ABSTRACT

Effects of mining on the quality of soil and water in the coal mining areas of Assam.

Environmental pollution due to industrialization has now become a serious international problem. Coal mining is such an industry. Coal is essential and a very important natural resource for energy production. On a worldwide basis, coal is substantially more abundant than oil or gas, the total coal reserves being estimated at about $7.4 \times 10^{12}$ MT (metric tones), which is equivalent to $4.7 \times 10^{22}$ calories of energy. This may be compared to the total world energy consumption from all fuels of $6.0 \times 10^{19}$ calories. It is the major fuel used worldwide for generating electricity.

Coal production in India has increased by about seven times in the past 40 years. Nearly 50 coalfields, ranging in size from a few square kilometers to greater than 1500 square kilometers, have been found in India. Coal mining by both opencast and underground methods affects the environment of the area. In the process of mining, huge amount of water is discharged on surface to facilitate the mining operations. The discharged water often contains high load of TSS, TDS, hardness and heavy metals, which contaminate the surface and ground water. Sometimes, the water is acidic in nature and pollutes the water regime.

Coal mining causes a great devastation of both terrestrial and aquatic environments on a local and a regional scale. It generates two major types of wastes namely acid mine drainage (AMD) and coal washeries. AMD is one of the most serious environmental problems faced by coal mining industry and is a major cause of water contamination near the coal mining area. It is generated from the oxidation of sulphur bearing minerals like pyrites in coalmines. Thus, all the sulphur present in the coal wastes as insoluble sulphate is converted to soluble form in the form of sulphuric acid. Pyrites often exist in association with other metallic elements such as As, Cd, Cu, Co, Pb, Hg, Zn. Mobilization of the trace metals like Arsenic (As), Lead (Pb), Mercury (Hg), Zinc (Zn), Copper (Cu), Cadmium (Cd), Cobalt (Co) occurs as a result of low pH (due to AMD), thus enhancing the concentration of these metals in the receiving water bodies and in many cases leading to the heavy metal toxicity. Common characteristics of AMD is low pH, sometimes less than
2, high sulphate content, high iron and manganese content and the formation of a yellow orange precipitate of Fe, Fe(OH)$_3$ called yellow boy, that coats the bottom of stream and obstructs the biological activities.

Despite the Assam coalfields being in operation for a very long time, only a few reports are found here and there on the effects of mining on water and soil quality of the area. In the present work, therefore, a study was conducted with the following objectives:

- To measure the physicochemical properties of water and soil samples.
- To find out the heavy metal concentration of water and soil samples.
- To carry out metal speciation studies with respect to a few significant heavy metals in soil samples for identifying the chemical forms in which the metals are present.
- To find out the soil composition with an aim to find out the level of contamination due to coal mining activities.
- Evaluation of the overall impact of the mining operations on water and soil by statistical computations.
- To arrive at conclusions from the analysis of the data about the extent of damage, if any, done to the water bodies, soil, and sediments by the continuous long term coal mining activities with particular reference to the accumulation of heavy metals.
- To suggest ways for remediation measures and damage control.

This thesis presenting the results of the study with the above objectives consists of six chapters and a detailed list of references. Chapter 1 gives a general introduction to coal mining and the problems created by it on the environment and cites a large number of published works.

Chapter 2 gives a description of the coal mining area with special emphasis on the topography and drainage, climate, flora and fauna, industry, inhabitants, general geological set-up of the area, etc. It also gives a brief description of the Coal quality, History of Coal mining, Pollutants present with coal and the existing methods of mining and the previous work carried out in this regard.

Chapter 3 gives a detailed description of the sampling seasons, the different sampling sites and the type of sampling sources. Water sampling was done in three seasons, viz, Post monsoon (October - December), monsoon (May- July) and pre monsoon (January -
March) over a three-year period. Soil sampling was done in two seasons, namely wet and dry seasons. Water samples were collected from wells, tube wells, ponds, rivulets and rivers. Soil samples were collected from the paddy fields and the banks of the rivers, rivulets and ponds. This chapter includes a brief description of the methodology used for analysis. The parameters taken up for analysis of water were

(a) pH, Electrical Conductivity (EC), Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS),
(b) Major Anions like CO$_3^{2-}$, HCO$_3^-$, Cl$^-$, F$^-$, NO$_3^-$, S$^{2-}$, SO$_4^{2-}$, and PO$_4^{3-}$
(c) Major cations like Na, K, Ca, Mg, Fe and Al, and
(d) Heavy metals and trace elements like As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se, Sn, V, Zn.

The physico-chemical parameters taken up for analysis of Soil samples were

(b) Major Anions like CO$_3^{2-}$, HCO$_3^-$, Cl$^-$, SO$_4^{2-}$, and PO$_4^{3-}$.
(c) Major cations like Na, K, Ca, Mg, Fe and Al.
(d) Heavy metals like As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se, Sn, V, Zn.
(e) Soil composition with respect to major and minor oxides.
(f) Identification of the soil clay fractions with XRD and IR measurements.
(g) Chemical partitioning of the metals in soil.

Chapter 4 (soil chemistry) presents the results from the experimental measurement of physico-chemical parameters and heavy metal content of soil samples along with a detailed discussion. The soil texture in the mining area shows that sand dominates over clay and slit in the soil from the study area and the soil can be described sandy in character. Bulk density was observed in the range of 0.56 g cm$^{-3}$ to 1.65 g cm$^{-3}$. The soil particle density varied from a minimum of 1.47 to a maximum of 2.7 g cm$^{-3}$.

The soil has water holding capacity starting from 20.5 to 93.4 % and the mean values varied from 32 to 67.5 %. The highest value was observed in the dry season and the lowest
value in the wet season. Such soil with high water holding capacity is good for agriculture. The porosity values are in the range of 0.157 to 0.769. The coalfield soil was found to be very rich in organic carbon in the range of 0.31 to 5.68 % with the mean values varying from 1.0 to 4.5 % respectively. This enrichment is most likely to be due to the input of coal wastes into the soil. With respect to hydraulic conductivity, no season variation was seen but the values varied from one location to another with a range of 0.01 to 1.08 cm min\(^{-1}\). For 75 % of the soil samples, hydraulic conductivity was \(\leq 0.20\) cm min\(^{-1}\), which shows that most of the soil samples have good water retaining power and hence are suitable for plant growth.

Considerable entry of acidic effluents into the soil is shown by very low values of soil pH, varying from 2.2 – 7.9 i.e. from very strongly acidic to slightly basic. The electrical conductivity of the soil samples varied from 20 – 9640 \(\mu\)S cm\(^{-1}\), the high values may be attributed to inflow of effluents rich in ionic matter from the mines and also due to appreciably low pH, which might have helped in accumulation of ionic matter.

The soil from the coalfield area was enriched with the nutrient, N. In this study, nitrogen was detected in the range of 0.02 to 0.17 %. This enrichment could be attributed to entry of nitrogen-rich liquid and solid wastes from the coalfield.

With respect to major metallic constituents, Na, K, Ca, Mg, Fe, Al, the soil samples had wide-ranging composition. Excessive amount of Fe was detected in this study that may be due the yellow boy (Fe (OH)\(_3\)) formed due to low pH of AMD. The soil samples also have significant trace metal content with respect to As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se, Sn, V, and Zn.

The chapter also gives soil composition with respect to major and minor oxides, identification of the soil clay fractions and the chemical partitioning of the trace metals into different fractions as per standard procedure. The distribution of nine heavy metals viz. Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn into five chemically distinct fractions, namely exchangeable phase, carbonate phase, reducible phase (iron and manganese oxide), organic and sulphate phase, and the residual or lattice phase is described elaborately and the possible impact of the heavy metals in the surrounding environment is discussed.
Chapter 5 (water chemistry) gives the results of analysis of the water samples from the mining area along with a detailed discussion. The results are presented parameter-wise with tables and figures.

The water from the mining area was found to be strongly acidic to slightly alkaline in nature. Range of pH was from 2.1 – 8.7. The electrical conductivity varied over a wide range from 15 – 9760 µS/cm. The solids content of the water (both suspended and dissolved) in the coalmining area showed a considerable seasonal variation as well as a changing trend with location. In monsoon period, due to heavy rainfall, river and runoff water carries a huge amount of debris, for which higher TSS value was observed.

All the major anions like carbonate, bicarbonate, chloride, sulphate, sulphide, fluoride, nitrate, phosphate, etc. were determined and the contents were explained. The water has high sulphate contents (2.1 – 521.0 mg/L) mainly due to entry of acid mine drainage.

Among the major cations, the range of Na was found from 1.5 to 25.9 mg/L and that of K was from 0.2 to 79.0 mg/L. The total hardness, which depends on Ca and Mg concentration, was in the ranges of 10 to 1700 mg/L in pond water, 16 to 430 mg/L in ground water and 16 to 3400 mg/L in river water. Excessive amount of Fe was found almost in all the samples with the concentration in the range of 1.0 to 560.4 mg/L. The trace metals viz. As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se, Sn, V, Zn were also present in the water in different concentrations. Most of the heavy metals exceeded the limits prescribed by World Health Organization for drinking water quality. All the results obtained have been discussed along with their significances and compared with various literature reports.

The thesis concludes with a summary of the results on the basis of the experimental observations (Chapter 6) and also with a few suggestions for further work in the area of the study. This is followed by a complete list of references.