nickel (Ni), zinc (Zn), iron (Fe), cadmium (Cd), and lead (Pb), due to the mining operations and associated waste generation (Hossain et al., 2014).

In the field of mineral exploration, a multitude of environmental consequences are frequently noticed. These effects encompass the decline of vegetation and heightened soil erosion, which occur as a result of vehicle activity when clearing vegetation to make way for exploration pathways. The inadequate handling and disposal of equipment and substances have been found to have an influence, on the degradation of both land based and aquatic ecosystems. The International Accountability Project has conducted investigations into the Barapukuria mine uncovering damage spanning over an area exceeding 300 acres (Rahman et al., 2021). The lives of 2,500 people, in seven villages have been greatly affected by the damage caused. The mining activities have resulted in soil subsidence leading to the deterioration of lands and infrastructure. Research in this field suggests that coal mining can alter the properties of soil such as reducing moisture content, cohesiveness and organic matter levels while increasing the angle of friction. These changes affect aspects related to the quality of soil. Moreover coal mining operations have an impact, on indicators that measure the quality of soil (Yang

& Bian, 2021). The Barapukuria coal falls into the category of bituminous coal according to the assessment of coal mining's effects on soil and water. This particular. type of coal is recognized for its energy values, which can be attributed to its levels of ash (12.04%) and moisture (2.83%) (Yang et al., 2016).

Since coal mining began, agricultural operations have been significantly impacted. The utilization of mine effluent for irrigation carries the risk of toxic metals building up in the soil, which can pose dangers to well-being. However, there needs to be more research investigating the levels of soil nutrients in the Barapukuria coal mine region. This emphasizes the pressing requirement for thorough assessments of soil nutrient and heavy metal concentrations from an agricultural perspective. Thus, the objective of this study is to assess soil fertility, suitability for irrigation, and the presence of heavy metal concentrations in the soil.

2. METHODOLOGY

The methodology section describes how this study identified the sample region and measured soil properties.

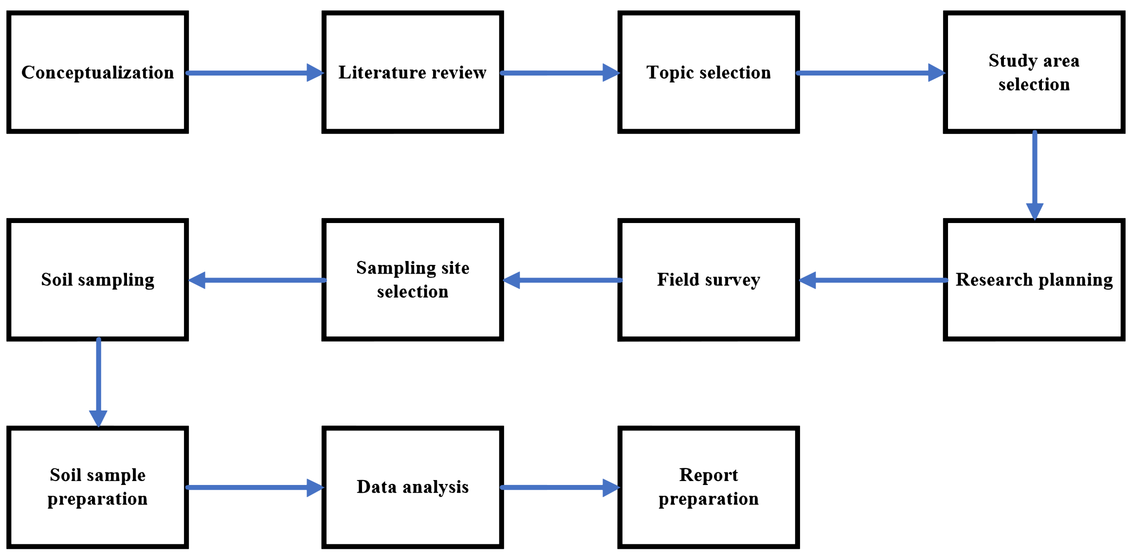

Figure 1: Flow chart of the gross outline of the study

2.1 Description of Study Area

The Barapukuria coal mine and power station are located in the flat agricultural landscape of the north-western region of Bangladesh, around 45 kilometers east of the district capital of Dinajpur and 20 kilometers from the border with India. It is physiographically located in the Dinajpur Shield of Bangladesh. The Indian Peninsular Shield to the west, the Shillong Shield to the east, and the Himalayan foredeep to the north surround it. The coal reserve that has been officially verified covers an approximate area of 5.25 square kilometers. There is a projected possibility of expanding this reserve by an estimated 1 to 1.5 square kilometers towards the southern region. The coal mine and power plant are situated in the Hamidpur union of the Parbatipur Upazila in the Dinajpur district. More specifically, their geographic coordinates range from 25°31′45″ to 25°33′05″ N in latitude and from 88°57′48″ to 88°58′53″ E in longitude (Hama Aziz et al., 2023). The coalfield encompasses various villages, such as Barapukuria, Banspukur, Dakshin Rasulpur, Kalupara, Hamidpur, Chauhati, Ichabpur, Patigram, Gopalpara, Baidyanathpur, Sherpur, and Baigram, either in their entirety or in part.

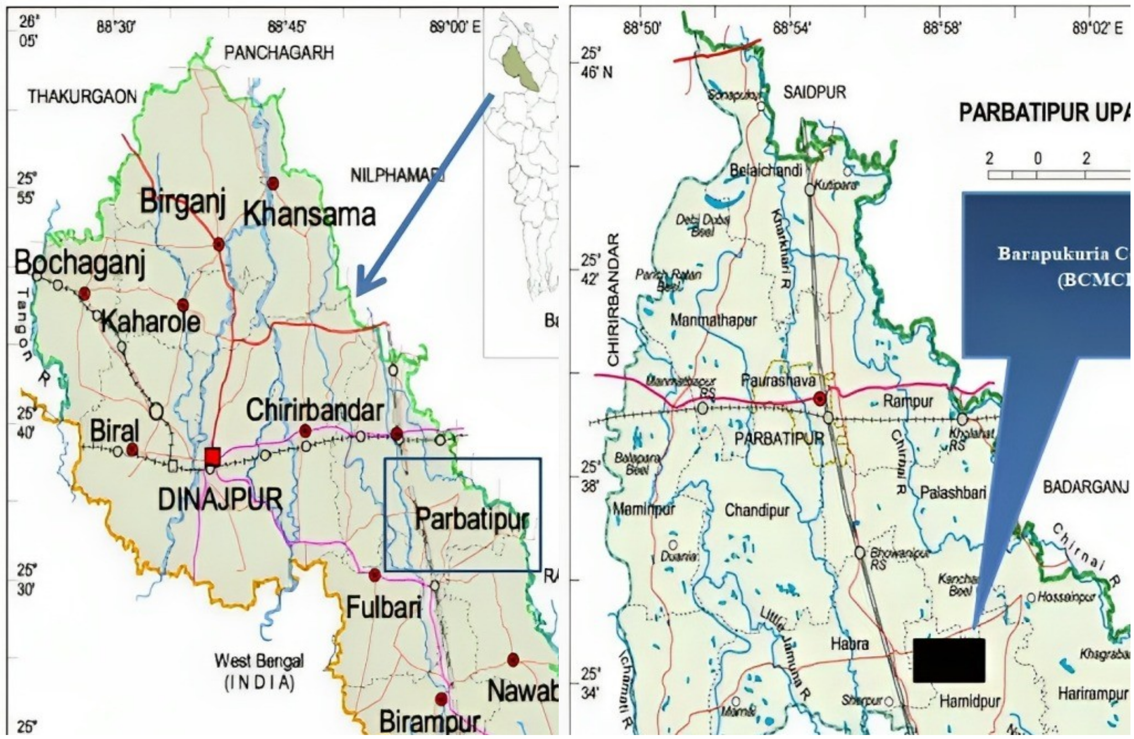

Figure 2: Location of the study area (Sabit, n.d.)

2.2 Site Selection and Sampling

Soil samples were obtained from three distinct locations near the Barapukuria coal mining area, as seen in Figure 3. Each sample was collected at a depth of 15 centimeters from the surface. A surface soil sample (location 1) was collected from the nearby mine drainage. The agricultural land soil (location 2), which was irrigated with mine or drain water, and the ordinary farmland soil (location 3) were also collected. These samples were obtained from different coordinates within the designated research area and stored in sealed polyethylene containers. The data collection procedure involved carefully removing material from the upper to the lower layer using a spade to facilitate further analytical evaluation. Every specimen was clearly labeled with the specific date and location of its collection. In order to facilitate a comprehensive examination of the many soil properties, the samples, as mentioned earlier, were meticulously transported to the Soil Resource Development Institute (SRDI) in Khulna.

Table 1: Location of sampling

Location	Location 1	Location 2	Location 3
Latitude	25°32’42”	25°32’37”	25°32’21”
Longitude	88°57’29”	88°57’21”	88°57’32”

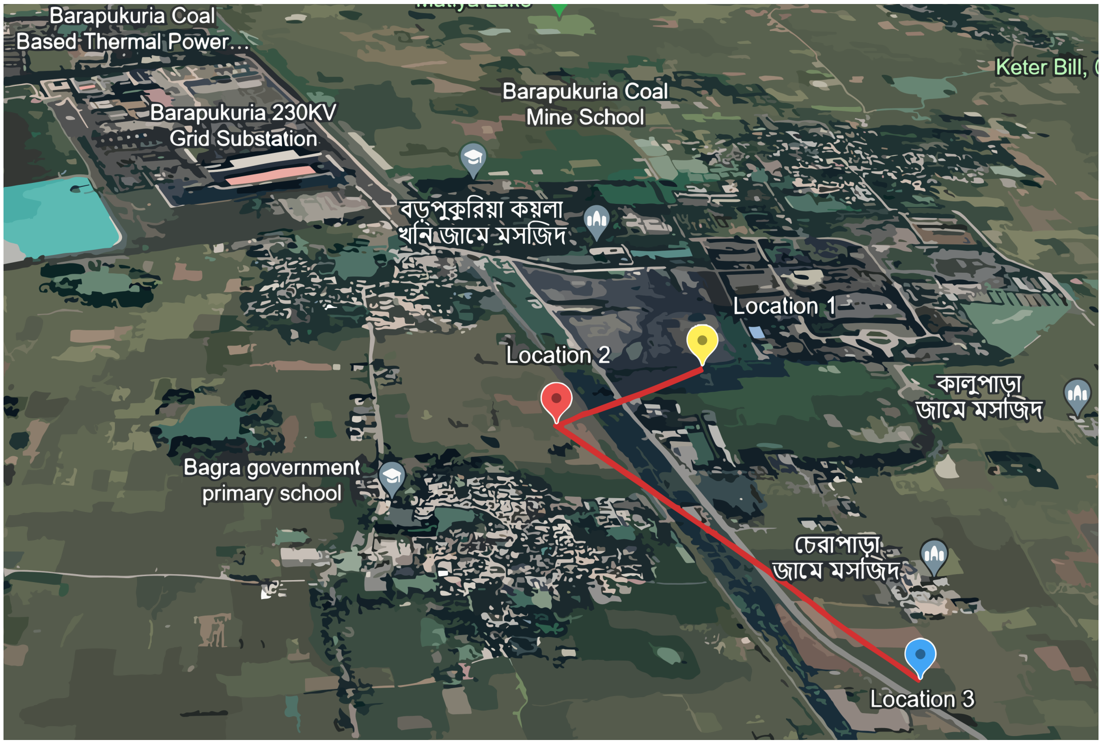

Figure 3: Location of soil sampling in the study area

2.3 Data Analysis of Soil Samples

Heavy metal contaminants were examined in the surface soil of the Barapukuria coal mine area. The assessment of critical factors involved a thorough assessment. Copper, zinc, lead, cadmium, and iron contamination levels in soil matrix were measured as a primary objective of this evaluation. For the successful establishment and long-term viability of agricultural activities, a range of soil quality indicators have been evaluated. pH level, organic matter content, calcium, phosphorus, magnesium, manganese, iron, and sulfur concentrations were also measured. The criteria mentioned earlier were employed to assess the quality of soil that underwent treatment with coal mine water, in contrast to soil obtained from typical farmland. Additionally, comparing soil quality indicators with the reference values established by the Soil Resource Development Institute (SRDI) enabled the assessment of their suitability for agricultural activities.

3. RESULTS AND DISCUSSION

3.1 Heavy Metal Contamination Analysis

Table 2: Surface soil characteristics from nearby mine drainage

No	Parameter	Unit	Location 1	FAO and EA standard
1	Cu	µg/g	3.67	100
2	Zn	µg/g	9.09	300
3	Pb	µg/g	1.08	100
4	Cd	µg/g	0.261	3
5	Fe	µg/g	75.70	50000

In surface soil samples collected near the drainage area of the Barapukuria Coal Mine, copper was detected at a concentration of 3.67 µg/g, zinc was detected at a concentration of 9.09 µg/g, lead was detected at a concentration of 1.08 µg/g, cadmium was detected at a concentration of 0.26 µg/g, and iron was detected at a concentration of 75.7 µg/g. These findings have been contextualized by comparing them with thresholds established by FAO and EA.

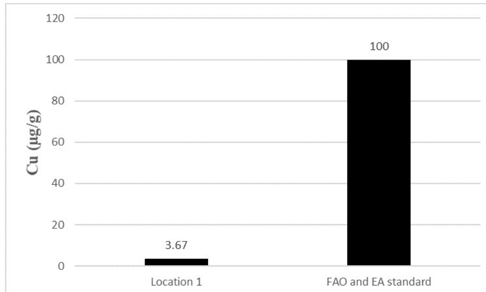

Figure 4: Concentration comparison of Cu with FAO and EA standard

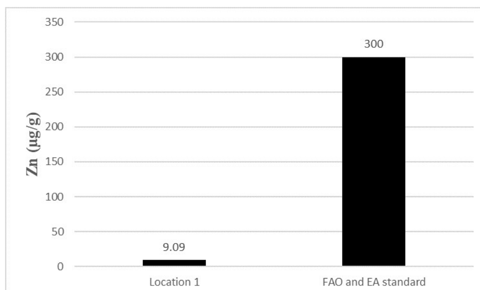

Figure 5: Concentration comparison of Zn with FAO and EA standard

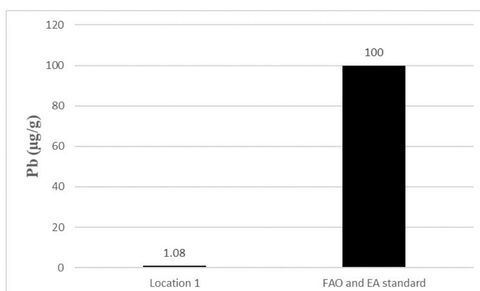

Figure 6: Concentration comparison of Pb with FAO and EA standard

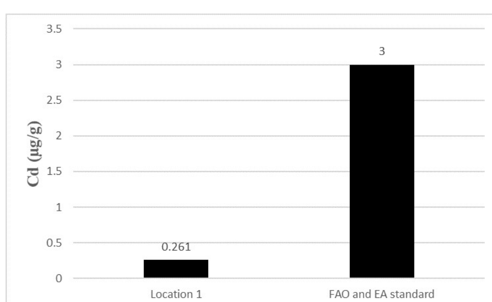

Figure 7: Concentration comparison of Cd with FAO and EA standard

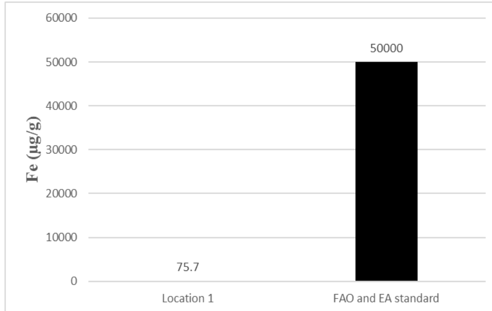

Figure 8: Concentration comparison of Fe with FAO and EA standard

According to their guidelines, the FAO and the EA have set the acceptable limit for copper (Cu) concentration in soil at 100 µg/g. The copper (Cu) concentration in the surface soil surrounding the mine drainage-affected area is much lower than the established threshold, indicating a relatively small extent of copper contamination. EPA and FAO guidelines have established upper limits for zinc (Zn) and lead (Pb) concentrations of 300 µg/g and 100 µg/g, respectively. As compared to established reference values, zinc (Zn) and lead (Pb) concentrations in the surface soil have decreased significantly. Metal contamination is less likely to occur as a result of this observation. The permissible limit of Cd has been established by the Food and Agriculture Organization (FAO) and the Environmental Agency (EA) at 3 µg/g. The measured concentration of Cd, however, marginally exceeding the established threshold, remains comparatively low. However, it is imperative to maintain continuous surveillance in order to monitor the concentrations of Cd since this is essential in preventing the possibility of exceeding the acceptable levels over an extended period. Over the element Fe, the concentration observed in the surface soil near the mine drainage area is 75.7 µg/g, far lower than the established standards set by the FAO and EA, precisely 50,000 µg/g. Fe pollution in the region is not of great concern based on this observation. According to an analysis of heavy metal concentrations in surface soil surrounding the mine drainage of the Barapukuria Coal Mine, these concentrations are below the existing requirements set by the Food and Agriculture Organization (FAO) and the Environmental Agency (EA).

3.2 Soil Fertility Analysis

Table 3: Soil quality parameters of coal water treated soil and normal field soil

No	Parameter	Unit	Location 2	Location 3
1	pH	-	6.30	5.90
2	Organic content	%	7.91	1.62
3	Zn	µg/g	7.25	1.04
4	Cu	µg/g	4.40	1.98
5	K	meq/100g	0.26	0.19
6	Ca	meq/100g	10.30	5.30
7	P	µg/g	9.76	5.16
8	Mg	meq/100g	2.13	1.65
9	Mn	µg/g	146.55	25.83
10	Fe	µg/g	133.39	25.49
11	S	µg/g	202.49	25.33

3.2.1 pH Levels

Table 4: Soil reaction ratings

No	P^H range	Soil reaction rating
1	< 4.6	Extremely acidic
2	4.6–5.5	Strongly acidic
3	5.6–6.5	Moderately acidic
4	6.6–6.9	Slightly acidic
5	7	Neutral
6	7.1–8.5	Moderately alkaline
7	> 8 5	Strongly alkaline

The pH level of soil, which indicates its acidity or alkalinity, plays a crucial role in determining soil fertility and the growth of plants. The pH level of soil has an impact on the availability of nutrients, which in turn affects the ideal growth conditions for various plant species. The pH values of the soil samples collected from Location 2 and Location 3 were 6.30 and 5.90, respectively, indicating that both locations can be moderately acidic. Soils are categorized as moderately acidic within the spectrum of soil acidity when the pH falls between 5.6 and 6.5. The present acidity level can influence nutrient availability, hence exerting an impact on crop growth. While most crops exhibit a certain degree of tolerance towards moderate levels of acidity, some crops may benefit from applying lime to elevate the soil's pH level, hence enhancing its fertility.

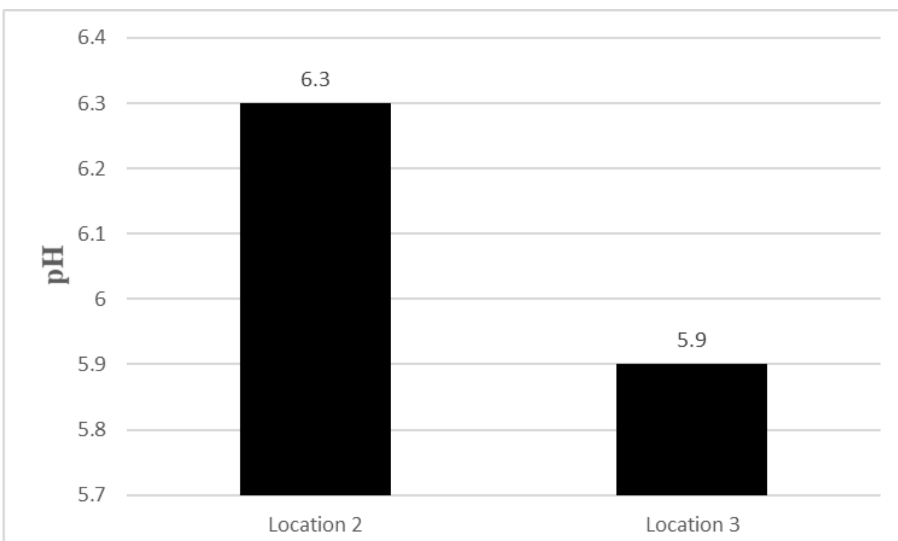

Figure 9: Comparison of pH level between location 2 and location 3

Nevertheless, the elevation of acidity levels might also result in an augmented solubility and mobility of heavy metals within the soil, presenting potential contamination hazards for both agricultural produce and the encompassing ecosystem. Therefore, it is imperative to conduct periodic evaluations of heavy metal concentrations in these soils and the associated crops and implement appropriate measures to mitigate any potential adverse effects.

3.2.2 Organic Content

Table 5: Standard of soil organic matter (%)

No	Value	Status
1	<1.00	Very low
2	1.00-1.70	Low
3	1.71-3.40	Medium
4	3.41-5.50	High
5	>5.50	Very high

Soil fertility is significantly affected by organic materials. As a result, the soil's physical properties, such as water retention capacity and structural stability, are enhanced. In addition, the presence of organic matter plays a significant role in enhancing nutrient accessibility and mitigating the impact of pests and diseases. Based on the standard of soil organic matter (%) in Table 5, the soil at Location 2 exhibits a very high organic matter content, suggesting a favourable condition for nutrient availability, moisture retention, and microbial activity. Conversely, the soil at Location 3 demonstrates a comparatively low organic matter content (1.62%).

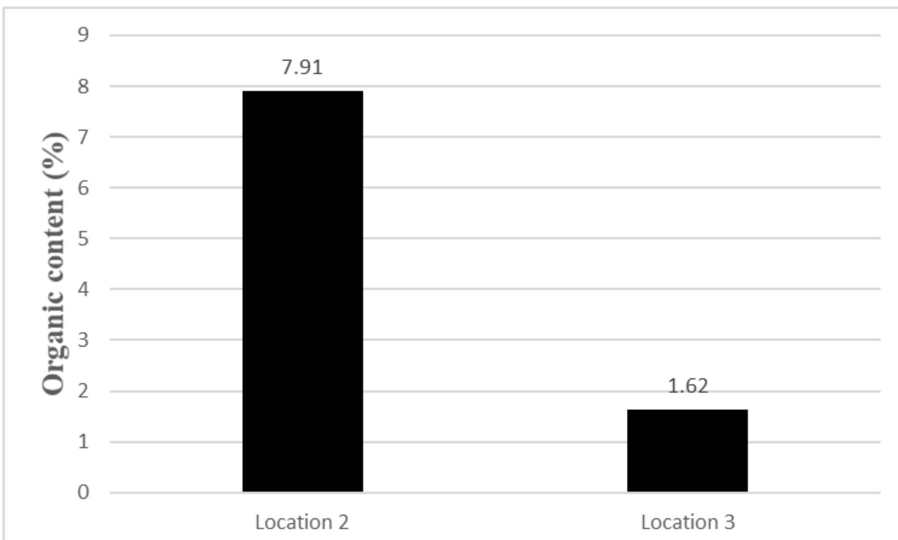

Figure 10: Comparison of organic content between location 2 and location 3

The elevated concentration of organic matter in the soil at Location 2 is likely due to the irrigation of the land with mine water. Mine water often contains high levels of organic matter, which is derived from the decomposition of plants and other organic materials in the mine. The presence of a substantial amount of organic matter in the soil can contribute to improved soil structure, enhanced nutrient cycling, and increased water-holding capacity, thereby supporting agricultural productivity. Conversely, diminished quantities of organic matter can have adverse effects on both soil fertility and productivity.

3.2.3 Analysis of Nutrients

Table 6: Nutrients level chart of soil (SRDI, Bangladesh) Standard

Nutrients	Nutrients status					
	Very low	**Low**	**Medium**	**Optimum**	**High**	**Very high**
N (%)	< 0.090	0.091 - 0.18	0.081 - 0.270	0.271 - 0.36	0.361 - 0.450	> 0.450
P (µg/g)	< 6.000	6.100 - 12.00	12.100 - 18.000	18.100 - 24.00	24.100 - 30.000	> 30.000
Zn (µg/g)	< 0.450	0.451 - 0.90	0.910 - 1.350	1.351 - 1.80	1.810 - 2.250	> 2.250
Fe (µg/g)	< 3.000	3.100 - 6.00	6.100 - 9.000	9.100 - 12.00	12.100 - 15.000	> 15.000
Mn (µg/g)	< 0.750	0.760 - 1.50	1.510 - 2.250	2.260 - 3.00	3.100 -1 3.750	> 3 750
B (µg/g)	< 0.150	0.151 - 0.30	0.310 - 0.450	0.451 - 0.600	0.610 - 0.750	> 0.750
K (meq/100g)	< 0.075	0.076 - 0.15	0.151 - 0.225	0.226 - 0.300	0.310 - 0.375	> 0.375
Ca (meq/100g)	< 1.500	1.510 - 3.00	3.010 - 4.500	4.510 - 6.00	6.010 - 7.500	> 7.500
Mg (meq/100g)	< 0.375	0.376 - 0.75	0.751 - 1.125	1.126 - 1.50	1.510 - 1.875	> 1.875
Cu (µg/g)	< 0.15	0.15 - 0.30	0.31 - 0.45	0 45 - 0.60	0.61 - 0 75	> 0.75

Plant growth. and soil fertility are strongly influenced by soil nutrient concentrations. Generally, soils loaded with nutrients tend to exhibit reduced concentrations of heavy metals. A comprehensive examination conducted in adherence to the standards established by the Soil Research and Development Institute (SRDI) has determined that the zinc (Zn) content in the soil obtained from Location 2 measures 7.25 µg/g, thereby classifying it as a "very high" concentration. On the other hand, it is noteworthy that the concentration of Zn at Location 3 is measured to be 1.04 µg/g, a value that falls within the categorization of the "medium" range. There is a difference, in the amount of zinc found at Location 2 compared to Location 3.

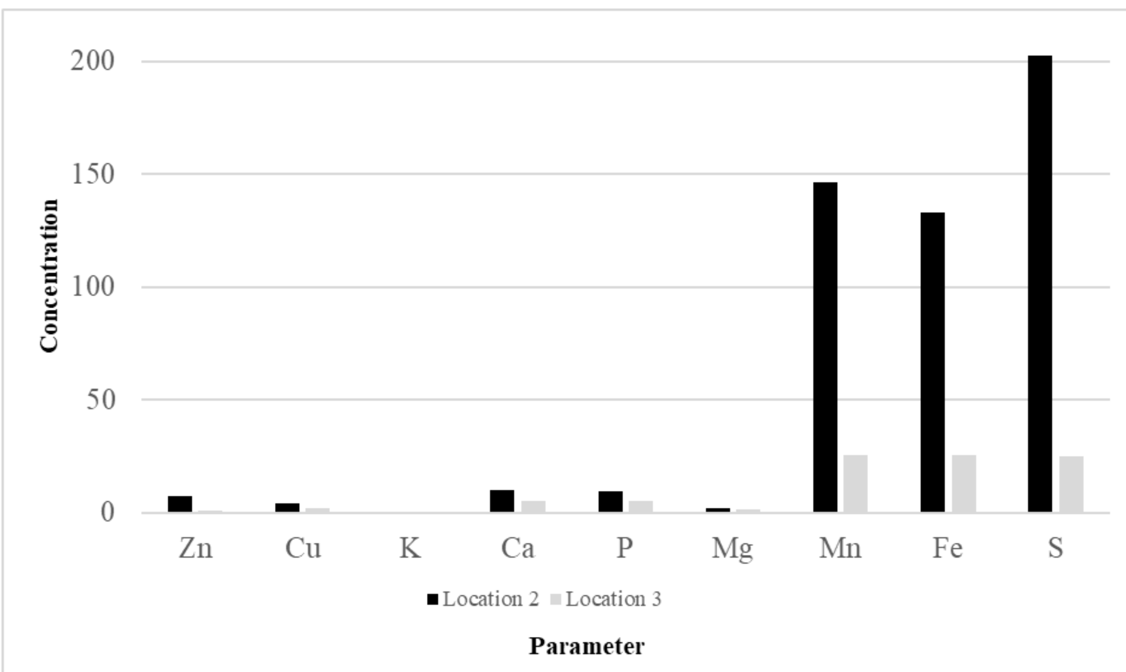

Figure 11: Comparison of nutrients in location 2 and location 3

According to the suggestions given by the Soil Research and Development Institute (SRDI), a study revealed that the soil in Location 2 had a concentration of zinc (Zn) at 7.25 µg/g classified as "very high". On the other hand, the zinc level in Location 3 was found to be "medium" at 1.04 µg/g indicating a disparity, between these two areas. Additionally, Location 2 exhibited a copper (Cu) concentration of 4.40 µg/g, which falls under the category of "very high". In comparison, Location 3 had a copper level of 1.98 µg/g also classified as "high". Moving on to the potassium (K), the concentration at Location 2 was found to be within the range measuring at 0.26 meq/100g which is slightly higher than the level observed at Location 3 (0.19 meq/100g). Furthermore, there was a disparity in calcium (Ca) concentrations between the two locations. Location 2 displayed an elevated value of 10.30 meq/100g compared to an optimal calcium concentration of 5.30 meq/100g at Location 3. Lastly, both locations showed levels of phosphorus (P). At Location 2, it was measured at a value of 9.76 µg/g while Location 3 only had a reading of 5.16 µg/g. In terms of magnesium (Mg), there was a difference between the two locations. The concentration at Location 2 was noticeably higher, with a measurement of 2.13 meq/100g compared to an elevated magnesium level of 1.65 meq/100g observed at Location 3. Both locations exhibited increased amounts of manganese (Mn) and iron (Fe) with Location 2 displaying concentrations. While the nutrient composition in Location 2 supports plant growth, there is a concern regarding the presence of concentrations of metals in this area. If crops grown there are consumed, it could potentially pose health risks.

4. CONCLUSIONS

The research focuses on examining soil fertility and the presence of metal pollutants, in land use types neighboring the Barapukuria coal mine in Bangladesh. In drainage areas, the concentration of copper (Cu) was measured at 3.67, µg/g, zinc (Zn) at 9.09 µg/g lead (Pb) at 1.08 µg/g, cadmium (Cd) at 0.261 µg/g and iron (Fe) at 75.7 µg/g. These concentrations mostly fall below the existing requirements specified by both the Food and Agriculture Organization (FAO) and Environmental Agency (EA). The pH values of the soil samples collected from Location 2 and Location 3 were 6.30 and 5.90, respectively, indicating that both locations can be moderately acidic, which can influence nutrient availability and metal mobility. The organic matter content varied, with Location 2 showing more favorable conditions for nutrient availability, moisture retention, and microbial activity compared to Location 3, which had a lower organic matter percentage (1.62 %). Zinc content in Location 2 was found to be very high at 7.25 µg/g, compared to a medium level of 1.04 µg/g in Location 3. Similar trends were observed with copper, where Location 2 had a "very high" concentration of 4.40 µg/g, and Location 3 had a "high" level of 1.98 µg/g. Potassium, calcium, phosphorus, and magnesium levels also varied between the two locations, with generally higher values in Location 2. While the nutrient composition, in Location 2 supports plant growth, there is a concern regarding the presence of concentrations of metals, in this area. If crops grown there are consumed, it could potentially pose health risks.

REFERENCES

Barapukuria coal mine. (2023). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Barapukuria_coal_mine&oldid=1140556913

Hama Aziz, K. H., Mustafa, F. S., Omer, K. M., Hama, S., Hamarawf, R. F., & Rahman, K. O. (2023). Heavy metal pollution in the aquatic environment: Efficient and low-cost removal approaches to eliminate their toxicity: a review. *RSC Advances*, *13*(26), 17595–17610. https://doi.org/10.1039/D3RA00723E

Hossain, S., Urbi, Z., & Islam, S. (2014). *Environmental Impact of Coal Mining: A Case Study on the Barapukuria Coal Mining Industry, Dinajpur, Bangladesh*.

Rahman, M. T., Khan, A. H., Negash, B. M., Sultana, K., Hasan, M. A., Askary, A., Rubbi, F., & Das, L. (2021). Effects of Disposed-water from Barapukuria Coal Mine, Dinajpur, Bangladesh on Agriculture and Aquaculture. *IOP Conference Series: Materials Science and Engineering*, *1176*(1), 012008. https://doi.org/10.1088/1757-899X/1176/1/012008

Ren, M., Zheng, L., Hu, J., Chen, X., Zhang, Y., Dong, X., Wei, X., & Cheng, H. (2022). Characterization of polycyclic aromatic hydrocarbons in soil in a coal mining area, East China: Spatial distribution, sources, and carcinogenic risk assessment. *Frontiers in Earth Science*, *10*, 1035792. https://doi.org/10.3389/feart.2022.1035792

Sabit, H. (n.d.). *STUDY ON THE EFFECT OF COAL MINE TO THE SURROUNDING SOIL PROPERTIES OF BARAPUKURIA DINAJPUR*.

Xu, Z., Qian, Y., Hong, X., Luo, Z., Gao, X., & Liang, H. (2023). Contamination characteristics of polycyclic aromatic compounds from coal sources in typical coal mining areas in Huaibei area, China. *Science of The Total Environment*, *873*, 162311. https://doi.org/10.1016/j.scitotenv.2023.162311

Yang, D., & Bian, Z. (2021). *Comparison of the Disturbance of Soil Physical Quality Indices Between Different Underground Mining Stages in Semi-Arid Regions of Western China*. https://doi.org/10.21203/rs.3.rs-524144/v1

Yang, D., Bian, Z., & Shaogang, L. (2016). Impact on soil physical qualities by the subsidence of coal mining: A case study in Western China. *Environmental Earth Sciences*, *75*. https://doi.org/10.1007/s12665-016-5439-2