Pollution of air, water and soil, deforestation and degradation of agricultural land are some of the environmental implications of coal mining which has been well illustrated by Dhar (1994). Bell and Kar (1993) reported that the major pollutants associated with coal mining were suspended solids, dissolved salts (especially chloride), acidity and iron compounds. Based on a study done on air pollution problem from various opencast coal mining operations in Dhanbad, Chaulya et al. (2002) developed a user friendly software called 'EmissCalc' to calculate emission rate of dust as well as gaseous pollutants (sulphur dioxide and nitrogen oxide) from various opencast coal mining activities. Sharma (2003a) reported that the main air pollutant associated with opencast coal mining was dust. Dust, SO$_2$ and NO$_x$ were found in the range of 287.1-1911.0 µg/m$^3$, 64.4-129.6 µg/m$^3$ and 75.0-89.0 µg/m$^3$ in coal mining areas of Damodar river basin, India (Tiwary and Dhar, 1994).
Many Studies have been done on effect of Acid Mine Drainage (AMD) on water quality and aquatic life (Weed and Rutschky, 1971; Rosemond et al., 1992; Pentreath, 1994; Henry et al., 1999; Cole et al., 2001). The study on the effect of different levels of AMD contamination on aquatic species revealed that moderate AMD contamination eliminated the more sensitive species whereas severely contaminated conditions were characterized by dominance of certain taxonomic representatives of pollution tolerant organism, such as aquatic worms, midge larvae, caddis fly larvae and non-benthic insects like predaceous diving beetles and waterboatman etc. The study done by Dieffenbach (1974) indicated that the acidic water with elevated metal concentrations invariably runs off mine lands in overland flow or percolates its way through the substratum to enter streams and degrade aquatic ecosystem. Pentreath (1994) reported that Acid Mine Drainage made water highly acidic and rich in heavy metal concentration which was responsible for degradation of water quality and the declining trend of biodiversity in the water bodies of the coal mining area. Henry et al. (1999) and Cole et al. (2001) reported that aquatic organisms do not tolerate AMD physiologically. Studies done by Tiwary (2001) on water quality status of coal mining regions of Dhanbad revealed that AMD degraded surrounding water resources by lowering the pH and increasing the level of Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and some heavy metals. Study on water quality status of coal mining areas of Jaintia Hills District, Meghalaya revealed that Acid Mine Drainage adversely affected water quality by decreasing pH (between 3-4),
increasing conductivity (2.7 mMHOS), increasing concentration of sulphates (76-168 mg/L) and decreasing Dissolved Oxygen (4.2 mg/L) (Swer and Singh, 2004a). The study done by Swer and Singh (2004b) also revealed that low pH, low Dissolved Oxygen, higher sulphate content and turbidity in water of coal mining areas of Jaintia Hills district lowered abundance and species diversity of macroinvertebrates.

Effect of Acid Mine Drainage on soil physico-chemical properties and thereby on agricultural productivity has been reported by many workers (Darmody et al., 1989; Haigh, 1992; Bai et al., 1998; Tedesco et al., 1999; Das Gupta et al., 2002; Adler and Sibrell, 2003). Study on probable impact on land due to open-cast coal mining in Dhanbad, Bihar done by Ghose and Kundu (1999) revealed that field capacity, wilting coefficient, bulk density, moisture coefficient, moisture retention capacity, pH and fertility status of the area were modified by mining activities. Darmody et al. (1989) reported that the weighted average yield reduction (affected area multiplied by the associated yield reduction) of maize was 4.7% for Long wall (LW) and 1.8% for High Extraction Retreat (HER) mining due to coalmine subsidence at Illinois, USA. Kundu and Ghose (1994) reported that field capacity of danga land (cultivable wasteland where there is little or no cultivation) ranged from 12.86 to 14.65% compared with 17.94 to 21.05% for agricultural land and Wilting coefficient on agricultural land ranged from 5.31 to 6.75 compared with 4.70 to 5.25% for danga land at an underground coal-mining site at Raniganj coalfield in eastern India. Das Gupta et al. (2002) reported that the low moisture content
(6%) of coal mine spoil of Bapung area of Jairitia Hills District, Meghalaya has been considered an important factor limiting the plant growth.

Rao (1989) reported that the region of Cherrapunji in the state of Meghalaya, the world’s wettest place shows sign of desertification now days due to extensive coal mining activities. Sarma (2005) reported that due to extensive coal mining, large areas of Jaintia Hills district of Meghalaya has been turned into degraded land, creating unfavourable condition for plant growth. The results of impact assessment of coal mining on land use/land cover using IRS-1A satellite data for Jaintia Hills District, Meghalaya showed that during the last 12 years (1983-95) coal mining area has increased by 1.2% and agricultural land has decreased by 1.5% due to the deposition of coal particles, soil erosion and water-logging through seepage water (Semwal et al., 2004).

Gruszcznski et al. (1998) reported that land degradation in Szczygłowicze coal mined area, Poland was the result of post mining subsidence and flooding. Ghose and Kundu (1998) reported that underground coal mining activities in South Bihar caused land subsidence resulting in accumulation of sand and increase of bulk density of soil of nearby area. Prakash and Gupta (1998) studied the impact of coal mining on the land use changes in the Jharia coalfield (JCF) by using temporal remote sensing data. The study revealed that extensive mining,
establishment of communication networks, expansion of settlements, decrease in the vegetation cover etc. have remodeled the face of JCF.

According to Haigh (1992) degradation of reclaimed lands previously disturbed by coal mining in Wales was due to gulling, soil erosion, soil compaction, accelerated run-off and poor vegetation cover. Problem of soil erosion in an abandoned coalmine in Cospuden, Germany was studied by Zartle et al. (1998). Bai et al. (1998) reported that open cast coal mining at Antaibao Coal Mine, Pingshuo city, China destroyed original vegetation of the mining site resulting in a soil erosion index greater than 1500 t/km² per year.

The contents of heavy metals Zn, Cu, Mn and Fe were determined in opencast coal mine spoil of Kolubara coal mining basin by atomic absorption spectrometry. Zinc availability was low, but those of the other trace elements high (Durdevic et al., 1988). Increasing concentration of total and extractable heavy metals (Ni, Pb, Cu, Zn, Mn) were found in some soils of the Lublin coal mining region (Filipek and Pawlowski, 1990). According to Sakel et al. (1996) movement of heavy metals down the profile is more near AMD discharge site, leading to higher pollution problem than at the points of increasing distances. Zhulidov et al. (1997) reported that various heavy metals namely Cd, Pb, Zn and Cu were found in the ranges of 10-32; 57-78; 315-480; 87-350 mg/kg, dry weight, respectively, in hydric soils of coal waste contaminated wetlands of the Russian
Arctic. The study conducted by Kuczynska and Zarudzki (1998) showed that the heavy metal contents of wheat grown near the coal mining site at Belchatow, Poland were more than the crop grown in unmined soil due to soil contamination with various heavy metals such as Cu, Mn, Zn, Pb, Ni and Cd. Field experiment conducted by Tedesco et al. (1999) revealed that plant species grown in a coal waste dumping area located on the Butia County Recreio mine, in Rio Grande do Sul state, Brazil were contaminated with four different types of heavy metals namely Cr, Cd, Ni and Pb. Bian et al. (1999) reported that the heavy metal content of the mine soils at Fan coal mine, China did not exceed the standard limit, but it was higher in surface soils than at 30 cm depth.

Nath (2004) reported the presence of as many as six heavy metals viz. Cobalt (0.1-0.2 ppm), Zinc (1.3-3.4 ppm), Manganese (0.2-3.8 ppm), Iron (1.6-2.7 ppm), Lead (0.1-0.4 ppm) and Copper (0.2-0.4 ppm) in mine water of Jarain coal field, JHD, Meghalaya. Long Peng et al. (2004) reported that coal mining activities significantly contributed to heavy metal pollution (Cu, Ni, Pb, Zn, Sn, Cr, Co) and metal accumulation in the soil of Huainan, East China which had a 100-year coal mining history and the concentration of heavy metals decreased with the history of mining. Lin et al. (2005) reported that the pH of agricultural soils irrigated with acidic mine water from the Guangdong Dabaoshan Mine, China, could be as
low as 3.9 and the crops grown in these soils were highly contaminated by heavy metals, particularly Cd.

Studies were made on the condition of plantations on leveled spoil banks of open-cast brown coal (lignite) working in the Moscow region. The substrate was highly acidic, with high sulfide and low nutrient content. It was pointless to plant trees on substrates with pH less than 2.8 and with exchange acidity greater than 5mg.eq./100g (Vasil, 1991). Results of analysis of soil collected from coal mine spoils of Galicia, Spain indicated acidic pH range (2.4) associated with low available phosphorous concentration (1 mg/Kg) (Monterroso et al., 1996). The results of soil analysis of a coal mining site in Taiwan indicated that the soils were extremely acidic (pH 3.2) associated with nutrient deficiency due to contamination with large amount of coal debris (Lin, 1999). Tedesco (1999) reported that low soil pH due to the oxidation of sulphur compounds was the most limiting factor for plant growth on the Butia County Recreio mine, in Rio Grande do Sul state, Brazil. Nath and Ahmed (2005) reported that agricultural activity has been on the decline in Bapung coal mining area of Jaintia Hills district, Meghalaya due to degradation of paddy fields. The land has become infertile (due to acidic nature) forcing farmers to give up cultivation of crops.

Concentration of soluble aluminum that could be toxic to plants were found in mine spoils that had a pH of 5.5 or below (Berg et al., 1973). Foy et al. (1978)
reported that aluminum inhibits root growth and interferes with the uptake of phosphorus, an essential plant nutrient.

The results of the analysis of a series of coal mine spoils (5, 10, 12, 16 and 20 years old) in a dry tropical environment of Madhya Pradesh, India indicated that total soil N, NaHCO₃-extractable P and exchangeable K were lower in mine spoils than native forest soil even after 20 years of succession (Jha and Singh, 1991). The nutrient status of N, P and K in plants grown on a recently reclaimed loose soils (4-20 years after recultivation) situated in a brown coal mining district in Germany was below the critical limit of 30, 3 and 35 g/kg, respectively (Springob and Lebert, 1995). Adler and Sibrell (2003) reported that solubilization and transport of phosphorous to the water environment from soil and manure caused by AMD is a critical environmental issue associated with agricultural productivity in coal mining areas.

Moran et al. (1989) reported that agricultural capability of surface coal-mined land in east-central Alberta was decreased due to degradation of chemical quality of ground water that provided the majority of agricultural water supplies. Studies done by Tiwary and Dhar (1994) revealed that Total Dissolved Solids (200-860 mg/L), Sulphates (14-401.2 mg/L), Hardness (68-711.4 mg/L) and Iron (0.28-4.2 mg/L) content of all major coal fields of Damodar river Basin were high enough to affect the chemical quality of both groundwater and surface water into which mine waters
are pumped in. Study done by Nath (2004) revealed that the seepage water from various coal mines of Jarain area, Jaintia Hills district, Meghalaya were quite acidic (pH < 6) and the corresponding conductivity varied from 305 to 950 μs/cm and TDS varied from 150 to 490 mg/L which rendered the water unsuitable and unsafe for drinking and other domestic uses.

Studies have indicated that certain types of alkaline amendments can successfully control AMD from pyritic spoil and refuse (Rich and Hutchinson, 1990; Brady et al., 1994; Rose et al., 1995). Smith and Dodge (1995) reported that the mine water discharge from a surface coal mine in Pennsylvania improved from an acidity of 120 mg/L as CaCO₃ to 19 mg/L net alkalinity and Fe was significantly reduced by adding 1350 Mg/ha (600 tons/ac) limestone. Caruccio and Geidel (1996) reported that limestone or lime routinely added to the soil as a surface amendment has improved ground water quality of coal mining area and enhanced vegetation growth. Javanovic et al. (1998) reported that the use of lime-treated acid mine drainage for irrigation of agricultural crops at Landau Kromdraai opencast section (near Witbank, Mpumalanga Province, South Africa) considerably increased soil pH as well as yields of irrigated crops compared with rainfed cropping.

Some studies indicated that phosphate rock could be used as an amendment to control AMD due to its reaction with Fe released during pyrite oxidation to form
insoluble coatings (Ghazi, 1985; Ziemkiewicz and Meek, 1994). Ghazi (1985) reported that rock phosphate applied alone at the rate of 0, 10, 20 or 40 g/kg soil in extremely acid mine spoils from Valley Point, Westover and Lenox alone increased maize yields more than treatment of rock phosphate and fly ash in combination in greenhouse trials. Sodium carbonate (NaCO₃) and Calcium hydroxide [Ca(OH)₂] were also found to reduce the acidity of AMD (Caruccio et al., 1984; Nawrot et al., 1994).

Study done by Bruns and Jochimsen (1989) in Germany reported that application of fertilizer significantly controlled soil erosion of coal mine spoils through the improvement of root growth of most of tree species grown on the spoils. The results of the study on effects of various reclamation methods such as lime, ground rock phosphate, manures, a mixture of coal with urea, ammonium phosphate and potassium chloride and various NPK fertilizers on the biological activity of coal mine spoil heaps in Moscow done by Lukina et al. (1990) indicated that the greatest increase in the bacterial population was caused by the application of manure with 300, 600, 600 kg N, P, K per ha, respectively. Kulhavy and Grunda (1991) found significant improvements to soil properties in coal-mining region of Czechoslovakia by liming, application of nitrogenous fertilizers and planting with suitable plant species Alnus glutinosa, A. incana, Lotus corniculatus and Lupinus. Jha (1992) reported that both NPK medium and forest soil had beneficial effects on growth and development of
leguminous plants grown on coal mine spoil of Singrauli, Madhya Pradesh, India.

Lundgren (1971) reported that readily decomposable organic matter reduces formation of AMD in coal mining areas by reducing the activity of *Thiobacillus* bacteria, which catalyzes iron oxidation. There is evidence from laboratory studies that the oxidation of pyrite can be inhibited by organic waste materials such as manures and sewage sludge (Backes et al., 1987). Study on use of organic waste to affect nitrogen fertility at a surface coal mine site of Kentucky, USA revealed that gross N mineralization and nitrification rates were 4.5 times greater in waste amended soil than unamended soil (Coyne et al., 1998).

Results of the study on effect of different combinations of overburden samples and compost on the distribution of nutrients in different plant parts and the biomass production of *Albizia procera* on coal mine overburden samples from Talcher, Orissa indicated that nutrient accumulation was highest in the 1:2 mixture followed by 1:1 and 1:0.5 mixtures (Singh et al., 1994).

Results of the pot experiment conducted using various combinations of coal mine spoil, fly ash and compost showed the maximum height, collar diameter, number of leaves, leaf area, nodule weight and biomass of *Albizia procera*
grown in 1:1:1 (coal mine spoil : fly ash : compost) combination followed by 1:0.5 (coal mine spoil : fly ash) (Singh et al., 1997).

Treatment of an open cast coal mining spoil of Hungary with sewage sludge (2.4% N, 1.3% P and 0.5% Ca) at 40-240 t DM/ha improved the soil moisture holding capacity, reduced soil bulk density and increased wheat grain yields to 5.7-6.7 t/ha compared with 1.0 t/ha on untreated spoil (Kreisztian et al., 1988). Result of a study done by Hangyel and Krisztian (1995) in Hungary showed that application of sewage sludge at the rate of 160 kg/ha in split dose increased the yield of wheat grown in coal mine spoil. Addition of alkaline sludges or flocs, generated from the neutralization of AMD, was reported to provide several benefits when used on the surface of backfills or to acid producing materials during mining and backfilling (Coleman et al., 1997).

Many studies have suggested remediation of coal mining site with vegetation (Spirik, 1988; Spotts et al., 1997). Struthers and Vimmerstedt (1965) concluded that revegetation of mine spoil was generally more successful in the spring months as plant establishment and growth are improved by precipitation infiltrating the mine spoil and leaching the salts from the surface layer. Study on reclamation of soils devastated by coal mining in Czechoslovakia found that forestry practice and important tree and shrub species not only had an economic importance, but also were important for the regeneration of
landscape and environment (Spirik, 1988). Hawkins (1995) reported that many Pennsylvania remining operations showed reduced pollution loading rates due to two factors- the regrading of abandoned mine lands and improved vegetation. Spotts et al. (1997) reported that runoff water from the vegetated area of a barren coal mine tailings in Montana had a higher pH (6.2), and metal loadings of As, Cu, and Zn were also more than four orders of magnitude lower than the unvegetated area.

Results of the trial conducted in coal mine overburdens at Talcher, Orissa to investigate the suitability of different species for afforestation indicated that Pithecellobium dulce was the most promising species in terms of survival and growth (Gupta et al., 1994). Results of the study done by Sonkar et al. (1998) on relative suitability of different nitrogen fixing and non-nitrogen fixing tree species on coal mine overburdens of Singrauli, Madhya Pradesh, India showed that Eucalyptus tereticornis among non-nitrogen fixing tree species and Albizia procera among N-fixing species were considered to be most promising for reclaiming mine spoil.

Phytoremediation of coal mine spoil with legumes had been studied by many researchers (Jha and Singh, 1993; Lyngdoh, 1995; Maiti, 1997). Study done to compare the performance of two crops (Cajanus cajan and Phaseolus mungo) grown on fertilized farm plots and coal mine spoil in Singrauli, Madhya Pradesh
indicated that *Cajanus cajan* performed better on the mine spoil than on the farm plots (Jha and Singh, 1993). Lyngdoh (1995) reported that a leguminous plant *Erisaema chinese* could grow frequently in the coal mine area of Jarain in the Jaintia Hills district and according to the study, this plant by virtue of nodulating profusely and by showing its ability to grow on the soils collected from the mine spoils, was likely to play a significant role in nitrogen economy of the soil. A field study conducted on the use of the legume *Stylosanthes humilis* and the grass *Pennisetum pedicellatum* in a ratio of 1:2 to provide vegetation cover and promote soil formation on coal spoil heaps at the Jharia coal fields, India resulted in increase of organic carbon by 140 and 79% at the end of second and third years respectively and increase of N accumulation rate to 715 kg/ha after three years (Maiti, 1997).

Phytoremediation of coal mine spoil with grass species has been reported by many workers (Lyngdoh *et al.*, 1992; Rensburg *et al.*, 1998). Lyngdoh *et al.* (1992) reported that the *Rhizomatous* and *Soloniferous* grass species such as *Axonopus compressus*, *Crysopogon gryllus* and *Arundinella nepalensis* could grow successfully on coal mine spoils of Jaintia Hills district, because the growth characteristics of these plants helped to bind the soil particles thus making the loose mine spoil more stable and less prone to soil erosion. Based on a study done in Queensland, Australia Truong and Hengchaovanich (1997) reported that vetiver grass was very much effective in land stabilization and
erosion control of coal mining site. Rensburg et al. (1998) reported that perennials Bermuda grass (*Cynodon dactylon*), weeping love grass (*Eragrostis curvula*) and the annual teff (*Eragrostis tef*) occurred with highest frequency on a coal fine ash disposal site in Sasolburg, South Africa.

Caruccio (1968) found in his work in evaluation of factors affecting Acid Mine Drainage that a soil cover played an important role in preventing AMD due to development of alkalinity as high carbon dioxide levels found in soil air contribute towards increasing neutralization capacity. Ciolkosz et al. (1979) reported that the effects of topsoil on oxygen concentrations within underlying mine spoil becomes more significant considering that mine spoil is typically comprised of coarse rock fragments resulting in substantial pore or void space which provides pathways for oxygen transport. The effect of straw, bark and newsprint mulches, lime and fertilizer applications on the establishment and growth of vegetation was determined on two surfaces mine sites in Western Pennsylvania, USA. Generally the response of vegetation to all treatments was better on the site with topsoil replacement than it was on the older site (Brenner, 1990). Bian et al. (1999) reported that appropriate pattern of covering soil, e.g. overall-covering and strip-covering effectively controlled acidic pollution of mine soil at Fan coal mine, China.
Results of a series of drainage trials set up to investigate various aspects of drainage design on opencast coal mining land of Hungary showed that secondary drainage was an essential type of field drainage reducing surface wetness and run-off from coal mined areas (Scullion and Mahammed, 1986). Shankar et al. (1993) suggested that the seepage water from the coal mined areas should be properly channelised to stop deterioration of soil quality in agricultural fields and low lying marginal land.

Although, studies have been done on environmental problems of coal mining of North East India in terms of water (Swer and Singh, 2003; Nath, 2004; Swer and Singh, 2004a, Swer and Singh, 2004b, Swer and Singh, 2004c, Swer and Singh, 2004d) and soil condition (Das Gupta et al., 2002; Sharma, 2003b; Semwal et al., 2004), no direct study has been done on agricultural impact of coal mining and its remediation in this region.