STUDY ON THE EFFECT OF COAL MINE TO THE SURROUNDING SOIL PROPERTIES OF BARAPUKURIA DINAJPUR

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DECEMBER, 2020

STUDY ON THE EFFECT OF COAL MINE TO THE SURROUNDING SOIL PROPERTIES OF BARAPUKURIA DINAJPUR

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REGISTRATION NO. 18-09251

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

IN

AGROFORESTRY AND ENVIRONMENTAL SCIENCE

SEMESTER: JULY-DECEMBER, 2020

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CERTIFICATE

*This is to certify that thesis entitled, "**STUDY ON THE EFFECT OF COAL MINE TO THE SURROUNDING SOIL PROPERTIES OF BARAPUKURIA DINAJPUR**" submitted to the Faculty of **Agriculture**, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGROFORESTRY AND ENVIRONMENTAL SCIENCE**, embodies the result of a piece of bona-fide research work carried out by **MD. HASAN SABIT**, Registration no. **18-09251** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Date: DECEMBER, 2020
Place: Dhaka, Bangladesh

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ACKNOWLEDGEMENTS

All praises are putting forward to The Almighty Who is the Supreme Planner and has blessed the author to complete this piece of study as required for the degree Master of Science.

It is a great pleasure for the author to make delighted his respected parents, who had been shouldering all kinds of hardship to establish a favorable platform thereby receiving proper education until today.

*The author wishes to offer his cordial appreciation and best regards to his supervisor, **Prof. Dr. Ferzana Islam**, Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka, who has supported me throughout my thesis with her patience and knowledge whilst allowing me to work in my own way. The author attributes the level of my Master's degree to her encouragement and effort and without her; this thesis would not have been completed or written.*

The Author is very much grateful to his co-supervisor Md. Abu Zafur Al Munsur, Additional Deputy Director, Department of Agricultural Extension (DAE), Khamarbari, Dhaka for his valuable advice, constructive criticism, and factual comments in upgrading the research with all possible help during the research period and preparation of the thesis.

The author wants to give very special thanks to his best companion S. M. Shahriar Zaman Shishir who was always with him in collecting field data and encouraged him in doing his research work properly. The author is indebted to his last but not least profound and grateful gratitude to his beloved parents and all of his friends for their inspiration, blessing, and encouragement that opened the gate of his higher studies in his life.

The author expresses his heartfelt thanks to his brothers, sisters, uncles, aunts and other relatives who continuously prayed for his success and without whose love, affection, inspiration and sacrifice this work would not have been completed.

May Allah bless and protect them all.

The Author
December, 2020

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ABSTRACT

Coal mining contamination poses an immense risk to the environment and underlying soil. The main objective of this research was to determine the consistency and deviation of soil quality around Barapukuria coal mine in Parbatipur, Dinajpur. Soil samples were collected from five different locations based on the Regional Land and Soil Resources Utilization Guide of SRDI during summer in 2019. Each sample was separated for the measurement of 12 chemical properties including pH, Organic Matter (OM), Nitrogen (N), available Phosphorus (P), exchangeable Potassium (K), available Sulfur (S), exchangeable Calcium (Ca), exchangeable Magnesium (Mg), Copper (Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn). Nitrogen (N), exchangeable Potassium (K), available Phosphorus (P) and available Sulfur (S) were determined by modified micro Kjeldahl method, Ammonium acetate method, stannous chloride method, and Ion Chromatography, respectively. On the other hand, Cu, Fe, Mn and Zn were determined by DTPA-extraction method at a soil DTPA ratio of 1:2 using Atomic Absorption Spectrophotometer. Data were analyzed by using MS Excel and SPSS software. Results indicated that many of the soil nutrient levels increased in 2019 in comparison with 1999 such as pH (5.28 to 5.70), OM (2.16 to 3.21%), N (0.047 to 0.067 ppm), K (0.41 to 4.12 meq 100g-1), S (16.75 to 31.17 ppm), Mg (1.62 to 6.73 meq 100g-1), Fe (202.67 to 303.50 ppm), Mn (13.11 to 27.40 ppm) and Zn (13.11 to 27.40 ppm). With the increase of time, the average content of Ca (4.15 to 5.74 meq 100g-1) and Cu (0.13 to 0.46 ppm) were decreased whereas the available P did not change much. From the analysis of soil samples it has been identified that several important chemical parameters that is necessary for agriculture are deviated from the Standard Reference value. It is due to the poor infrastructure of coal stock pile and improper disposal of mine water. The findings of this research help us to assess the level of soil contamination in the region of the Barapukuria coal mine.

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Acronyms

%	Percentage
AEZ	Agroecological Zones
AMD	Acid Mine Drainage
ARD	Airborne Respirable Dust
BBS	Bangladesh Bureau of statistics
BCML	Barapukuria Coal Mine Limited
BOD	Biochemical Oxygen Demand
CV	Coefficient of Variation
DO	Dissolved Oxygen
DTPA	Diethylene Triamine Pentaacetic Acid
et al.	and others
GPS	Global Positioning System
LS	Level of Significance
LSD	Least Significant Difference
NFS	Normal Farmland Soil
OC	Organic Carbon
OM	Organic Matter
ppm	Parts Per Million
SRDI	Soil Resource Development Institute
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
USDA	United States Department of Agriculture

CHAPTER I

INTRODUCTION

Coal, a natural mineral reserve, is a black or brownish-black rock that is formed from plants, which died about 100 to 400 million years ago (Ashton, 1999). It is a heterogeneous mixture of numerous components such as sulfur, elemental carbon, arsenic, ash, and heavy metals, etc. (Ashton *et al.*, 2001). More specifically, it is an ignitable solid, usually stratified, which originated from the accumulation, burial, and compaction of partially decomposed vegetation over the geologic ages (Hessley, 1986). It is a chief energy source of nature and is mostly used as a solid fuel to produce electricity and heat through ignition (Tiwary, 2001).

Coal is a very important but dirty fossil fuel. Coal is also the world's largest source of fossil fuels (Rashid *et al*., 2014) which accounts for about 75% of the total energy resources (Elliott 1981; Rashid *et al*., 2014). So, coal mine is necessary to meet the energy demand of a country.

The over increasing gap between supply of and energy is a problem for several countries around the world. Governments are forced to examine different sources of energy in an attempt to create a secure energy supply. The results of those examinations cover an outsized range of energy sources, not only traditional ones like oil and gas but also nuclear power and renewable resources. In addition, governments are looking at increasing energy efficiency because of the pressing need; there has also been a strategic shift in some countries back to using traditional fossil fuels. This has grown increasingly popular and ubiquitous in developing countries where coal is the most dominant of the conventional choices employed. There are two key reasons for this choice: first, there's abundant supply of coal; it's one among the most cost effective ways to make electricity (Jaccard, 2005).

Mining activities have significant economic, environmental, labor and social consequences on local and global scales (Veiga *et al*., 2004). The effect of coal mining cannot be overlooked because of severe environmental, ecological, human-health consequences (Pokale, 2012; Ribeiro *et al.*, 2013b) including indiscriminate vegetation loss and degradation of farmland (Boadi *et al.*, 2016), river sedimentation, inadequate waste management, abandonment of excavated pits, and lack of reclamation (Bansah *et al*., 2018). Coal mining methods both opencast and underground affect the environment of the area. Huge volumes of water are dumped on the surface during the mining process, which typically contains high levels of TSS, TDS, hardness, and heavy metals, contaminating the surface and groundwater. (Tiwary, 2001).

The coal mine in Barapukuria is treated as a red category industry (ECR, 1997). The major composition of Barapukuria coal is: ash 12.4%, sulphur 0.53%, moisture 10%. And so far, the rank of coal is Bituminous (high volatile) coal as well as it's calorific value is also high (Imam, 2005; Safiullah *et al.* 2011; Howladar *et al.* 2014). It is the only mine in Bangladesh where coal production started in 2005 and is currently operating underground multi-slice long wall mining method (Islam *et al.* 2008). 923,276.080 metric tons of coal has been extracted from this coal mine till 2017-2018 (Petrobangla, 2018). In this mining operation underground sump water is released to the surface without proper treatment. In addition, there is no proper infrastructure for coal storage so coal dust can easily mix with the surrounding soil and contaminate the soil which ultimately affects the vast paddy lands around the Barapukuria coal mine area.

As it is known that soil acts as the storehouse for plant nutrients; in other words, soil is the ultimate source of almost all essential nutrient elements for plant growth. Soil plays a major role in determining the sustainable productivity of an agro-ecosystem. The sustainable productivity of soil mainly depends upon its ability to supply essential nutrients to the growing plants. The deficiency of micronutrients is major constraint to productivity, stability and sustainability of soils (Bell and Dell, 2008). Soil fertility is an important factor, which determines the growth of plant. Soil fertility is determined by the presence or absence of nutrients i.e. macro and micronutrients. Although micronutrients are required in minute quantities, they have the same agronomic importance as macronutrients because they play a vital role in the growth of plants (Nazif *et al*., 2006).

For plants, the essential nutrients are nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, copper, iron, manganese which plays a very important role in plant growth, productivity, soil fertility and animal nutrition. They also help in the maintenance of cellular organization, and in energy transformation in enzyme action (Renwick and Walker, 2008).

The yield of almost all crops is very low in Bangladesh compared to some other developed countries. There are a number of reasons behind such low crop yield in which soil is a dominating factor. The agriculture of Bangladesh has been suffering from various problems such as nutrient deficiency and toxicity of soil, improper soil and crop management, alteration of agricultural land for other uses, insects and disease hazards, and natural calamities (Benson and Clay, 2002).

Whereas, the mine wastes, polluted water adversely affects the surrounding agricultural land and water body. The cumulative effects of mining exploration activities at multiple sites within the area have the potential to drive the environmental changes. For instance, the more common and noticeable effects of these cumulative impacts include changes in aquatic and terrestrial ecosystem (Kibria *et al.*, 2012). The International Accountability Project reports that mining operations at Barapukuria have destroyed roughly 300 acres of land, impacting about 2,500 people in seven villages, as land subsidence of over one meter in depth has destroyed crops and lands and damaged homes. The people in 15 villages have also apparently lost their access to water, as huge quantities of water pumped out for the Barapukuria mine, which consequently caused a rapid drop in water level (Akhtar, 2000).

However, only few studies found to report the status of soil nutrients at Barapukuria coal mine area and there is a clear need for a soil nutrient assessment for agricultural perspectives. In order to understand the impacts, a thorough analysis considering the impacts on soil and biological environment was carried out in this study. Keeping the aspects in mind the study was undertaken with the following objectives:

- To determine the quality of surface soil samples and find out how much soil is degraded with respect to the agricultural point of view; and
- To find out the impact of coal mining practices in Barapukuria on the surrounding environment.

CHAPTER II

REVIEW OF LITERATURE

2.1 Impact of mining on land use/ land cover

In a study, Yang Dejun *et al.* (2016) observed that coal mining could decrease the average value of soil water content, cohesion and organic matter, and upsurge the average value of internal fraction angle. The relationship between the physical quality indicators of the soil was also influenced by the impact of coal mining.

Rashid *et al*. (2014) concentrated to assess the effects of coal mining on the general climate explicitly on soil and water. Their discoveries of coal investigation showed that the Barapukuria coal is under bituminous coal and it comprises high energy esteems because of low measure of ash (12.04%) and moisture (2.83%) substance. The pH of coal water was discovered marginally acidic and accessible supplements/ heavy metal, organic carbon, exchangeable cations of coal water treated farmland soil recommend that coal mining changes the encompassing water and soil quality. Sulfur (0.64%) and debris content were found in the acceptable focus.

A case study by Hasan *et al.* (2013) revealed that the concentration of organic Carbon, K, Ca, Mg, P, S were 105.37 ppm, 145.09 ppm, 197.06 ppm, 6.16 ppm, 30.78 ppm, 111.39 ppm, 555.31 ppm, 200.73ppm, 11.10 ppm, 220.20 ppm, 1.48 ppm respectively and for coal water treated farm soil respectively for normal farmer's field soil. Thus the effect of coal water, discharged from Barapukuria coal mine area to the surrounding agricultural fields was found good for organic carbon, P, S, Ca, Mg fertility of soil but the continuous deposition of trace metals in the agricultural field soil may cause a serious deterioration of soil resources.

A study by Kumar and Pandey (2013) revealed that an increase in coal mining leads to changes in land-use primarily by expending agriculture and forested areas. A detailed knowledge of land use practices is essential to understand the land use pattern, its dynamics and implications for the management and planning of land, as well as policy making and infrastructure developmental initiatives.

The sulphurin in the coal deposits of this region is organic as well as pyretic in nature. The organic sulphuris structurally bound in coal and is difficult to separate, wash or drain. On the other hand, pyretic sulphuris present as an intrusion in the coal seams and the immediate vicinity in the form of balls –circular or elliptical mass or fine, dispersed particles. These tiny particles are mainly responsible for the acid mine drainage. Under the influence of seeping water, the pyrite (Fe, SO_2) is oxidized, forming sulfuric acid. As a result, the pH value of the water is increased, making it unfit for normal consumption and industrial use (Goswami, 2013).

Singh (2012) studied to evaluate the impacts of coal mining on the surrounding environment specifically on soil and water on the Meghalaya coal mining project in India. In his study, he found that low pH (between 2-3), high electrical conductivity, high concentration of ions of sulphate and iron and toxic heavy metals, low dissolved oxygen (DO) and high BOD are some of the physico-chemical and biological parameters which characterize the degradation of water quality. Overall environmental degradation and disruption of traditional values in the society can also be attributed to coal mining in the area. Large scale denudation of forest cover, scarcity of water, pollution of air, water and soil and degradation of agricultural lands are some of the conspicuous environmental implications of coal mining.

Alam *et al.* (2011) was conducted an analysis on environmental impact assessment of Barapukuria thermal power and coal mining project through environmental, socio-economical and meteorological study. The analysis showed that the Mn concentration was found in the satisfactory range. The pH was found slightly alkaline and surface water was bacteria contaminated.

The agricultural productivity nearby coal mining areas of Orissa was also studied by Mishra (2008) and the study revealed that the agricultural productivity is reduced significantly as a result of mining. They also observed that people involved in agriculture changed their occupation to works associated with mining.

Ghose (2004) found that the average sulphur content of the coal in the Gondwana stage was below 1%, which has been increased to as 8% in the Jharia Coalfield; the average being within 3.5%. The sulphur content of the semi-anthracite deposits of Raniganj is even higher, up to 9%.

Soil degradation among others is one of the leading factors to low food productivity by mining activities. The nutrients in the soil are depleted leading to an infertile land thus no farming being done. The soil is a natural resource which is not renewable in the short or very difficult to renew, or expensive to reclaim or to improve, following erosion, physical or chemical degradation (Stoops and Cheverry, 1992).

Biswas *et al*. (1992) observed that breaking of coal and leaching pyrite of sulphur content from the coal and surrounding formation leads to Acid Mine Drainage (AMD); a problem known worldwide. Oozing out of yellow sludge, the smell of H_2S and an increase in the pH value are some of the physical symptoms of the AMD.

2.2 Impact of mining on water regime

Mining activities not only use a lot of water but it also affect the hydrological regime in the region and can affect the water quality. The disturbance of lithosphere, yield and movement of ground water, dewatering of the workings and the recharging of overburden formation are the interrelated operations of underground mining. Dewatering from underground, recharging from rainwater precipitation and an inflow of surface water are complimentary to each other.

Khan *et al.* (2017) evaluated the heavy metals contamination of groundwater in Barapukuria Coal Mine (BCM) area and its vicinity, nine groundwater samples from different location, two waste water either treated and/or untreated that were used to irrigate in and around the coal mine areas, three surficial soil samples (~20cm depth). Each sample was analyzed for As, Mn, Fe total, Cu, Pb, Zn, Mo, Ni, Co, Cr, Cd and Hg. It was found that As, Cu, Pb, Zn, Mo, Co, Cr, Cd and Hg did not exhibit significant elevated levels, but concentration of Mn, Fe total and Ni ranging from 0.15 to 3.85mg/L, 0 to 1.88mg/L and 0.01 to 0.09mg/L respectively both in groundwater and mine waste water samples exceeded the World Health Organization (WHO, 2004) drinking water guideline values.

Fardushe *et al.* (2016) found in their field observation, it is apparent that the color of coal leached drainage water and the agricultural land water are blackish and slightly blackish respectively, which pollutes surface water and the agricultural land. Their study showed the present status of the water quality through analyzing different parameters including color, temperature, pH, EC, DO, TDS, BOD, COD, Cl-, Cu, Zn and Fe as well as the status of soil quality where pH, OC, PO_4-, Cu, Cr and Zn were analyzed. All the water quality parameters (e.g. temperature, pH, EC, TDS, DO, and BOD) were within normal levels but the value of COD was higher, which affects the aquatic environment. The concentration of heavy metals in water varied with Zn>Cu>Cr and in soil the concentration varied with Cu>Cr>Zn.

The study of Wright *et al.* (2015) examined a single underground coal mine and investigated two aspects of its operation: the disposal of the mine waste through a discharge to a nearby river and the impact of subsidence from an underground longwall to a small waterway above. Mean electrical conductivity (EC) increased in surface waters below the mine discharge, rising 4.8 times from (186 µS/cm) upstream to 1078 µS/cm below the waste inflow. Mean EC increased in a small stream that was disturbed by subsidence from longwall mining, rising 3.8 times from (247 µS/cm) upstream to 1195 µS/cm below. Both the waste discharge and the subsidence caused increases in the concentrations of zinc by about four times and nickel by 20 to 30 times the background levels.

Dwivedi *et al.* (2014) studied the pollution levels in Hasdeo River due to coal mining activities nearby and assess it for its portability. Water samples collected from three different locations on the river in Korea district and analyzed for parameters such as pH, alkalinity, hardness, sulphate, fluorite and chloride concentrations, total oxygen and total dissolved solids. The samples were analyzed in the laboratory for physio-chemical properties. It was found that all the tested parameters were within the permissible limit and there was no adverse effect on the waste quality of the river.

Sandipan *et al.* (2013) assessed the ecological status and seasonal variation of surface water parameters of opencast coal pit lakes in Raniganj Coalfield area. Parameters like temperature, pH, electrical conductivity, free carbon dioxide, dissolved oxygen and primary conductivity were analyzed on time in the field. The rest of the parameters were analyzed in the laboratory. It was found that the surface water quality in the abandoned mines were alkaline, soft to moderately hard and fresh in nature.

Starting from precipitation, the water travels overland, adopts through flow, interflow and base flow leading to the basin channel flow and is partially retained in the aquifers. With the creation of underground voids; there is percolation through mine roofs and walls and ultimately flows with the failure of confining beds occurring. The water accumulated in the mine is pumped back to surface. Mine water is pumped from the working face contained 1500-1600 mg/1 of suspended impurities, mainly coal dust, particles and Salts of Calcium, Magnesium and Iron (Goswami, 2013).

Zakir *et al.* (2013) assessed the water quality around Barakpuria opencast coal mine for suitability in domestic, industrial, livestock and irrigation use. 26 water samples from different water sources (19 mine water and 7 ground water sources samples) were collected from different sides of Barakpuria coal mine area. The samples were analyzed in the laboratory for pH, electrical conductivity, total dissolved solids, dissolved oxygen, major cations and anions and trace elements. The analysis showed the water samples to vary from neutral to little alkaline, high values of EC, TDS, TH, HCO_3^-, Cl^-, SO_4^{2-} and K. Among the trace metals Fe, Zn, Cu and Mn analyzed, Mn content was found to be dominant.

Muthangya and Samoei (2012) assessed the quality of water due to mining activities in coal rich Mui Basin on Kitui County, Kenya. 9 sampling points were chosen from shallow open wells and boreholes to collect water samples. The results showed that the samples were alkaline but within guidelines suggested by WHO. The conductivity was high ranging from 1600 - 3700 micro Siemens/cm at 25^{o}C which is outside the permissible limit. TDS values varied from 635 – 2637 outside the 500 – 2000 mg/L prescribed limit.

Verma *et al.* (2012) analyzed the water sample of pond located near Nandani Mines in Durg district, Chhattisgarh. The water samples taken from the pond were analyzed for BOD, TDS, COD, nitrate, chlorine, iron sulphide, magnesium, calcium, carbonate, PO_4, NH_3. It was found that the pond water was slightly alkaline and hardness was high. The

TDS value was 1970 mg/L. the values were also compared to tap water samples and were found to be quite higher in comparison. They concluded that the pond water was unsafe for drinking because of contamination by nearby mining activities.

Carlos *et al.* (2011) studied the impact of coal mining on water quality of three artificial lakes in Morizini River Basin. The physical and chemical variables selected for the PCA were temperature, total solids, calcium, aluminium, silicon, iron, zinc, nickel, pH, electric conductivity and dissolved oxygen. The results showed that pH increased with depth ranging from 5-7; the pH being slightly higher during winter. The electrical conductivity values were high ranging from 700 to 900 μs cm^{-1} in both periods. DO values were lower during summer. The data observed showed that coal mining has made a strong environmental impact.

Atkins *et al.* (2010) analyzed the water quality in the aquifers of the Thar lignite deposit in Sindh, Pakistan to improve the life of the people inhabiting the nearby areas. The test results indicated that the aquifer can be classified as (sodium, potassium) chloride type water with a TDS range of 1000 to 2000 mg/L. there was no detection of heavy metals and toxic metals including arsenic, mercury and lead or cyanide. The aquifer classified as brackish (saline water) was required to undergo treatment before it can be utilized for domestic or industrial consumptions.

Xu and Gao (2009) measured the water quality in Huainan and Panyi coal mine to provide the theoretical basis for comprehensive utilization of coal mine subsided water resources. Water temperature, pH value, clarity, dissolved oxygen etc. were measured onsite and for heavy metals were analyzed in the laboratory. Fuzzy evaluation method was to conduct comprehensive evaluation of its water environment and the standard for evaluation criteria used was GB3838-2002. The results showed that the two subsided areas in the Hainan Panyi area were both polluted with different degree with the west bank being lesser polluted than the eastern bank.

Khandelwal and Singh (2005) endeavored to predict the chemical parameters like sulphate, chlorine, chemical oxygen demands, total dissolved solids and total suspended solids in mine water using artificial neural network (ANN) by incorporating the pH, temperature and hardness. The forecast of result of chemical parameters of mine water by ANN was very satisfactory and acceptable as compared to MVRA and seems to be a good alternative for pollutants prediction.

Singh (2005) considered that the implementation in the ground of water drainage induces additional cracks and fissures over the surface. As a result, the rate of precipitation increases when higher percentages of rain and surface water infiltrate downwards; raising the overall water table. Furthermore, in place of a few confined aquifers, extensive unconfined/leaky aquifers are formed with the ground movement.

A study was conceded by Bose (1989) and he found that the concentration of suspended impurities drops slowly in slumps from underground. With the filling of cracks by silt or clay particles during the rainy season, the overburden character is restored with time when water pools are formed on the surface, and subsides through. Unless care is taken, the river water would flow down through fracture planes, flooding the workings. Depending upon thickness of the burden and the working seams, the fractures have become open channels or are sealed with silting. Loss of streams or the formation of water pools are the two extremes of the phenomena.

Singh (1988) performed a research to reflect the impact of mining on water quality. Various physico-chemical characteristics of mine waters as analysed include pH, alkallnity/acidity, specific conductivity, hardness, total solids, sulphate, chloride iron and trace materials. This investigation reveals that mining activity, markedly pollute the mine waters. Mine waters are of highly complex nature and of widely varying composition. These are nearly neutral, alkaline, mildly acidic and highly acidic in nature. Special emphasis on water quality deterioration due to acid mine drainage which result in significant concentration levels of tract (toxic) metals, is given.

Quality of water, however, is the main issue, where hardness of the water increases up to 700 mg/l inclusive of 300-500 mg/l permanent hardness which necessitates special treatment (Nish, 2012). The other impurities such as heavy metals and the oxygen balance of the underground water in most of the Indian coalfields are well within the accepted limit.

Dharmappa *et al.* (1998) carried out the analysis of water quality in the Illawarra coal mines, NSW, Australia to study the waste water quality management of the mines. A total of 12 water sampling and monitoring points were established for 3 months and 6 months interval monitoring periods. The test results showed that the wastewater though neutral in pH had high conductivity and total dissolved solids classifying it in class 3 i.e. characterized the water as highly saline and hence unfit for irrigation. The investigations on the treated waste water revealed neutral pH, low suspended solids content, low to medium conductivity and medium total dissolved solids thus placing it as class 2 i.e. medium saline water and hence approved for irrigating soils of moderate draining characteristics.

Pathak and Banerjee (1992) carried out water analysis in Chapha incline of Umaria Coalfield in eastern Madhya Pradesh to determine the water quality parameters including trace element detection and microbial analyses. From the results it was found that the coal mine water was severely polluted. Parameters like turbidity, BOD, alkalinity and bacterial colonies were not within permissible limits as compared to standards. High cationic and anionic concentrations were also noticed. They concluded that the mining operations were having degrading effect on the WQI.

Fish, in natural habitat often depend for their food on small aquatic organisms including macro-invertebrates. As a consequence of depletion of aquatic invertebrates, the fishes do not get adequate supply of food and suffer indirectly from AMD contamination. AMD also has direct effect on fish by causing various physiological disturbances. The primary cause of fish death in acid waters is loss of sodium ions from the blood. Less availability of oxygen to the cells and tissues leads to anoxia and death as acid water increases the permeability of fish gills to water, adversely affecting the gill function (Brown and Sadler, 1989).

Ionic imbalance in fish may begin at pH of 5.5 or higher, depending on the tolerance of the species. Severe anoxia occurs below pH 4.2 (Potts and McWilliams, 1989).

Low pH that is not directly lethal may adversely affect fish growth rates and reproduction (Kimmel, 1983). It has been found that fish species are severely impacted below the pH 5.5. Water pH below 4.5 in most of the rivers in Jaintia Hills is most likely responsible for complete elimination of fish from the natural waters of the area.

2.3 Impact of mining on air quality

The release of toxic gases like methane, nitrogen oxides and sulphur dioxide pollutes the surrounding air and hence deteriorate the air quality. These are also the major gases that contribute to global greenhouse gas emissions and overall warming of the planet.

Pandey *et al.* (2014) observed the variations in air quality in terms of sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter around JCF were evaluated over the period of 2010 and 2011 at five sites during different seasons. The mean concentrations of heavy metals in PM10 were found in the order of Fe>Cu>Zn>Mn>Pb>Cr>Cd>Ni. The major sources contributing to air pollution in Jharia were coal mining related activities and active mine fires, and secondarily vehicular emissions, while wind–blown dust through unpaved roads also contributed to some extent.

Khan and Bagaria (2011) carried out the study in Dhanappa limestone mines, Nagpur with the main objective to suggest a monitoring programme to evaluate the effectiveness of meditative measures to suppress air pollutants coming from mining areas. They analysed SO_2 and NO_x on spectrophotometer employing West-Geake method and Jacob-Hochheiser method respectively. The results that they obtained suggested that ambient air quality in the mines zones with respect to SO_2 and NO_x shows low pollution, while with respect to RSPM and SPM it is moderate. They also suggested that regular monitoring and analyzing of those parameters will definitely restrict them below prescribed limits.

Mandal *et al.* (2011) analyzed that majority of air pollutants that are contaminating the atmosphere traces its source from the haul and transport roads in coal mining areas thus enhancing different health problems. As high as 93.3% of total generated dust comes from haul roads of South African coal mines, according to the analysis carried out by Amponsah-Dacosta using USEPA guidelines. Due to the partial failure of the available techniques, the dust doesn’t get removed from the haul road completely. In this study the qualitative as well as quantitative aspects of road dusts is being dealt by them.

Khalaji *et al.* (2011) used the new technique of spark induced breakdown spectroscopy (SIBS) as a simple, rapid and in situ method for continuous dust monitoring as this method can detect elemental composition of dust simultaneously and no sample preparation is required. They formulated an experimental technique using a high voltage and a breakdown is created between two electrodes. Each element in the plasma between electrodes emits its characteristic spectral emissions by analyzing the spectral emission of plasma, the elemental composition of dusty air is determined. With this experiment the team showed that SIBS can be used as a method for dust level monitoring and also can be used to alarm a remarkable increase of dust in mines.

A research was conducted by Bian *et al.* (2010) about environmental pollution due to underground coal mining. In their study, the total methane drainage from 56 Chinese high methane concentration coal mines is about 101.94 million cubic meters. Of this methane, 19.32 million, 35.58 million and 6.97 million cubic meters are utilized for electricity generation, civil fuel supplies and other industrial purposes, respectively. About 39% of the methane is emitted into the atmosphere. The production of coal mining wastes can be decreased 10% by reuse of mining wastes as underground fills, or by using the waste as fuel for power plants or for raw material to make bricks or other infrastructure materials. In European countries more than 50% of previously mined lands are reclaimed as forest or grass lands.

Sharma and Siddiqui (2010) carried out a study for the assessment and management of the air quality around Jayant open cast coal mining situated at Jayant in Sidhi district of Madhya Pradesh, India. Air monitoring for SO_2, NO_x and TSP was done for 24 hrs. Once every 15 days at each sites and concentration were expressed as μgm. Mean value for pollutant were calculated on 24 hours sampling basis. For the sampling of particulate matter HVS (High Volume Sampler) was used. Samples were collected for two years using glass fibre filter paper on fort nightly basis. They also sought upon the observations on 'spatial and temporal variations in concentration of gaseous and particulate pollutants' had done by Chaulya (2004) during both the year of air monitoring. The study suggested that concentration of particulate pollutant exceeded the prescribed limit especially during summer and winter season. They finally recommended implementing a plan of regular cleaning of transportation roads, watering of paved and unpaved roads with chemical binding agents, installation of sprinkler system at high polluting coal transport roads within the plant premises and effective dust suppression mechanism at coal handling plant.

Silva *et al.* (2010) observed that monitoring of light hydrocarbons is extremely critical, basically on two aspects; one is due to global climate change and other one for economic and safety reasons. Due to the difficulty to access and lack of correct procedures of gas sampling in Brazilian coal mines, they aimed to apply standard gas chromatography procedures of gas sampling to determine LHCs (light hydrocarbons) levels from their 2 surface mines and 3 underground mines. Samples of gas were collected with the help of sequential sampler and were placed in polypropylene tedler gas sampling bags. Then the LHCs concentration was calculated from gas chromatograph equipped with flame ionization detector. The results indicated higher percentage of LHCs in u/g mines than surface mines with CH_4 levels varying from 3 ppm to 27% in coal mine atmosphere. They found that the proposed methodology was very effective in measuring LHCs levels and was finally concluded that sampling of air using tedler bags and sequential sampler was better than steel canisters.

Chen *et al.* (2010) dealt with the application of matter-element method in estimation of ambient air quality in Huizhou opencast coal fields in Fuxin colliery.

Ghose and Majee (2001) observed that In India, coal is mainly mined out from opencast mines, contributing more than 70% of total coal production and it also has a high share in air pollution. To keep a track upon the local atmosphere impact, a survey was conducted by them taking emissions data which were utilized to find out the dust generation due to various mining activities. They noticed that the air pollutants coming from mines and their seasonal fluctuations in its quantity had high pollution potential and greater negative impact on human health. They have given a lot of control measures to deal with this situation and even chalked out ‘afforestation and tolerating capability of trees’ against the dust particulate matter. They emphasized the need of utilization of different chemicals to minimize the air pollutants coming from haul road and stated that a pollution free environment can be achieved by implementing suitable abatement measures.

Chakraborty *et al.* (2001) developed empirical formulae with the objective to calculate emission rate of various opencast mining activities. They selected 7 coal mines and 3 iron ore mines with the consideration of geographical location, working method, accessibility and resource availability. 12 Empirical formula for Suspended particulate matter were developed for many opencast mining activities like drilling, coal loading ,coal handling plant , haul road , workshop , etc. but the formula was for the overall mine for NO_x and SO_2 estimation. To verify the universal applicability of the empirical formulas, they selected Rajpura opencast coal mine. A good accuracy was indicated between the calculated value and field measured value which varied from 77.2% to 80.4%. They concluded that Suspended particulate matter is the main constituent of emissions while emissions due to NO_x and SO_2 are negligible. They revealed that the results of this study is of great importance for mine environmental engineers and scientists working in the field of air quality monitoring to monitor air quality and its impact from pollutants generating projects.

Dahmann *et al.* (2008) investigated the results of exposure assessment with respect to nitrogen oxides and carbon monoxide in German hard coal mines. The measurement campaign was accompanied by an epidemiological study investigating possible health effects on the airways of the lungs. For this purpose time weighted 8-hour shift values were determined by them, for typical groups of coalminers according to the European measurement standards. Based on these measurements and on experts' assessments of the retrospective exposure situation, time-dependent cumulative and average NO and NO_2 exposure estimates were derived for an inception cohort of two groups of coalminers. They concluded that Miners working in blasting crews (no blasting specialists) were estimated by experts to experience 2/3 of the nitrogen oxide exposure of blasting specialists. Especially, for the diesel engine drivers, exposure can be rather higher than the prescribed value.

Study conducted by Fu *et al.* (2000) described air pollution of Fuxin to be composed of total suspended particulates (TSP), SO_2 and NO_x. To verify their studies, dust samples were taken from four different monitoring stations located in 4 different districts around Fuxin colliery. They applied 'fuzzy concept' to the air quality assessment based on extension of matter-element theory, which handles the concept of partial truth. Moreover this idea can predict the relative influence of each dust pollutant on environment based on the upper and lower maximum allowable exposure limits. They concluded that re-vegetating appropriate sites as well as the initiatives from government can successfully help in complying ‘air quality’ within the prescribed limits of CAAQS, 1996. The future work of this study is to develop an integrated and automated decision support system for air quality assessment with the help of a programming language.

Chaulya (1999) carried out a study for assessment of air quality in Lakhanpur area. He found out that the annual average of concentrations of TSP and PM10 were higher than the prescribed limits given by NAAQS. He took the help of linear regression analysis to predict the concentrations of one type of particulate matter by knowing the level of the other, for O/C coalmines with same as conditions. Monitoring stations were placed to evaluate air quality and plan any control measures. Sampling and analysis were done twice monthly for residential areas (buffer zone) and six times monthly for industrial areas (core zone/ mining area) during the year from September 1998 to August 1999.

Kumari *et al.* (1995) carried an analysis in different coal and metal mines showed that quartz content in respirable dust is <1% which is less than the prescribed MEL (Maximum exposure limit) 3mg/m^3 except for 2-3 locations in Longwall and bunker top. It was observed that drilling, haulage, crusher house are main high risk zone of silicosis and was eventually concluded that wet drilling as well as improved ventilation is effective to control airborne dust as well as emission of quartz. Frequent rotation of workers is a must in locations like crusher sites where, even after adoption of dust suppression measures, dust is not reduced to safe limits.

2.4 Impact of mining on biodiversity

Biodiversity sustains human livelihoods and life itself. An estimated 40 per cent of the global economy is based on biological products and processes. As the biodiversity harbors a great amount of diversity with respect to species diversity, crop diversity, etc. which provides a rich amount of a well evolved system over time background support for rich resources. The first and direct impact of mining operations in forested areas is the eviction of forests which alters the food availabilities and wildlife habitat.

Kumar and Pandey (2013) noticed that in some of the coalmines, the forest cover is completely lost to the mining enterprises. On the other hand the existing forests were subjected to human disturbances of various kinds like tree felling for fuel-wood requirement, expansion of agriculture into the forest area and diminished renewal of flora due to a polluted environment.

According to Gaurav and Khan (2014), large scale mining causes massive deforestation and conversion of forested areas into non-forest areas. The coal dust also settles on the leaves of plants which affects the growth of plants.

Charak *et al.* (2009) studied the impact of coalmines on ecology like, species richness and abundance around the Moghla Coal mines in Kalakote area of Jammu and Kashmir. The study revealed that the open coal mining activities affect both the qualitative as well as the quantitative parameters of species distribution. Therefore, on a large scale, the mining operations change the biodiversity by changing the species composition.

Malviya *et al.* (2010) studied the habitat diversity in the coal mining areas of Bokaro, Jharkhand. He concluded that while intact forests may be resistant to the impacts of mining and development, fragmented forests are less likely to withstand such invasions. Yet only a few studies have been reported in this aspect. The indirect infrastructure developmental activities like construction of roads and new pipelines routes lead to habitat fragmentation and open up the remote areas for accessibility. A study concluded that degradation of forest is one of the major externalities of open cast mining which is yet to be addressed properly and therefore needs a thorough attention in the upcoming days.

Giam *et al.* (2018) carried out a study on land-use change in the US and he found coal mining the major cause. This scientific consensus has emerged that coal mining negatively affects water quality, a quantitative synthesis of biodiversity impacts is currently lacking. They showed that mining under current federal statutes the 1972 Clean Water Act and the 1977 Surface Mining Control and Reclamation Act has negative implications for freshwater biota. Streams affected by coal mining averaged one-third (32%) lower taxonomic richness and one-half (53%) lower total abundance than unmined streams, with these impacts occurring across all taxa investigated thus far (invertebrates, fish, and salamanders). Even after post-mining reclamation, biodiversity impacts persisted.

Vegetation is an important part of the biodiversity but may be subjected to disturbance in areas close to coalmines. Huang *et al.* (2014) observed that the rate of biomass growth, which is caused by fading of vegetation. Simultaneously, carbon stored in vegetation is constantly released, weakening vegetation ability to act as a carbon sink. Within the study area, factors that affect vegetation were divided into: natural factors; human surface activities; and coal mining, with each of these directly reflected in the spatial and temporal variation of the Normalized Difference Vegetation Index (NDVI). To clarify the relationship between coal mining and local vegetation damage, high spatial–temporal resolution remote sensing images were created using the spatial and temporal adaptive reflectance fusion model. Data showing the mine coalface and the variation of vegetation at Xinzhouyao coal mine allowed identification of influential factors. Quantized synthetic effect values of NDVI from coal mining and changes in local climate were then evaluated. Using a theoretical analysis of carbon released from vegetation, the net primary productivity (NPP) and biomass loss of vegetation were calculated. Results showed that fluctuations in vegetation NDVI as a response to changes in local climate were positively correlated with the average NDVI value.

Vegetation disturbance caused by coal mining leads to loss of biomass and decreases the ability of vegetation to absorb atmospheric CO_2. From 2001 to 2010, loss of vegetation biomass owing to coal mining was 2,608.48 t with annual rates of biomass loss of 33.48 gC/m^2 year. Over the same period, the amount of atmospheric carbon absorbed by vegetation was reduced by 1,925.23 t with annual vegetation NPP loss of 24.71 gC/m^2 year. Comparing these figures with the amount of coal produced, this calculates the carbon release from vegetation owing to coal mining at Xinzhouyao coal mine as 77.568 g/t. Because much of the carbon in lost biomass is recycled to the soil, the biggest impact on the carbon balance of vegetation near coal mines may be attributed to a reduced ability to absorb atmospheric CO_2. These results may be useful for further analysis of the impact of mining on local environments and for the calculation of appropriate ecological compensation.

2.5 Impact of mining on public health and society

Kumar *et al.* (2012) used high resolution satellite data to study the area of settlement at risk in the Jharia coalfields. He concluded that a majority of the settlement areas are at high risk due to mine fires and subsidence of land. Moreover, surface mining poses a potential threat as there is danger from the frequent mine fires and unstable rocks subsequently lowering the land productivity.

The earliest study reported on the impact on physical and cultural environment by Majumdar and Sarkar (1994). The mine workers are constantly exposed to high concentrations of dust and gases along with and elevated noise levels thus posing a threat to their life. Other than this, they are also prone to respiratory diseases due to the suspended particulate matters in the air created by mining activities like blasting and drilling operations. Some activities like drilling, blasting, loading-unloading of materials, overburden. The effects of these particulates matter might vary depending on the exposure time and the concentration of the particles in the air found by Sneha *et al.* (2012).

Singh *et al.* (2010) concluded a study that the mine workers suffer from various types of skin and respiratory problems which takes a toll on their overall health, living standards and working capability. Also the high noise levels and vibrations tend to influence the wildlife more than the human. Health of the local population is also impacted due to contamination from leakages of chemicals and vibration from blasting/drilling operations.

Senapaty and Behera (2012) observed that in IBvalley coalfield of Odisha, India the coal as well as the ground water has high levels of trace elements, India. He also studies the probable implications of these for human health aspects.

Adu-Yeboah *et al.* (2008) have stated that, the process of mining and processing of minerals involve various activities which give rise to environmentally related diseases. These diseases include: respiratory tract diseases such as Tuberculosis, Pulmonary diseases and Silicosis; water - borne diseases such as Shistosomiasis and Onchocerchiasis; skin diseases of all types, eye diseases and mental illness

2.6 Impact of mining on sustainable development

The economic benefits arising from coal mining are very less when compared to the losses incurred to the nature and ecosystem (Feng, 2011). The society and environment are highly neglected by the mining enterprises while economy is often given more priority. Therefore a balance is essential between these three interconnected factors to achieve sustainable development. Mining industries must be responsive to various sustainability challenges and address their sustainability concerns (Daizy, 2015). This requires extensive and detailed research into the sustainability component of coal mining.

CHAPTER III

MATERIALS AND METHODS

This chapter portrays the working framework of the study. This chapter contains information about the study area, methods followed for sampling, sample preparation, micronutrient analysis, statistical analysis and overall flow chart of the whole study.

3.1. Location of study area

Barapukuria coal mine is located in flat paddy land of the north-western part of Bangladesh at about 45 km east of the district headquarters of Dinajpur and 20 km east from the border of India. It is physiographically located in the Dinajpur Shield of Bangladesh, surrounded by the Himalayan foredeep to the north, Shillong Shield to the east and Indian Peninsular Shield to the west (Safiullah *et al.* 2011). The coal proven reserved area of the field is about 5.25 km^2. In addition, the field is suggested to have possible extension for 1 to 1.5 km^2 area to the south. The coal mine and power plant are located in the Hamidpur union of Parbatipur Upazila in Dinajpur district and the absolute location is within the latitude of 25° 31′ 45″ to 25° 33′ 05″ N and longitude of 88° 57′ 48″ to 88° 58′ 53″ E (Plate 1). The total coal field area covers full or part of the following villages, for example Barapukuria, Kalupara, Hamidpur, Chauhati, Ichabpur, Banspukur, Baidyanathpur, Patigram, Gopalpara, Dakshin Rasulpur, Baigram and Sherpur.

3.2. Sampling site selection

The sampling sites were selected based on the sampling points from Land and Soil Resources Utilization Guide of Parbatipur Upazila that provided by Soil Resource and Development Institute. Under the scope of this study the sampling sites were only selected from AEZ-3 (Tista Meander Floodplain). The soil and land type map of Parbatipur Upazila was scanned, projected and interpreted with Google earth map and the coordinates (Latitude and Longitude) were determined to identify the sampling locations. A portable GPS machine and Google map were used to reach the sampling sites.

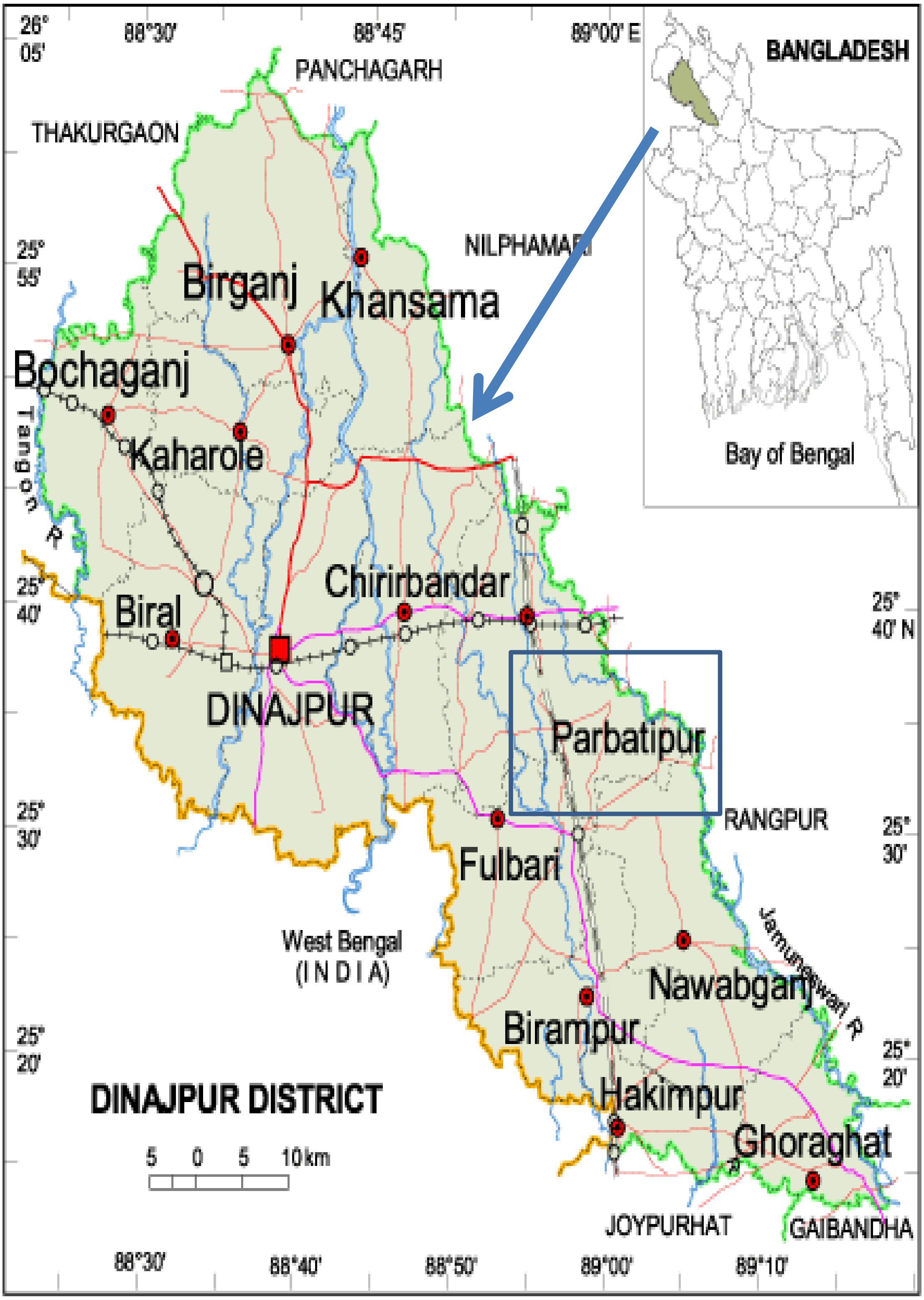


Plate 1. Location of the study area

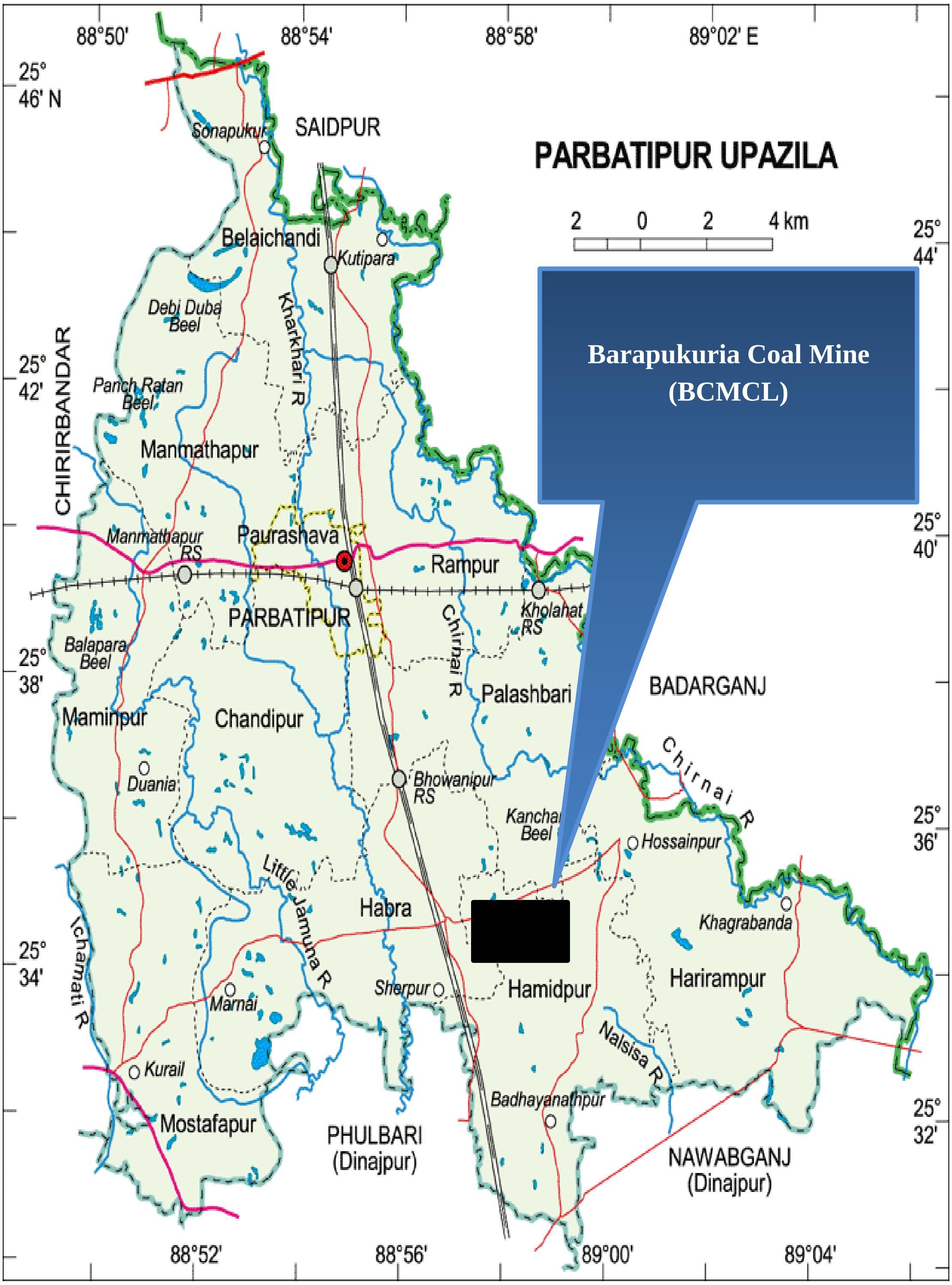


Plate 2. Barapukuria coal mine area

3.3. Soil sampling

A total of 5×3=15 surface soil samples (0-5/5-10/10-15 cm) were collected from identified sampling locations following random sampling method. Representative numbers of samples were collected from each location. Soil sampling was carried out by composite sampling method as suggested by the Soil Survey Staff of the USDA (1951). Soil samples were collected during summer in the year of 2019. A portable Global Positioning System (GPS) was used to record the location of each sampling site. Collected soil samples were put in plastic bags and labeled properly.

A total of 5 soil sampling locations were selected for soil sample site and their general information is shown in Table 1.

3.4. Preparation of soil samples

The collected samples were air dried, powdered, screened, and sieved. The classified sieved soil were then preserved in plastic container and labeled properly. These were later used for various chemical analyses.

Table 1. Site specific information of sampling locations

Sampling Site No	Location (GPS)		Soil Series	Land Type	Texture
	Longitude	Latitude			
S-1	25°32'47.8" N	88°58'32.9" E	Amnura	Medium High land	Loamy
S-2	25°32'15.0" N	88°58'17.8" E	Amnura	Medium High land	Loamy
S-3	25°31'44.8" N	88°58'27.1" E	Amnura	Medium High land	Loamy
S-4	25°33'38.9" N	88°59'08.9" E	Amnura	Medium High land	Loamy
S-5	25°34'23.9" N	88°58'05.9" E	Belabo	High land	Clay Loam

Source: Land and Soil Resource Utilization Guide, Parbatipur, Dinajpur. (SRDI, 1999).

*S-1= Banspukur, S-2= Balarampur, S-3= Bigram, S-4= Hamidpur, S-5= Barnamala

3.5. Soil sample analysis

Each soil sample was reduced to 200 g by quartering. The samples were dried naturally without sun light and then sieved through a 2-mm sieve. Each sample was separated for the measurement of 12 chemical properties including pH, Organic Matter (OM), Nitrogen (N), Phosphorus (P), exchangeable Potassium (K), Sulfur (S), exchangeable Calcium (Ca), exchangeable Magnesium (Mg), Copper (Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn). Soil sample analyses were carried out in Regional Laboratory, Soil Resource Development Institute (SRDI), Dinajpur.

3.5.1 Estimation of soil pH

Soil pH in water was measured from a soil: water ratio 1:2.5 using glass electrode method (Peech, 1965). Twenty gram of air-dried 80 sieved soil samples was taken in a 100 ml of plastic bottle and 50 ml of distilled water was added. The suspension was stirred with a glass-rod at regular interval for 30 minutes. A glass electrode pH meter calibrated with buffer pH 7.0 and 4.0 and the pH of soil suspension was measured. The measurement was done in triplicate

3.5.2 Estimation of organic matter

The organic matter was calculated by multiplying the content of' organic carbon by Van Bemmelen Indictor. 1.73). The soil organic matter was calculated using the following formula-

Organic matter (%) = OC (%) x 1.73

3.5.3 Estimation of nitrogen

The estimation of N was made by modified micro-Kjeldahl method (AOAC), which depends on the fact that organic nitrogen, when digested with concentrated sulphuric acid that converted into ammonium sulphate. Ammonia liberated by making the solution alkaline is distilled into a known volume of standard boric acid, which is then back titrated.

Reagents

i) Kjel Tab/Catalyst mixture (Potassium sulphate + Selenium)

ii) Concentrated sulphuric acid (H_2SO_4) solution

iii) 2% Boric acid (HBO_3) solution

iv) Hydrochloric acid (0.01 N HCl) solution

v) 40% sodium hydroxide solution (NaOH)

vi) Mixed indicator (Methyl red and Methyline blue)

About 0.2 g of dried ground samples was taken in weighing paper and measured accurately. Then it was poured into a 75 ml clean and dry Kjedahl flask, to which 5 ml conc. H_2SO_4, 1 gel tab, 2 ml H_2O_2 and 2-3 glass balls were added. The sample mixture was heated at 370°C for 1hr, over a preheated heater. When the sample colour becomes colourless then the digestion of the sample was completed. The digested sample was cooled at room temperature (25°C) and diluted to 75 ml. Ten milliliter of the digested diluted sample solution was taken in a distillation apparatus with 10 ml 40% NaOH. The distillate (about 60 ml), was collected in a conical flask containing 10 ml 2% boric acid solution and 2 drops of mixed indicator (methyl red and methyline blue).The total distillate was collected and titrated with standardized HCI solution (0.01 N HCl).

Calculation:

The amount of nitrogen was calculated according to the following equation:

$$\% \text{ Nitrogen} = \frac{(T_S - T_B) \times \text{Strength of HCl acid} \times 0.014}{\text{Weight of the sample (g)}}$$

Where,

TS= Titrate value of sample in mL

TB= Titrate value of blank in mL

Strength of HCl acid= 0.01N

3.5.4 Estimation of available phosphorus

Preparation of soil extract for different nutrients

Exactly 1 g of finely grind soil materials were taken into a 250 mL conical flask and 10 mL of di-acid mixture (HNO3 : $HClO_4$=2:1) was added to it. Then it was placed on an electric hot plate for heating at 180 – 200°C until the solid particles disappeared and white fumes were evolved from the flask. Then it was cooled at room temperature, washed with distilled water and filtered into 100 mL volumetric flask through Whatman No. 42 filter paper making the volume up to the mark with distilled water following wet oxidation method as described by Jackson (1958).The solution was used for the estimation of P.

Phosphorus (P)

Phosphorus of soil extract was determined colorimetrically by stannous chloride method In this method, stannous chloride ($SnCl_2 . 2H_2O$) was used as a reducing agent to form molybdophosphoric blue complex with sulphomolybdic acid. One mL soil extract sample was taken in a 100 ml volumetric flask followed by the addition of 4 mL of sulphomolybdic acid and 5 drops of stannous chloride solution. Then the volume was made up to the mark with distilled water and the content was shaken thoroughly. Finally the intensity of blue color was measured with the help of Spectrophotometer (model: Spectrum 21D) set as 660 nm wave length within 15 minutes after the addition of stannous chloride reagent following the procedure mentioned by Jackson (1958).

3.5.5 Estimation of available potassium

Ammonium acetate method of K determination (Hanway and Heidel 1952)

- 5gm of soil sample in 100 ml of conical flask 24
- Added 25 ml of the neutral 1N ammonium acetate solution and shaked for 5 minutes
- Filtered through WHATMAN NO - 1 filter paper
- Measured K concentration in the filtrate using flame photometer
- Prepared the standard curve for K
- Recorded the flame photometer for each of the Working standards of K after adjusting blank to zero

Equation followed for calculation of Available potassium in soil:

Available K = $C \times 25 \div 5 \times 10^6 \div 10^6 \times 2.24 = C \times 11.2$

Where, C stands for the concentration of potassium in the sample.

On the other hand, Cu, Fe, Mn, Zn were determined by DTPA-extraction method at a soil: DTPA ratio of 1:2 using Atomic Absorption Spectrophotometer. The extractant consists of 0.005*M* DTPA (diethylenetriaminepentaacetic acid), 0.1*Mb* triethanolamine, and 0.01*M* $CaCl_2$, with a pH of 7.3 (Lindsay and Norvell, 1978).

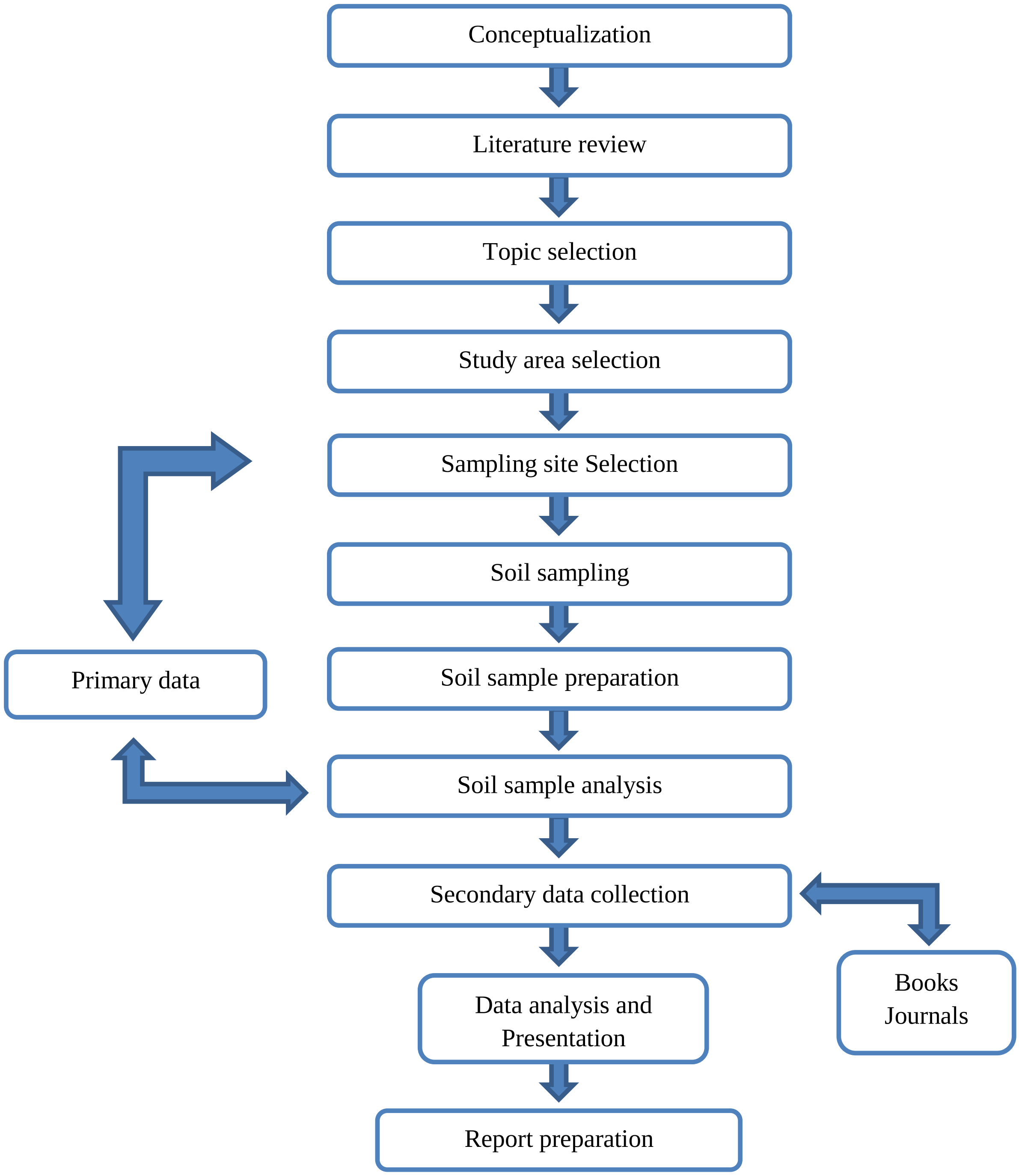
3.6. Secondary data collection

The previous concentrations of nutrients (determining pH, OM, N, P, K, S, Ca, Mg, Zn, Cu, Fe, Mn) of 1999 were collected from Land and Soil Resource Utilization guide of Parbatipur upazila to compare the present analyzed data of 2019 with the previous data. Other secondary data was collected from various sources like books, published thesis, journals, reports, Bangladesh Bureau of statistics (BBS) etc.

3.7. Data analysis and presentation

Collected data were coded by statistical technique. SPSS computer program was used for analysis of data. Various descriptive statistical measures such as range, frequency, number, percentage and mean were calculated for categorization and describing the variables.

3.8. Flow chart of the research



CHAPTER IV

RESULT AND DISCUSSION

After soil sample analysis and secondary data collection, data analysis was carried out in which mean and standard deviation of fifteen representative soil samples from five different points. The analyzed data are illustrated and presented in this chapter. For having a comprehensive idea about the probable change, if any, in nutrient status, the study executed by the SRDI study staff in 1999 has been considered as the baseline information.

4.1. Status of pH

The pH is an important indicator of ecological conditions of earthly environment. According to this study, pH of five representative sites are illustrated. SRDI 1999 data was taken as baseline data and found that the value of pH ranges between 4.80 to 5.40.

In 2019, the range of pH varies from 5.28 to 5.70 and mean value 5.52 with standard error 0.09 (Table 2). The result showed that pH value of all studied five sites in 2019 were statistically significant. Among them first three sites data were statistically similar but Banspukur site showed the highest pH (5.70) whereas Hamidpur site contains the lowest pH (5.28). Similar results found by Rahman *et al*. (2017), they found the level pH 5.74 surrounding Barapukuria coalmine area's agricultural land. Tisdale *et al.* (1999) recommends the optimum range of soil pH for crop production as 6.5 - 7.0. Goswami and Sarma (2008) stated that different factors like leaching action of wastes, soil nature, mechanical composition, etc. may be responsible for being acidic soil. In another study, Maiti and Ghose (2005) reported that the pH vary from 4.9 to 5.3 in a mining dump site situated in Central Coalfield Limited (CCL). North Karanpura area in the Ranchi district of Jharkhand State of India.

The mean pH value suggested that the soil was strongly acidic in nature (Appendix I) which decreases the availability of plant nutrients, such as phosphorus and molybdenum, and increases the availability of some elements to toxic levels, particularly aluminium and manganese. Essential plant nutrients can also be leached below the rooting zone. Besides, acidity can degrade the favorable environment for bacteria, earthworms and other soil organisms due to strong status of pH.

Table 2. The status of pH value from different location

Sampling Sites	pH value	
	Year 1999	Year 2019
Banspukur	5.10	5.70a
Balarampur	5.40	5.65a
Baigram	5.20	5.69a
Hamidpur	4.90	5.28b
Barnamala	4.80	5.30b
Range	4.80-5.40	5.28-5.70
Mean ± SE	5.08 ± 0.11	5.52 ± 0.09
LS		**
LSD $_{(0.05)}$		0.278
CV		2.76

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference
CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability

The result of the paired sample 't' test showed that the calculated t-value (7.561**) of pH was found in year 1999 vs year 2019 of collected soils (Table 3) which indicated that the value was highly positive and significant. The results of comparative study showed that pH value was higher in soil sample collected from 2019 than that of 1999. Results indicated that the pH value was increasing trend ($R^2 = 0.3564$). This might be due to accumulation of acidic materials from coal mining.

Table 3. Paired sample 't-test' of pH value of 1999 vs 2019

pH value	T value	Significance
Year 1999 VS Year 2019	7.561	0.002**

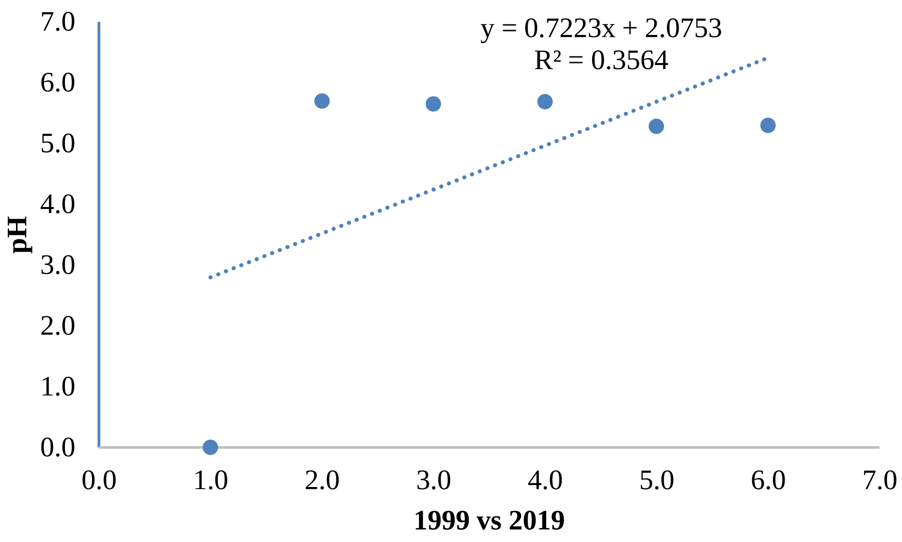


Figure 1. pH value 1999 vs 2019.

4.2. Status of organic matter (OM)

Mean values of OM obtained in the soils under different sampling sites under the scope of this research and that carried out in 1999 by SRDI staff are illustrated Table 4 for comparison.

The value of OM increased in all sampling sites and that the percentage at present range from as low as 2.16% to as high as 3.21%; while from SRDI (1999) results, we find that the concentration range between 1.69% and 2.44%. The study finds that the highest (3.21%) and lowest (2.51%) values in Barnamala and Balarampur site, respectively and this range is considered as medium status.

According to Ahmed *et al.* (2018), the mean value of organic matter of our study area indicates medium status in nature (Appendix II). About 3.4% organic matter in soil is suitable for almost all agricultural crop production (Ahmed *et al.*, 2018). The SRDI (2017) reported that the value of organic matter in Rangpur division ranges from 1.55 % – 1.82%. Rashid *et al*. (2014) found 2.67% OM in the Normal Farmland Soil (NFS) in Barapukuria coal mine area which is quiet similar to our study.

Table 4. Status of OM% from soils of different location

Sampling Sites	OM%	
	Year 1999	Year 2019
Banspukur	2.10	2.42b
Balarampur	1.98	2.16b
Baigram	1.69	2.17b
Hamidpur	1.80	2.58ab
Barnamala	2.44	3.21a
Range	1.69-2.44	2.16-3.21
Mean ± SE	2.01± 0.13	2.51± 0.19
LS		*
LSD $_{(0.05)}$		0.674
CV		14.78

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference

CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability
^{NS} = Not Significant

The results of comparative study showed that OM% was higher in soil sample collected from 2019 than that of 1999. Results indicated that the OM% was increasing trend (R^2 = 0.5845). The result of the paired sample ‘t’ test showed that the calculated t-value (4.260*) of OM was found in year 1999 vs year 2019 of collected soils (Table 5) which indicated that the value was positive and significant.

Table 5. Paired sample ‘t-test’ of OM% value of 1999 vs 2019

OM%	T value	Significance
Year 1999 VS Year 2019	4.260	0.013*

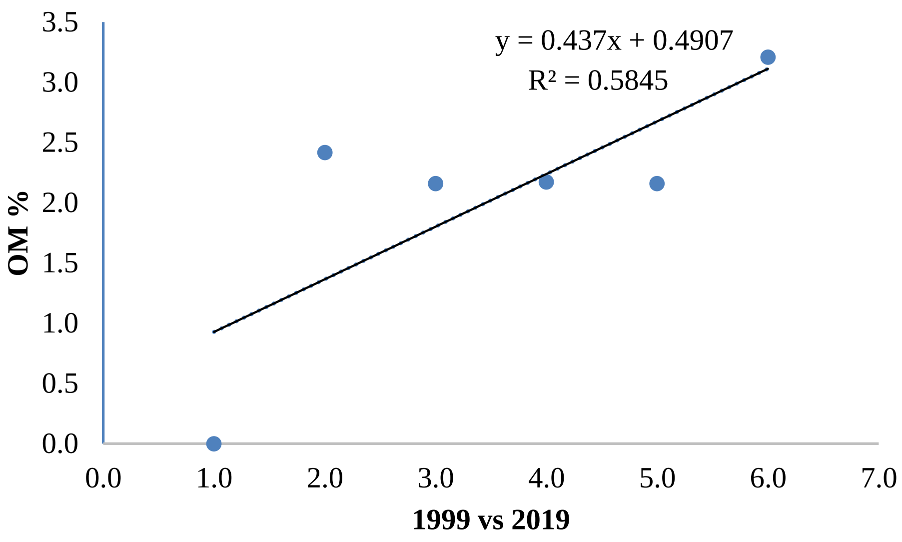


Figure 2. Organic matter value 1999 vs 2019.

4.3. Status of nitrogen (N)

N contents of surface soil under five sample sites adjacent to Barapukuria coal mine area were determined. Mean values of N obtained in the soils under different sampling sites under the scope of this research and that carried out in 1999 by SRDI staff are illustrated Table 6 for comparison.

Study conducted SRDI in 1999 shows that N content in soils ranges from as high as 0.12 ppm to as low as 0.02 ppm. The optimum value of N is 0.27 to 0.36 ppm for agricultural land (Ahmed *et al.*, 2018). The status of nitrogen in soil ranged from 0.047 to 0.067 ppm with a mean of 0.054 ppm (Table 6) which was below the optimum level (Ahmed *et al.*, 2018).

Below optimum level (very low, low and medium) nutrient status, makes soil nutrient deficient and consequently limits crop yield (Heckman, 2006). The N deficiency can be due to de-nitrification, leaching, immobilization of nitrogen from the soil. Other reasons may include intensive crop cultivation, and imbalanced use of fertilizer.

Table 6. Status of N from soils of different location

Sampling Sites	N (ppm)	
	Year 1999	Year 2019
Banspukur	0.020	0.050b
Balarampur	0.030	0.051ab
Baigram	0.030	0.047b
Hamidpur	0.030	0.054ab
Barnamala	0.120	0.067a
Range	0.020-0.120	0.047-0.067
Mean ± SE	0.046± 0.019	0.054± 0.003
LS		*
LSD $_{(0.05)}$		0.015
CV		14.94

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference

CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability
^{NS} = Not Significant

The result of the paired sample 't' test showed that the calculated t-value (.522 ^{NS}) of pH was found in year 1999 vs year 2019 of collected soils (Table 7) which indicated that the value was positive but not significant. The results of comparative study showed that N value was higher in soil sample collected from 2019 than that of 1999 except Barnamala. Results indicated that the pH value was increasing trend (R^2 = 0.6001).

Table 7. Paired sample 't-test' of N value of 1999 vs 2019

N	T value	Significance
Year 1999 VS Year 2019	0.522	0.630 ^{NS}

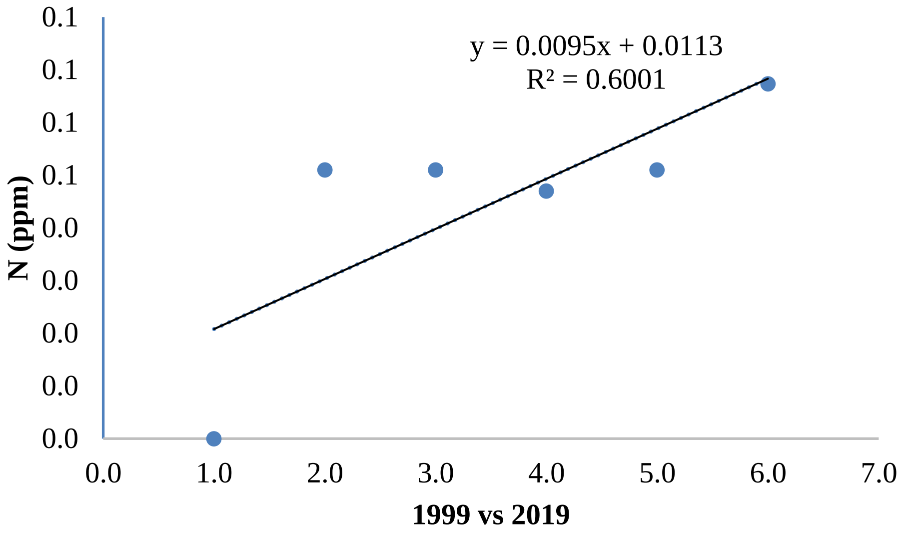


Figure 3. Nitrogen value 1999 vs 2019.

4.4. Status of available phosphorus (P)

Mean values of P obtained in the soils under different sampling sites under the scope of this research and that carried out in 1999 by SRDI staff are illustrated Table 8 for comparison. The baseline data shows that P content in soils ranged from 1.00 ppm to 6.00 ppm.

Study conducted by SRDI (1999) found lowest (1.00 ppm) and highest (6.00 ppm) in Barnamala and Balarampur, Baigram site, respectively while this study finds those lowest (2.057 ppm) and highest (5.970 ppm) concentration in Barnamala and Baigram, respectively. The mean available P was 4.66 ppm, which indicated very low status of nutrient (Table 8). The optimum nutritional level of available P in soil is 18.1 to 24.0 ppm for agriculture practice in Bangladesh (Ahmed *et al*., 2018). Portch (1984) reported that the 41% soils of Bangladesh contained phosphorous with below critical level and 35% below optimum level. The available phosphorous content varied with different location and layer of soil profile.

Among five sites in three sites, the status of available P decreased which indicates the degradation of soil quality. Sadhu *et al*. (2012) narrated that P played a crucial role in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement and several other properties in living plant. As the soil test indicates that phosphorus is low and fertilizer is needed, the rate recommended is intended to satisfy immediate crop needs and begin to build soil phosphorus levels to the optimum range Rashid *et al*. (2014) in his case study found 6.16 ppm P content in Normal Farmland Soil (NFS) which is little higher than the result we found.

Table 8. Status of available P from soils of different location

Sampling Sites	P (ppm)	
	Year 1999	Year 2019
Banspukur	5.00	4.707b
Balarampur	6.00	4.813b
Baigram	6.00	5.970a
Hamidpur	5.00	5.770a
Barnamala	1.00	2.057c
Range	1.00-6.00	2.057-5.970
Mean ± SE	4.66± 0.87	4.66± 0.70
LS		**
LSD $_{(0.05)}$		0.670
CV		8.13

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference

CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability
^{NS} = Not Significant

The result of the paired sample 't' test showed that the calculated t-value (0.009 ^{NS}) of P was found in year 1999 vs year 2019 of collected soils (Table 9) which indicated that the value was slightly positive but not significant. Results indicated that the P was increasing trend (R^2 = 0.0789).

Table 9. Paired sample 't-test' of P value of 1999 vs 2019

P	T value	Significance
Year 1999 VS Year 2019	0.009	0.993 ^{NS}

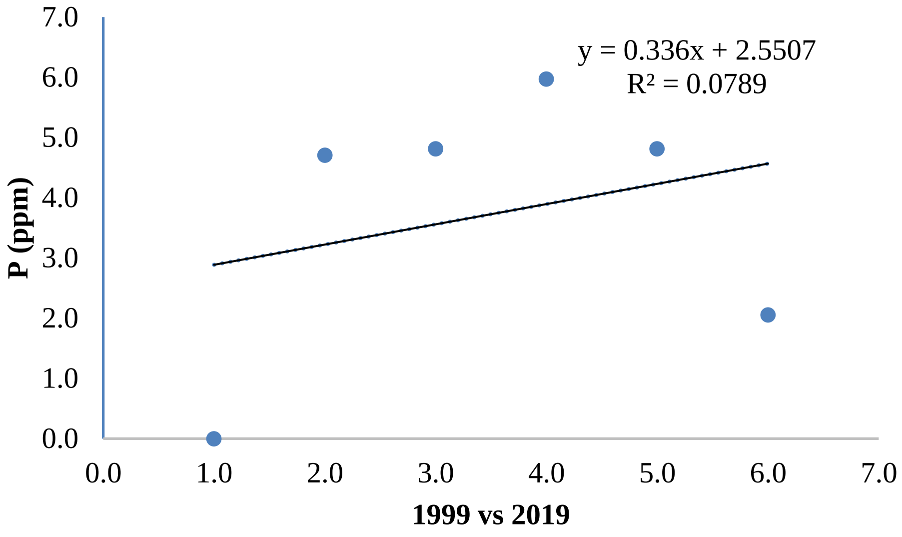


Figure 4. Phosphorus value 1999 vs 2019.

4.5. Status of exchangeable potassium (K)

Mean values of K obtained in the soils under different sampling sites under the scope of this research and that carried out in 1999 by SRDI staff are illustrated Table 10 for comparison.

Data obtained by SRDI staff in 1999 shows that K content in soils ranged from 0.08 meq $100g^{-1}$ to 0.40 meq $100g^{-1}$, while this study finds K to range from 0. meq $100g^{-1}$ to 4.12 meq $100g^{-1}$. Study conducted by SRDI (1999) found the lowest (0.08 meq $100g^{-1}$) and highest (0.40 meq $100g^{-1}$) concentrations in Hamidpur and Barnamala site, respectively, while this study finds those lowest (0.41 meq $100g^{-1}$) and highest (4.12 meq $100g^{-1}$) concentrations in Barnamala and Balarampur sites, respectively (Table 10). The concentration of K was increased in all five sampling sites and the result indicated that the concentration of nutrient status was very high (Ahmed *et al*., 2018).

Ghosh and Biswas (1978) reported that continuous application of potassium fertilizers in soil may increase the content of exchangeable K appreciably as well as progressively. Hossain *et al*. (2015) and Rahman *et al*. (2014) carried out a study in Barapuria coalmine area and they found 105.37 meq $100g^{-1}$ and 49.52 meq $100g^{-1}$, respectively.

Table 10. Status of exchangeable K from soils of different location

Sampling Sites	K (meq $100g^{-1}$)	
	Year 1999	Year 2019
Banspukur	0.09	2.38b
Balarampur	0.25	4.12a
Baigram	0.24	3.68a
Hamidpur	0.08	1.68c
Barnamala	0.40	0.41d
Range	0.08-0.40	0.41-4.12
Mean ± SE	0.21± 0.06	2.45± 0.67
LS		**
LSD $_{(0.05)}$		0.691
CV		15.48

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference

CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability
^{NS} = Not Significant

The result of the paired sample ‘t’ test showed that the calculated t-value (3.251 *) of K was found in year 1999 vs year 2019 of collected soils (Table 11) which indicated that the value was highly positive and significant. The results of comparative study showed that K value was higher in soil sample collected from 2019 than that of 1999. Results also indicated that the K value was in slightly increasing trend (R^2 = 0.0003).

Table 11. Paired sample ‘t-test’ of K value of 1999 vs 2019

K	T value	Significance
Year 1999 VS Year 2019	3.251	0.031*

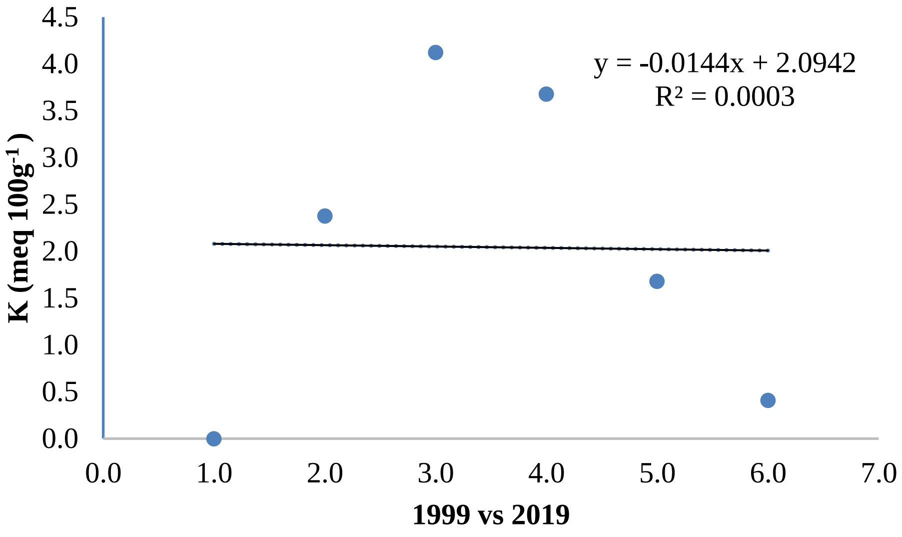


Figure 5. Potassium value 1999 vs 2019.

4.6. Status of available sulphur (S)

S contents of surface soils under five sampling sites nearby agricultural lands of Barapukuria coalmine were determined. Mean values of K obtained in the soils under different sampling sites under the scope of this research and that carried out in 1999 by SRDI staff are illustrated Table 12 for comparison.

Table 6 portrays that the concentration of S in all five samples were increased and that the concentrations at present range from as low as 16.75 ppm to as high as 31.17 ppm; while from SRDI study (1999) results, we find that the concentration range between 9.00 ppm to 22.00 ppm.

Study conducted by SRDI (1999) found the highest (22.00 ppm) and the lowest (9.00 ppm) contents in soil under Barnamala and Hamidpur site, respectively, while this study finds the highest (31.17 ppm) and the lowest (16.75 ppm) concentrations in Banspukur and Barnamala sites, respectively. The result shows that there is no significant differences between Standard Reference value (22.51 ppm- 30.00 ppm) of SRDI. Similar result found by Rahman *et al.* (2014). In their study they found the value of S was 30.78 ppm. Portch and Islam (1984) found that 68% of the soils were below the critical level for S.

Table 12. Status of available S from soils of different location

Sampling Sites	S (ppm)	
	Year 1999	Year 2019
Banspukur	22.00	31.17a
Balarampur	17.00	25.21b
Baigram	12.00	24.36b
Hamidpur	9.00	21.69c
Barnamala	22.00	16.75d
Range	9.00-22.00	16.75-31.17
Mean ± SE	16.40± 2.62	23.83± 2.35
LS		**
LSD $_{(0.05)}$		2.464
CV		5.68

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference

CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability
^{NS} = Not Significant

The result of the paired sample ‘t’ test showed that the calculated t-value (2.261 ^{NS}) of S was found in year 1999 vs year 2019 of collected soils (Table 13) which indicated that the value was highly positive but not significant. The results of comparative study showed that S value was higher in soil sample collected from 2019 than that of 1999 except Barnamala. Results also indicated that the S value was in increasing trend (R^2 = 0.0994).

Table 13. Paired sample ‘t-test’ of S value of 1999 vs 2019

S	T value	Significance
Year 1999 VS Year 2019	2.261	0.087 ^{NS}

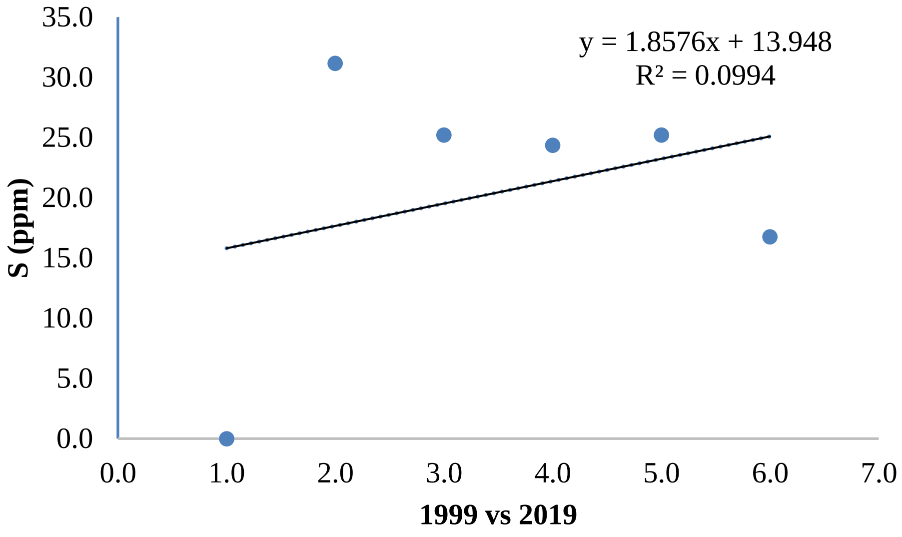


Figure 6. Sulphur value 1999 vs 2019.

4.7. Status of exchangeable calcium (Ca)

Ca contents of surface soils under five sampling sites of Barapukuria, were determined. Means values of Ca obtained in the soils under different sampling sites under the scope of this research and that carried out in 1999 by SRDI staff are illustrated Table 14 for comparison.

Study conducted SRDI in 1999 shows that Ca content in soils ranges from as high as 26.90 meq $100g^{-1}$ to as low as 1.50 meq $100g^{-1}$ in Baigram and Hamidpur site, respectively; while this study finds Ca to range from 5.74 meq $100g^{-1}$ to 4.15 meq $100g^{-1}$ for Baigram and Balarampur site, respectively (Table 14).

The concentration of Ca was increased in three sampling sites and other two sites decreased. The upsurge of Ca might be due to heavy application of potassium fertilizers. The data shows high standard deviation which means there's a wider range of variability.

The result of the paired sample 't' test showed that the calculated t-value (-1.198^{NS}) of Ca was found in year 1999 vs year 2019 of collected soils (Table 15) which indicated that the value was highly negative as well as not significant. Results also indicated that the Ca value was in slightly increasing trend ($R^2 = 0.4396$).

Table 14. Status of exchangeable Ca from soils of different location

Sampling Sites	Ca (meq $100g^{-1}$)	
	Year 1999	Year 2019
Banspukur	2.20	4.55bc
Balarampur	26.70	4.15c
Baigram	26.90	5.74a
Hamidpur	1.50	4.35bc
Barnamala	2.30	4.90b
Range	1.50-26.90	4.15-5.74
Mean ± SE	11.92± 6.08	4.74± 0.28
LS		**
$LSD_{(0.05)}$		0.624
CV		7.23

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference

CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability
^{NS} = Not Significant

Table 15. Paired sample ‘t-test’ of Ca value of 1999 vs 2019

Ca	T value	Significance
Year 1999 VS Year 2019	-1.198	0.297 ^{NS}

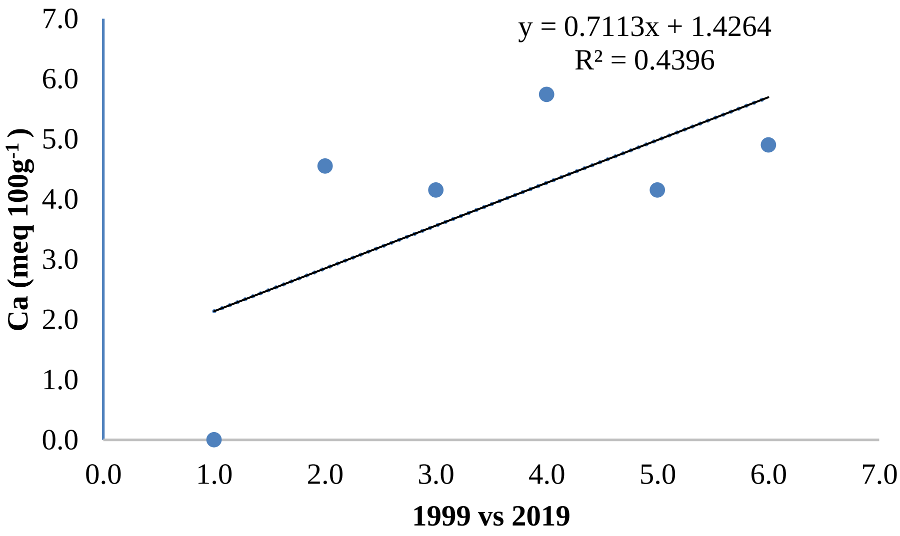


Figure 7. Calcium value 1999 vs 2019.

4.8. Status of exchangeable magnesium (Mg)

Mean values of Mg obtained in the soils under different sampling sites under the scope of this research and that carried out in 1999 by SRDI staff are illustrated Table 16 for comparison. The value of Mg increased in all the sampling sites except Balarampur. Previous data shows that Mg content in soils ranged from 0.57 meq $100g^{-1}$ to 2.31 meq $100g^{-1}$.

Study conducted by SRDI (1999) found lowest (0.57 meq $100g^{-1}$) and highest (2.31 meq $100g^{-1}$) in Hamidpur and Balarampur site, respectively, while this study finds those lowest (1.62 meq $100g^{-1}$) and highest (6.73 meq $100g^{-1}$) concentration in Balarampur and Baigram, respectively. The mean value was 3.14 meq $100g^{-1}$ (table 16) which was very high in terms of nutrient status (Ahmed *et al*., 2018).

The result of the paired sample 't' test showed that the calculated t-value (2.197^{NS}) of Mg was found in year 1999 vs year 2019 of collected soils (Table 17) which indicated that the value was highly positive but not significant. The results of comparative study showed that Mg value was higher in soil sample collected from 2019 than that of 1999 except Balarampur site. Results also indicated that the Mg value was in increasing trend ($R^2 = 0.1069$).

Table 16. Status of Mg from soils of different location

Sampling Sites	Mg (meq $100g^{-1}$)	
	Year 1999	Year 2019
Banspukur	0.73	2.37c
Balarampur	2.31	1.62d
Baigram	2.25	6.73a
Hamidpur	0.57	2.80b
Barnamala	0.76	2.20c
Range	0.57-2.31	1.62-6.73
Mean ± SE	1.32± 0.31	3.14± 0.92
LS		**
LSD $_{(0.05)}$		0.323
CV		5.64

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference

CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability
^{NS} = Not Significant

Table 17. Paired sample 't-test' of Mg value of 1999 vs 2019

Mg	T value	Significance
Year 1999 VS Year 2019	2.197	0.093 ^{NS}

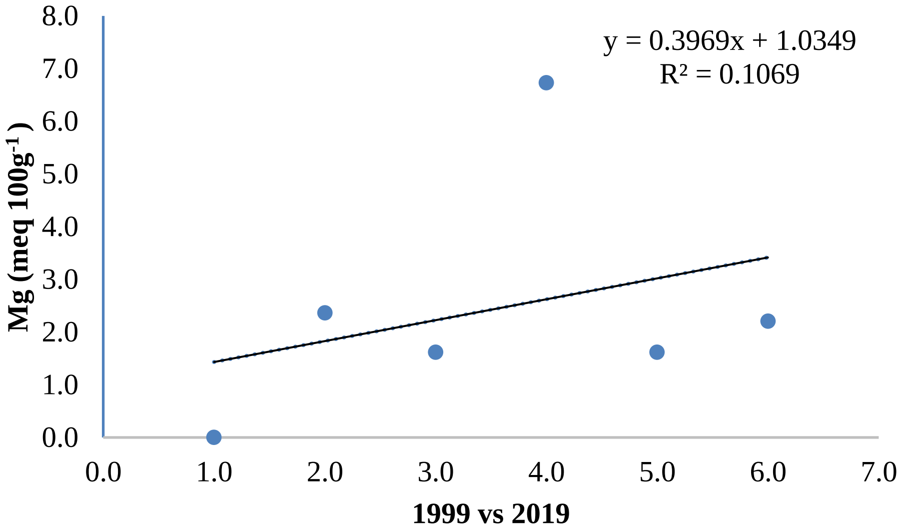


Figure 8. Magnesium value 1999 vs 2019.

4.9. Status of available copper (Cu)

Means values of Cu obtained in the soils under different sampling sites under the scope of this research and that carried out in 1999 by SRDI staff are illustrated Table 18 for comparison.

This table illustrates that the concentration Cu were decreased in all five sampling sites. Data obtained by SRDI staff in 1999 shows that Cu content in soils ranged from 2.80 ppm to 4.20 ppm, while this study finds Cu to range from 0.13 ppm to 0.46 ppm.

Study conducted by SRDI (1999) found the lowest (2.80 ppm) and highest (4.20 ppm) concentrations in Banspukur and Barnamala site, respectively, while this study finds those lowest (0.13 ppm) and highest (0.46 ppm) concentrations in Barnamala and Baigram sites, respectively.

The result of the paired sample ‘t’ test showed that the calculated t-value (-1.712 ^{NS}) of Cu was found in year 1999 vs year 2019 of collected soils (Table 19) which indicated that the value was highly negative as well as not significant. The results of comparative study showed that Cu value was higher in soil sample collected from 2019 than that of 1999. Results also indicated that the Cu value was in slightly increasing trend (R^2 = 0.0079).

Table 18. Status of available Cu from soils of different location

Sampling Sites	Cu (ppm)	
	Year 1999	Year 2019
Banspukur	2.80	0.33c
Balarampur	3.20	0.28b
Baigram	2.90	0.46c
Hamidpur	2.90	0.14a
Barnamala	4.20	0.13a
Range	2.80-4.20	0.13-0.46
Mean ± SE	3.20± 0.26	2.57± 0.47
LS		**
LSD $_{(0.05)}$		0.532
CV		11.36

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference

CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability
^{NS} = Not Significant

Table 19. Paired sample‘t-test’ of Cu value of 1999 vs 2019

Cu	T value	Significance
Year 1999 VS Year 2019	-1.712	0.162 ^{NS}

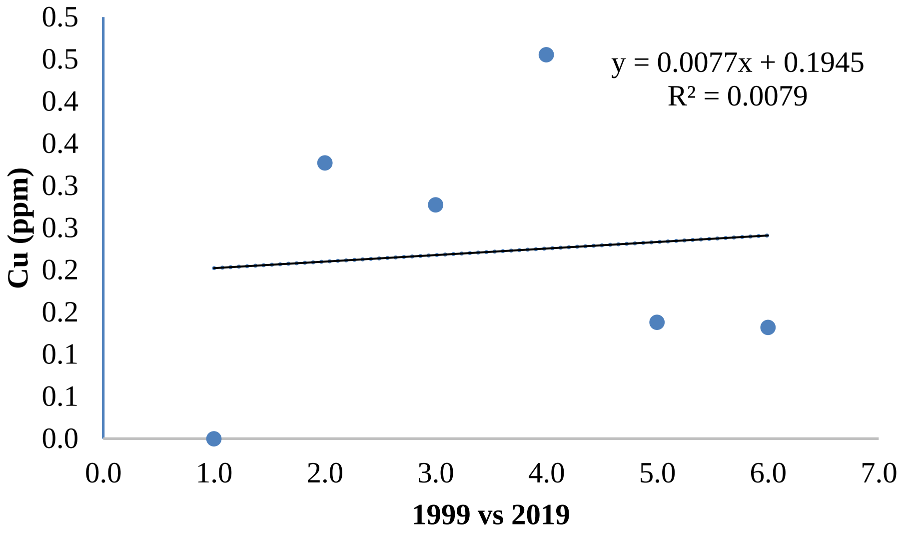


Figure 9. Copper value 1999 vs 2019.

4.10. Status of available iron (Fe)

Fe contents of surface soils under five sampling sites adjacent to Barapukuria coalmine area were determined. Mean values of Fe obtained in the soils under different sampling sites under the scope of this research and that carried out in 1999 by SRDI staff are illustrated Table 20 for comparison.

The concentrations at present range from as low as 206.67 ppm to as high as 303.50 ppm; while from SRDI study (1999) results, we find that the concentration range between 134.00 ppm to 278.00 ppm (Table 20). The concentration of Fe increased in three sites and decreased in other two sites.

Study conducted by SRDI (1999) found the highest (278.00 ppm) and the lowest (134.00 ppm) contents in soil under Barnamala and Balarampur site, respectively, while this study finds the highest (303.50 ppm) and the lowest (202.67 ppm) concentrations in Hamidpur and Banspukur sites, respectively.

The optimum level of available Fe is 9.1 to 12.0 ppm, which is comparatively high and adequate to crop yield (Ahmed *et al*., 2018). Therefore, there is no need to apply any additional available Fe in these lands.

Higher value of Iron (Fe) indicates that that Iron pyrite (FeS_2) and chalcopyrite ($CuFeS_2$) which are released during coal mining operations are liable for high Iron (Fe) and Copper (Cu) in the soil samples.

The result of the paired sample 't' test showed that the calculated t-value (0.888 ^{NS}) of Fe was found in year 1999 vs year 2019 of collected soils (Table 21) which indicated that the value was highly positive but not significant. Results also indicated that the Fe value was in increasing trend ($R^2 = 0.4579$).

Table 20. Status of available Fe from soils of different location

Sampling Sites	Fe (ppm)	
	Year 1999	Year 2019
Banspukur	238.00	202.67d
Balarampur	134.00	236.67b
Baigram	160.00	220.00c
Hamidpur	221.00	303.50a
Barnamala	278.00	215.00cd
Range	134.00-278.00	202.67-303.50
Mean ± SE	206.20± 26.20	235.57± 17.84
LS		**
LSD $_{(0.05)}$		16.270
CV		3.80

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference

CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability
^{NS} = Not Significant

Table 21. Paired sample 't-test' of Fe value of 1999 vs 2019

Fe	T value	Significance
Year 1999 VS Year 2019	0.888	0.425 ^{NS}

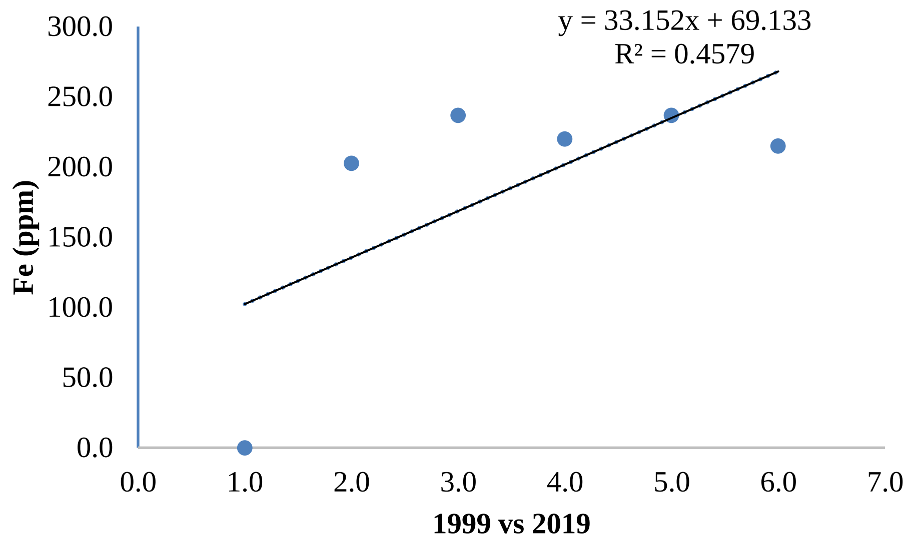


Figure 10. Iron value 1999 vs 2019.

4.11. Status of available manganese (Mn)

Mean values of Mn obtained in the soils under different sampling sites under the scope of this research and that carried out in 1999 by SRDI staff are illustrated Table 22 for comparison. The concentrations of Mn were increased in all five sampling sites. Data obtained by SRDI staff in 1999 shows that Mn content in soils ranged from 5.00 ppm to 37.00 ppm, while this study finds Mn to range from 13.11 ppm to 27.40 ppm.

Study conducted by SRDI (1999) found the lowest (5.00 ppm) and highest (37.00 ppm) concentrations in Baigram and Barnamala site, respectively, while this study finds those lowest (13.11 ppm) and highest (27.40 ppm) concentrations in Balarampur and Barnamala sites, respectively.

The optimum content of available Mn in soil is 2.26 to 3.00 ppm for agricultural activities (Ahmed *et al*., 2018). However, the mean status of Mn of the study area soil was 17.90 ppm, which indicated very high content of available Mn (Table 22). Average content is higher than optimum level and so addition of available Mn was not required in these lands.

Manganese is an essential plant micronutrient as it regulates plant growth and development. It affects plant development, when at deficient or toxic levels. So higher amount of manganese causes toxicity to plant which is also an impact of coal mining.

The results of comparative study showed that Mn value was higher in soil sample collected from 2019 than that of 1999. Coal mining causes acid mine drainage, which causes heavy metals like Mn to dissolve and seep into ground and surface water. Results also indicated that the Mn value was in increasing trend ($R^2 = 0.4541$). The result of the paired sample 't' test showed that the calculated t-value (1.300 ^{NS}) of Mn was found in year 1999 vs year 2019 of collected soils (Table 23) which indicated that the value was positive but not significant.

Table 22. Status of available Mn from soils of different location

Sampling Sites	Mn (ppm)	
	Year 1999	Year 2019
Banspukur	10.40	20.80b
Balarampur	5.80	13.11c
Baigram	5.00	14.64c
Hamidpur	7.40	13.56c
Barnamala	37.00	27.40a
Range	5.00-37.00	13.11-27.40
Mean ± SE	13.12± 6.04	17.90± 2.75
LS		**
LSD $_{(0.05)}$		1.816
CV		5.58

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference

CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability
^{NS} = Not Significant

Table 23. Paired sample 't-test' of Mn value of 1999 vs 2019

Mn	T value	Significance
Year 1999 VS Year 2019	1.300	0.263 ^{NS}

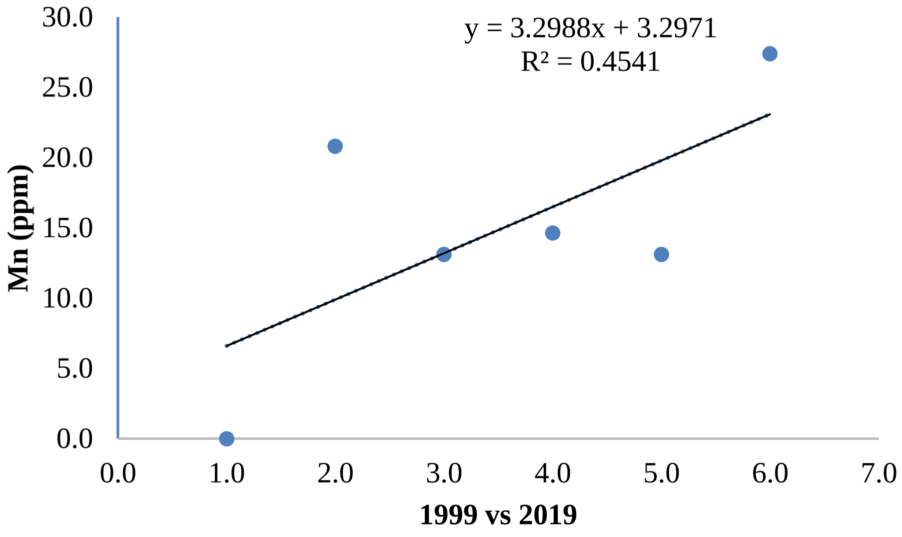


Figure 11. Manganese value 1999 vs 2019.

4.12. Status of available zinc (Zn)

Mean values of Zn obtained in the soils under different sampling sites under the scope of this research and that carried out in 1999 by SRDI staff are illustrated Table 24 for comparison.

The Table illustrates that Zn value increased in all the sampling sites. Previous data shows that Zn content in soils ranged from 0.70 ppm to 1.00 ppm. Study conducted by SRDI (1999) found the lowest (0.70 ppm) and the highest (1.00 ppm) in Balarampur and Hamidpur site respectively, while this study finds those lowest (1.62 ppm) and highest (2.15 ppm) concentration in Barnamala and Hamidpur respectively. The result showed that the available Zn in soil was optimum in status (Ahmed *et al.,* 2018).

The results of comparative study showed that Fe value was higher in soil sample collected from 2019 than that of 1999. It might be due to discharges of wastes, mine tailings, coal and bottom fly ash, and the use of chemical products such as fertilizers that contain zinc. The result of the paired sample 't' test showed that the calculated t-value (9.236 **) of Zn was found in year 1999 vs year 2019 of collected soils (Table 25) which indicated that the value was highly positive and significant. Zinc does not volatilize from soil. Results also indicated that the Zn value was in slightly increasing trend (R^2 = 0.3571).

Table 24. Status of available Zn from soils of different location

Sampling Sites	Zn (ppm)	
	Year 1999	Year 2019
Banspukur	0.90	1.76b
Balarampur	0.70	2.13a
Baigram	0.90	1.85ab
Hamidpur	1.00	2.15a
Barnamala	0.80	1.62b
Range	0.70-1.00	1.62-2.15
Mean ± SE	0.86± 0.05	1.90± 0.10
LS		*
LSD $_{(0.05)}$		0.336
CV		9.70

Figures in a column followed by different letter(s) differs significantly whereas figures having common letter(s) do not differ significantly from each other as adjusted by LSD.

SE = Standard error
LS= Level of Significance
LSD= Least Significant Difference

CV= Coefficient of Variation
** = Significant at 1% level of probability
* = Significant at 5% level of probability
^{NS} = Not Significant

Table 25. Paired sample 't-test' of Zn value of 1999 vs 2019

Zn	T value	Significance
Year 1999 VS Year 2019	9.236	0.001**

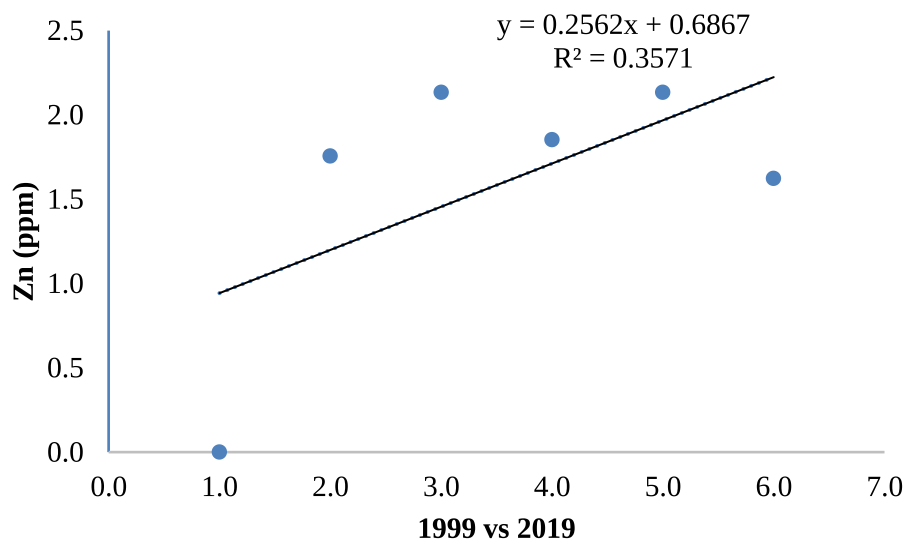


Figure 12. Zinc value 1999 vs 2019.

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

Barapukuria underground coal mine in Dinajpur district is the only coal mine in Bangladesh that was discovered at shallow and mineable depth in 1985 by the Bangladesh Geological Survey. This study was conducted on Barapukuria coal mine located in a rural area at Dinajpur district in Northwest Bangladesh during the summer of 2019. The main objective of this research was to determine the consistency and deviation of soil around Barapukuria coal mine in Parbatipur, Dinajpur. Soil samples were collected from five different locations based on the Regional Land and Soil Resources Utilization Guide of SRDI. Each sample was separated for the measurement of 12 chemical properties including pH, Organic Matter (OM), Nitrogen (N), Phosphorus (P), Potassium (K), Sulfur (S), Calcium (Ca), Magnesium (Mg), Copper (Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn). Soil sample analyses were carried out in Regional Laboratory, Soil Resource Development Institute (SRDI), Dinajpur.

Nitrogen (N), exchangeable Potassium (K), available Phosphorus (P), and available Sulfur (S) were determined by modified micro Kjeldahl method, Ammonium acetate method, stannous chloride method, and Ion Chromatography, respectively. On the other hand, Cu, Fe, Mn, Zn were determined by DTPA-extraction method at a soil: DTPA ratio of 1:2 using Atomic Absorption Spectrophotometer.

In analyzing the status of soil quality, it was found that many of the soil nutrient levels increased such as pH, OM%, N, K, S, Mg, Fe, Mn and Zn. On the other side, the average content of Ca and Cu were decreased. Available P did not change much from the previous baseline data.

The highest pH value 5.70 was found in Banspukur site and the lowest 5.28 in Hamidpur which were strongly acidic in nature. The result of the paired sample 't-test' showed that the calculated t-value of pH indicated that the value was highly positive and significant. The value of OM increased in all sampling sites and the 't' value was also significant. The range of organic matter was 2.51 % to 3.21% and the mean value was 2.16% which is medium in status. The status of nitrogen in soil ranged from 0.047 to 0.067 ppm with a mean of 0.054 ppm which was below optimum level. The status of K showed a wide range of variability because of higher standard deviation. The 't' value of S was highly positive but not significant. The range of S in our study area was 16.75-31.17 ppm with mean value 23.83 ppm. The calculated 't' value of Mg was highly positive but not significant and the range was 1.62 to 6.73 ppm. In our study, we found the lowest value of Cu 0.13 ppm and the highest was 0.46 ppm respectively.

From the field observation and agricultural point of view, it was apparent that the color of coal leached drainage water and the agricultural land water were blackish and slightly blackish respectively, which polluted surface water and the agricultural land. This type of condition hampers overall agricultural production specially paddy.

Conclusion

Agriculture is the driving force to boost up the economy of a developing country like Bangladesh and soil quality is the most important factor in this regard. Industrialization has an adverse effect on agriculture throughout the whole world. Mining brought new potential hazards and risks to the environment. In spite of development of renewable energy technologies, our dependence on fossil fuels still has been continuing. But the deficiency of poor infrastructure for coal storage and unsatisfactory treatment of underground mine water polluted the surrounding soil. From the analysis of soil samples it has been identified that several important chemical parameters that is necessary for agriculture are deviated from the Standard Reference value. With the agricultural point of view a few chemical parameters of the soil are deviated from the standard reference value and are not suitable for the agriculture. Without proper initiatives, degradation may lead to a severe damage to the soil quality and it can be brought disaster on the agriculture of the study which ultimately affects the vast paddy land around the Barapukuria coal mine area. The chemical properties of surrounding soil such as concentration of Potassium, Sulfur, Magnesium, Iron, Manganese and Zinc are greatly increased by the mixing of coal water and greatly impacts on the farmer's field soil. On the other hand, the average content of Calcium and Copper were decreased. Available P did not change in this connection. These impacted soil quality may also hamper on flora and fauna of the surrounding environment of the Barapukuria coal mining.

Recommendations

It may be recommended that the proper precautionary measures should be under taken to minimize the magnitude of pollution. Again, it is desirable to monitor the soil and soil quality routinely for taking the necessary precautionary measures for preventing the future degradation of soil quality in this region which might play the key role to protect the green and clean environment and fruitful coal-mining operations around the mine area as well as in the country. Besides, storage system of coal should be developed and waste disposal system should be improved. Nowadays the main conceptual question is to classify it (discharge drainage coal mining water) for proper utilization with respect to international standard water for domestic, agricultural and aquatic lives in and around the mine area followed by organization of recycling process of cleaning discharge coal mining water Barapukuria for domestic use and to ensure the safety of the agricultural land, aquatic lives around the mine area.

CHAPTER VI

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CHAPTER VII

APPENDICES

Appendix I. Soil reaction ratings

pH range	Soil reaction rating
< 4.6	Extremely acidic
4.6–5.5	Strongly acidic
5.6–6.5	Moderately acidic
6.6–6.9	Slightly acidic
7.0	Neutral
7.1–8.5	Moderately alkaline
> 8.5	Strongly alkaline

Appendix II. Standard of soil organic matter (%)

Value	Status
<1.00	Very low
1.00-1.70	Low
1.71-3.40	Medium
3.41-5.50	High
>5.50	Very high

Appendix III. Status of soil nutritional level.

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 ($\mu g\ g^{-1}$)	<6.000	6.100-12.00	12.100-18.000	18.100-24.00	24.100-30.000	>30.000
Z ($\mu g\ g^{-1}$)	< 0.450	0.451-0.90	0.910-1.350	1.351-1.80	1.810-2.250	>2.250
Fe ($\mu g\ g^{-1}$)	<3.000	3.100-6.00	6.100-9.000	9.100-12.00	12.100-15.000	>15.000
Mn ($\mu g\ g^{-1}$)	<0.750	0.760-1.50	1.510-2.250	2.260-3.00	3.100-3.750	>3.750
B ($\mu g\ g^{-1}$)	< 0.150	0.151-0.30	0.310-0.450	0.451-0.600	0.610-0.750	>0.750
K (meq $100g^{-1}$)	<0.075	0.076-0.15	0.151-0.225	0.226-0.300	0.310-0.375	>0.375
Ca (meq $100g^{-1}$)	< 1.500	1.510-3.00	3.010-4.500	4.510-6.00	6.010-7.500	>7.500
Mg (meq $100g^{-1}$)	<0.375	0.376-0.75	0.751-1.125	1.126-1.50	1.510-1.875	>1.875

Appendix IV Map of Barapukuria coal mine adjacent to soil sampling location