Chapter VII

Summary and recommendations

In Northeastern region (NER) of India, Assam is recognized as the one of the major coal producing states which has an enormous deposition of high sulphur tertiary rank of coal. Assam coals found in Makum coal field of Tinsukia District contains 2.7-7.8 wt % sulphur due to which Assam coal is said to be abnormal in nature. The major part of the sulphur present in coal is the pyrite sulphur. Although it is very demandable due to its essentiality for economic growth of a country, but it's ever lasting impact on surrounding environment is equally pronouncing. The major impact of coal mining activity in Ledo colliery of Assam is the degradation of soil and water quality of surrounding areas even upto 5 km radius from mining source. The main source of environmental problem due to coal mining activity in this colliery results from generation of highly acidic acid/coal mine drainage (AMD/CMD). Weathering of rock forming materials and anthropogenic effects caused from mining related activities are the major controlling factors for maintenance of the water quality in the region.

The impact due to AMD on soil and water resources may vary in different seasons namely monsoon and non-monsoon seasons. The results of the present study revealed that AMD produced in the mining activities of Ledo (Assam) is a major source of trace element and ions to the water system during monsoon season. It is observed that the flow of AMD is fully dependent on the seasonal change in the mining site. AMD generated from high sulphur coal in Ledo open cast mining is highly acidic in monsoon season having pH range within 3.3-6.1. This strongly acidic character of AMD creates a major threat due to the dissolution of PHEs thereby contaminating water bodies in habitat areas. The co-relation analysis also reveals that there is a very weak relationship of pH with the EC and TDS of mine water, but there is a strong relationship of EC with TDS of mine water. The high TDS value of AMD and other water samples from mine-affected areas implies the dissolution of a large number of ions in soil due to the AMD which spreads into water bodies and nearby land. The increased amount of ions in the form of salts in soil affects the soil environment mainly by decreasing crop productivity and soil quality by decreasing the ability of crops as well as the plants to absorb water and cause a remarkable economic loss in agricultural productivity.

The cytotoxicity study of the water samples from mining sites depict more toxicity in HepG2 followed by A549, MIAPaCa2 and L6 cell lines at higher concentrations. The analyses of sixteen polynuclear aromatic hydrocarbons (PAHs) of AMD water revealed that the mine water samples have highest total average PAHs concentration with 17.33±4.10 µg/l. Since these samples were collected from nearby point sources of AMD in Ledo colliery, this high value indicates that the PAHs were generally leached from coal and OB into the nearby water bodies. Naphthalene, Acenaphthylene, and Fluoranthrene were found to be present in all water samples. The high concentration of Phenanthrene (84.962 µg/l) may be due to the spill oil and other petroleum fuels from engine used in the mining operation which also leads to the discharge of polycyclic aromatic hydrocarbons in runoffs. The total concentrations of PAHs in the study sites was found to be exceeded the WHO's limit (0.05µg/l) indicating a high level of PAHs contamination in the AMD water samples producing a large threat to aquatic lives. The ecosystem performs as an exceptional filtering device that holds contaminants like metals in its soil profiles. Nevertheless, the inconclusive nature of the environment is that it can transfer a number of pollutants into groundwater and surface water systems, either in dissolved or undissolved (particulate) form. This may create serious problems for aquatic lives, while entering of metals in groundwater resources can cause a substantial health hazard.

The major and minor elements present in coal and overburden of Ledo colliery are released to the environment by the process of leaching. These elements are leached out with the help of rain water and contaminated nearby rivers, streams, and drains along with the agricultural land. Thus leaching is found to be one of the primary pathways for trace elements entering into the ecosystem. Dumping of coal and overburden causes large environmental degradation due to direct release of potentially hazardous elements through leaching and oxidation of pyrite minerals. The leaching property of different elements has been found to be dependent to several factors like specific element solubility and availability or release potential. Also the other factors that enhance the metal leaching include swiftly weathering metal containing minerals and the mine drainage conditions that can increase the solubility and flow rates through the contaminated mineral. The

major question in terms of environmental issues is not only the total amount of a specified metal but also the quantity of it transportable to an aqueous media as ions. The modes of occurrence of metals in aqueous leachates play a crucial role in their mobility and successive release to the environment. The potential to produce acidity of drainage from mine water and mine wastes can be predicted by both geochemical methods static and kinetic leaching processes. The leachates generated from overburden dump are found to be rich in heavy metals specially Fe, Cu, Mn and Ni. The concentration of some of these elements increases with increase in leaching time and temperature. High concentration of elements in AMD water and other mine affected water resources is attributed to the continuous raining. Thus Ledo coal mine can cause more threat to the quality of water resources, ground as well as the surface water. Thus in view of the influence of heavy as well as hazardous metals like Fe, Pb, Cr, Hg, As, Cd etc. on human and other life systems is a matter of major concern. So, a detailed study on the occurrence and leaching of different elements in coal and OB is of major importance in present situation. In addition to this, the geochemical assessment of a number of water samples collected from different sites near Ledo colliery shows high values of EC, TDS, SO_4^{2-}, Ca^{2+}, and Mg^{2+} which make them unsafe for drinking purposes. By implementation of environmental regulations with a growing concern about the health effects as a result of exposure to heavy metals even at trace amount have focused by a number of researchers by studying about the dissolution of these elements in AMD.

The studies have primarily focused on the elements which are directly related to the major environmental concern like As, Cr, Pb, Hg, Cd, and Se among the others. Also, the nano-mineralogical analysis of coal and overburdens of Ledo colliery revealed the presence of Si minerals like kaolinite with other minerals including sulphate minerals such as barite jarosite, pickeringite, sulphide mineral galena, pyrite, oxide mineral hematite, and organic matters which are combined with pyrite. The HR-TEM analyses of these samples revealed the presence of nano-minerals which are associated with a number of potentially hazardous elements. Galena containing high proportions of Pb, kaolinite with high concentrations of Al and Si can cause a hazardous effect on health. The nano

minerals like nano-hematites have high surface area and high reactivity which making them environmentally sensitive. Also, the concentrations of various metals in the soils increase with decrease in particle size. Thus nano minerals and their association with natural organic matters have possibility to impart toxicological effect on animals and aquatic lives along with human beings. The overall environmental impact of coal mining activity in Ledo colliery is the deterioration of water and soil quality of coal mining and nearby areas.

To diminish the effect, the quality of water and soil in nearby areas can be improved by reducing the acidity of mine drainage water as this acidity is the major cause for the dissolution of heavy metals which then contaminates the natural water resources. Minimization of the acidity (by increasing the pH) of the mine water can be done by some active treatment. Limestone is mainly used for active treatment of AMD. But some problems arise on using limestone for the treatment of AMD. For instance, it is less effective for high iron containing water. Furthermore, the formation of gypsum due to use of limestone leads to scaling of pipelines and the equipment used to eradicate the acidity. Avoiding these problems, use of limestone is more preferable because it is cheap, easy to handle. Experimentally it is found that complete elimination of some elements cannot be done effectively by using normal sized limestone. Thus a laboratory based experiment using nano limestone have carried out to minimize some specific elements like chromium. The nano-remediation laboratory scale analysis also revealed that the absorption of some PHEs increases with a decrease in particle size of the limestone, thus the presence of nano limestone particles is more responsible for effective absorption of these elements from mine water thereby diminishing their concentrations in AMD which will reduce the contamination of nearby water bodies and land systems.

Thus the usage of limestone offers an advantage as an effective media for neutralization and minimization of heavy metal contamination from AMD. The results obtained from the overall experiment have a scope to give a probable way for mitigation of the problems associated with acid mine drainage generated in Ledo coal mine area. The

present thesis will serve as a way forwards for the environmental impact assessment of Ledo colliery, Margherita and suitable remediation strategy.