CHAPTER 1
INTRODUCTION

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 tonnes), 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 (De 1999). It is the major fuel used worldwide for generating electricity. It generates about 36% of the world electricity and provides around 27% of global primary energy need (Tiwary 2001). In India, coal provides 67% of the total energy consumption of the country. However, the mining wastes generated from active and inactive coal mining sites and from beneficiation activities, their impact on human health and the environment are a continuous problem for the governments, the private industry and the general public (Thomas 1994).

1.1 Coal production in India

Coal production in India has increased by about seven times in the past 40 years. In 1994, Indian coal reserves (proven) were estimated to be 68 billion tonnes against total 196.9 billion tonnes reserve. Of the total reserves 63% are within a depth of 300 m. 27% within the depth range of 300-600 m and 10% are beyond 600 m. Since a substantial percentage is within the depth of 300 m, there is an increased share of opencast technology for coal extraction.

The bulk of coal reserves are of non cooking coal with high ash content (20-30%) and low calorific value leaving only 15% as cooking coal and 12% as superior grade cooking coal. 90% of the country’s coal reserves are found in the central and the eastern parts of the country.

Nearly 50 coal fields, ranging in size from a few square kilometers to greater than 1500 square kilometers, have been found in India. Most occur in peninsular India in the quadrant bounded by 78° E longitude and 24°N latitude. Within the basins the number of coal seams ranges from as few as two or three up to 44 with total minable intervals of 0.5 to 160 m with the rank of coal varying from sub-bituminous to bituminous rank.

Coal mining by both opencast and underground method affects the environment of the area (Dhar 1993). 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 (Tiwary and Dhar, 1994). Sometimes, the water is acidic in nature and pollutes the water regime.

1.2 Waste generated from coal mining

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 facing by coal mining industry (Gray, 1996) 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 coal mines. When the minerals react with water and oxygen in the presence of bacteria through a series of reactions, sulphuric acid and iron hydroxide or iron sulphate are generated. Thus, all the sulphur present in the coal wastes as insoluble sulphate is converted to soluble form in the form of sulphuric acid. Chemolithotrophic bacteria like Thiobacillus ferroxidans or thiobacillus thioxidans oxidize Fe(II) at low pH and thereby increase the rate of the reaction several fold. These bacteria are also known to attach to solid ore surfaces and attack the sulphide mineral in coal directly (Chirstensen et al, 1996). The low values of pH result in further dissolution of minerals and the release of toxic metals and other contaminants into the water bodies. This can occur on the surface of pyritic waste dumps and stockpiles.

Pyrites often exist in association with other metallic elements such as As, Cd, Cu, Co, Pb, Hg, Zn (Monterroso and Macias, 1998). 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 enhances the concentration of these metals in the receiving water bodies and in many cases leads to the heavy metal toxicity (Nemerow, 1978).

In case of underground mines ground water infiltrates into the mines and come into contact of pyritic coal and thus form AMD. In the case of open cast mines groundwater, rain water and associated runoff into the pit may be acidic in nature. Several recent studies (Dragovich and Patterson, 1994; Banks et al., 1997a, b; Tiwary, 2001; Gray, 1997; Foos, 1997; Schuring et al., 1997; Younger, 1997) have reported the environmental consequences of the mine wastes. The process of acid generation may be described as follows (Singer and Stumm, 1970) –
FeS₂ + 3.5O₂ + H₂O → Fe²⁺ + 2SO₄²⁻ + 2H⁺

Bacteria

Fe²⁺ + 0.25 O₂ + H⁺ → Fe³⁺ + 0.5H₂O

Fe³⁺ + 3 H₂O → Fe(OH)₃ + 3 H⁺

FeS₂ + 14 Fe³⁺ + 8H₂O → 15Fe²⁺ + 2SO₄²⁻ + 16H⁺

At low pH (< 4.6) the chemical oxidation of pyrite is slow (Kirby and Brady, 1998) and the dominant process is the direct bacterial (e.g. thiobacillus ferrooxidans or thiobacillus thioxidans) metal sulphide oxidation (Ehrlich, 1996).

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 called yellowboy, that coats the bottom of stream and obstructs the biological activities (Tiwary 2001).

Waste piles created from open cast coal mining activities at the abandoned Makum and Dilli-Jaipur coalfields in Assam have exposed pyrite (FeS₂) to atmospheric conditions. This has led to the formation of yellowboy, acidification of the surface tailings and nearby drainage water which causes the increase in heavy metals concentration such as As, Cd, Cu, Co, Pb, Zn and Hg in the nearby water bodies and soil. Lower pH may harm aquatic organisms and it makes the water unfit for drinking. The high concentration of the heavy metals in water and soil has toxic effects upon the human beings, aquatic life, wild life and surrounding vegetation.

Black and Craw (2001) have found that very low pH (2 – 4) generated by AMD from the abandoned Wangalao coal mine in SE Otago; New Zealand in the receiving water has led to mobilization of As, Cu and Zn. Two rivers receiving the drainage from the Iberian Pyrite Belt in Spain have been found to have highly acidic water (pH 2.2 – 3.6) (Braungardt et al., 2003) and high concentration of metals like Cd, Co, Cu, Mn, and Zn (Achterberg et al., 2003; Braungardt et al., 2003).

Coal washeries contain suspended coal particulates and other impurities and are the major source of contamination of nearby surface water resources (Kelly, 1988). The coal washeries are produced when coal after mining is processed at preparation plants to remove impurities through crushing, screening, classifying and washing. The large quantity of water used for washing coal contains suspended coal as fine particulates along with other impurities. In mining area, surface runoff after rain may also cause serious
pollution problems. A variety of pollutants may be transported into water bodies by runoff. Sometimes rainfall may enter into the dumps and may dissolve some toxic metals from the heap and may contaminate the soil and water sources. If the dump contains pyretic wastes, the problem becomes more complicated. If the overburden dump material is piled up at the bank of the river, suspended particulate load in the surface water may increase.

The water used in domestic and sanitary purposes by the mining community may also cause pollution problem if not treated properly before discharge. It may contain detergents, suspended solids and organic matters.

In the case of opencast mines, a large numbers of mining machineries and vehicles are used regularly. Workshop effluents contain high amounts of oil and grease which are released during washing of the machineries. Sometimes spillage of oil and other toxic reagents do occur in these areas which ultimately affect the water regime.

1.3 Major pollutants from coal mining industry

The wastewater discharged from underground and open cast mines generally contain high level of TDS, TSS, Fe, Mn, heavy metals, hardness, Sulphate, Nitrate and Oil and grease. Mine water often consists of high levels of TSS in the range of 200 to 860 mg L$^{-1}$ (Tiwary 2001). TSS can diminish the light penetrating power of water and hence photosynthesis reactions and thus interfere with the self-purification capacity of water. TSS normally contains high amount of fine coal particles and makes water blackish and reduces the aesthetic values of receiving water bodies. In extreme cases, silt deposition can lead to the flooding and interfere with other biological activities. The origin of the heavy metals is the coal itself. High load of Fe is due to the presence of pyrite ore along with coal. Selenium is often present with coal. The dissolved cations include Ca, Mg, Na and K; and the anions sulphate, chloride, fluoride, nitrate, bicarbonate and carbonate. Thiosulphate and sulphur minerals may create environmental problems through their oxidation to acid in receiving waters. They originate from the dissolution of pyritic sulphur in the underground mines and are present in high concentration in the mine water and increase the hardness of water and reduce its utility in drinking purposes. Nitrates generally originate from explosives, which are used to blast the coal in the mines. It is found in pit water or waste rock from spilled or undetonated explosives or by leaching under wet blast condition. Nitrate ion factor from explosives account for about 85% of the total nitrogen released in mine drainage while ammonia accounts for the rest (Sobolewsky, 1998). Pb concentration
of the mining area may increases from transportation. Oil and grease are the workshop effluents released during washing of the machineries. Oil can form a thin film on the water surface and may interfere with the re-oxygenation of water, can coat the gills of fish and feathers of birds and is dangerous for aquatic ecosystem.

1.4 Importance of uncontaminated water and soil

Water is the basic need of all living things. The quality of water is of vital concern for mankind since it is directly linked with human welfare. The quality of water used by humans varies widely depending upon the purpose of uses. For human consumption, water must be free from chemical pollutants and microorganisms. Water having objectionable test or smell, colour, turbidity, is also not suitable for drinking purposes. Water contaminated with pathogens, bacteria, virus and parasites may cause diseases from mild gastro enteritis to severe and fatal dysentery, cholera, typhoid, hepatitis etc. Some naturally occurring bacteria may cause a verity of infections in the skin and in the mucous membranes of the eyes, ears, nose and throat.

The chemical contaminations do not cause immediate, acute health problems unless they are present in massive quantities through some accident. But they may be toxic to human health if people are exposed to even very small concentrations for a prolonged period. Some chemicals are carcinogens like As, Ba, Be, Hg, etc. High concentration of heavy metals may damage kidney, liver, lungs, heart, central nervous system, etc. High fluoride concentration may damage teeth and bone.

Soil also plays a very important role as it produces food for human beings and animals. Good soil and a congenial climate for productivity are valuable assets for any nation. But due to human activities, soil is the receptor of large quantities of waste products – industrial, domestic, human, animal, and agricultural. Rapid industrialization to speed up the economic growth is continuously degrading the environment through air, water and soil (Hodges 1973, Rajannan and Oblisami 1979, Slobe 1986). Soil can purify limited amount of contaminants and the excess amount of pollutants may get into the human food chain from the soil. Once they enter our biological system they disturb the biochemical processes leading in some cases to fatal result.

1.5 Water and soil contamination with industrial waste

The Industrial effluents as well as the solid wastes are the main sources of ground water and Soil pollution (Kisku et al., 1998, Bachewar and Mehta., 2000). For industrial
wastewater, the pollutant contribution depends on the following factors (Deshpande et al., 1999):

i) Various raw materials used
ii) Different processes adopted in manufacturing and processing
iii) Intermediate and final products
iv) Generation points of wastewater in processes
v) Efficiency of processes of manufacturing and treatment of effluent, and
vi) Types of equipment, machinery used in industry.

Besides these, transportation of raw-materials and products as well as workers is also an important factor of pollutant contribution.

Four types of pollutants may be generated from industry, viz.,

a) Physical pollutants like colour, odour, taste, temperature, turbidity and TSS,

b) Chemical pollutants e.g. pH, acidity, alkalinity, organic matter, oil and grease, hydrocarbons, fluoride, cyanide, penolic substances, sulphate, phosphate, nitrate, heavy metals like Fe, Hg, Pb, Cd, As, Se, Cu, Cr, Zn, etc.

c) Biological pollutants e.g. different microorganisms including various pathogenic bacteria,

d) Radioactive pollutants e.g. different radioactive compounds and elements like U, Ra, Rn, etc.

Besides these, sound pollution may be caused by different types of industries, which pollutes the surrounding area of the Industrial area.

In coal mining area, bacteria (e.g. thiobacillus ferroxidans or thiobacillus thioxidans) may act as biological catalyst and they can increase the rate of acid forming reaction producing large amount of sulphuric acid.

In industrial processes, pollutants or contaminants can reach the water body or soil by traveling along the three pathways,

i) Through drainage system. Industrial effluent or waste water draining from spoils and rubbish heaps may enter the water bodies and nearby soil. Soil may be polluted indirectly by the use of contaminated water in irrigation.
ii) Through the gaseous and particulate contaminants, emitted from chimneys which ultimately sink to the ground and enter the nearby water bodies with surface runoff.

iii) Through direct mechanical or gravitational deposition on the soil.

In any given contaminated situation, all three transportation modes may be involved (Brain, 1980). Some of the major pollutants, released to soil and water by a few industries are given in Table 1.1 (Kudesia 2000).

1.6 Pollution due to heavy metals and some trace metals

Water sources and soil near the coal mining area are rich in heavy metals. Dissolution of heavy metals from coal takes place at low pH in that area. The term heavy metal has been vigorously used to denote:

a) metals with atomic number 23 (i.e. Vanadium) onwards except Rb, Sr, Y, Cs, Ba, and Fr
b) Metals with N/P ratio of more than 1.5
c) Metals with density greater than 5 and
d) Metals which are toxic to man and other life forms when found in the environment

According to Environment Protection Agency (EPA), the eight most common heavy metal pollutants are As, Cd, Cr, Cu, Hg, Ni, Pb and Zn. Dubey (1985) had listed some heavy metals as very toxic like Ag, As, Au, Be, Bi, Cd, Co, Cr, Cu, Hg, Ni, Pb, Pt, Sb, Se, Sn, Te, Tl and Zn.

Though some heavy metals are necessary for human growth and development, in higher concentration they cause adverse effects on human health. The ecological problem of water and soil contamination with toxic heavy metals is of extreme importance in the present global scenario. The contamination of soil with heavy metals from sewage can potentially result in phytotoxicity (Chaney et al, 1978). In general, heavy metals attack the active sites of enzymes inhibiting essential enzyme function. Heavy metal ions particularly Hg$^{+2}$, Pb$^{+2}$ and Cd$^{+2}$ act as effective enzyme inhibitors. They can break the sulphur hydrogen bonds of enzymes. Toxic effects of some heavy metals and trace metals are as follows:
Table 1.1. Pollutants released by a few industries to soil and water

<table>
<thead>
<tr>
<th>S/N</th>
<th>Industry</th>
<th>Major pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coal</td>
<td>Low pH, TDS, TSS, SO$_4^{2-}$, Cl$^-$, NO$_3^-$, Fe, Hardness, Heavy metals like As, Cd, Cu, Pb, Hg, Mn, Se, Be, B and Oil and grease.</td>
</tr>
<tr>
<td>2</td>
<td>Pulp and paper</td>
<td>Colour, High pH, BOD and COD, sodium salts, organic matter, lignosulphates, trace metals like Hg, Pb, etc.</td>
</tr>
<tr>
<td>3</td>
<td>Fertilizer</td>
<td>High F$^-$, PO$_4^{3-}$, trace metals like Pb, Cd and As, NO$_3^-$, CaSO$_4$.</td>
</tr>
<tr>
<td>4</td>
<td>Diary products</td>
<td>Colloidal solid, mainly proteins, acids, alkalis, fats, high BOD, oil and grease</td>
</tr>
<tr>
<td>5</td>
<td>Textiles</td>
<td>Organic matter, colour, fats, oil, mineral acids, etc.</td>
</tr>
<tr>
<td>6</td>
<td>Tanneries</td>
<td>Colour, dissolved solids, suspended solids, Ca, Cr and SO$_4^{2-}$.</td>
</tr>
<tr>
<td>7</td>
<td>Distilleries</td>
<td>Colour, dissolved and suspended solids containing K and N, high BOD, Organic matter, SO$_4^{2-}$.</td>
</tr>
<tr>
<td>8</td>
<td>Rubber industry</td>
<td>Dissolved solids, suspended solids high BOD, grease, C, Zn, Cl$^-$, SO$_4^{2-}$.</td>
</tr>
<tr>
<td>9</td>
<td>Dyestuffs</td>
<td>Colour, NaOH, KOH.</td>
</tr>
<tr>
<td>10</td>
<td>Metal plating</td>
<td>Low pH, Cyanides, Al, Cd, Cr, Cu, Zn</td>
</tr>
<tr>
<td>11</td>
<td>Thermal power plant</td>
<td>Heavy metals, Inorganic compounds.</td>
</tr>
<tr>
<td>12</td>
<td>Galvanizing industry</td>
<td>Zn</td>
</tr>
<tr>
<td>13</td>
<td>Paint industry</td>
<td>Pb.</td>
</tr>
</tbody>
</table>
Arsenic (As). Among the compounds of As, As (III) is the most toxic. It attacks the SH groups of an enzyme, thereby inhibiting enzyme action. The enzymes which generate cellular energy in the citric acid cycle are adversely affected. It interferes with some biochemical processes involving phosphorous due to its chemical similarity to Phosphorous. At high concentrations, As can coagulate proteins. Three major biochemical actions of As are coagulation of proteins, complexation with co-enzymes and uncoupling phosphorylation.

Aluminium (Al). It is the second most abundant element in the earth’s crust. Low level of Al in food and drinks are non toxic but high level is toxic. It may cause phosphate depletion through the formation of insoluble AlPO$_4$. Al content in human plasma from 0.005 to 0.25 ppm leads to osteodystrophy, an adverse neurological condition affecting speech and memory, eventually leading to dementia. Among the harmful affects of Al, constipation and the neurotoxicity are not ruled out.

Cadmium (Cd). It is a non essential, non beneficial and very poisonous metal even at extremely low concentration. Once ingested, it is transported to all parts of the body through the blood stream. The high concentration of Cd is found in the liver and kidney. Cd may cause a disease Itai-Itai, where bones become fragile. At high levels, it causes kidney problems, anemia and bone marrow disorders caused by disruption of calcium phosphorous balance in the renal tube. Cd is a cumulative poison. Ingestion of small amount over the years may lead to the accumulation of chronically or even acutely toxic levels of Cd in our body (Laws, 1993). It replaces Zinc biochemically causing metabolic disorders. In plants, root growth is reduced due to cadmium toxicity (Dosskey and Adriano, 1993).

Cobalt (Co). Limited amount of cobalt is essential to human body. Co (II) is an enzyme activator (Forstner et al., 1984) and it is present in vitamin B$_{12}$ complex. It is found as +2 and +3 oxidation states in the earth’s crust but the dominant form is the +2 state in soil solution. This metal associates preferentially with Fe and Mn oxides because of chemisorption and co-precipitation. Solubility of cobalt decreases as the pH of soil increases because of increased chemisorption by organic matter and possible precipitation of Co (OH)$_2$. Co is considered to be somewhat mobile in acid soils. Excess amount of cobalt has toxic effect in humans and other animals. It affects the thyroid gland, heart and
kidneys. It may also cause lung diseases, allergic manifestations, etc. The concentration of Co in the soil of the different climatic zones may vary from 0.05 to 200-300 ppm (Aubert et al., 1980).

**Chromium (Cr).** Cr is the fourth abundant element among 29 elements of biological importance from the essential and toxic perspectives. It exists in three main forms Cr (0), Cr (III) and Cr (VI). Cr (III) is an essential nutrient for our body which helps in maintaining normal metabolism of glucose, cholesterol and fat. Cr (VI) is the most toxic form among the three. It can produce irritation of the skin and respiratory tract, dermatitis, perforation of the nasal septum, ulcers and cancer of the respiratory tract. The toxic effect depends on the solubility and concentration. Since Cr is a naturally occurring element in abundance, hence river water is considered as one of the main source through which chromium makes way into the body.

**Copper (Cu).** Cu is an essential heavy metal for living systems. Soil with less than 8 ppm of Cu may be deficient for crops. Several Cu containing proteins have been identified in the biological system. Hemocyanin is a Cu containing protein found in Snails and Crabs. Plastocyanin contains blue copper and can help in electron transfer. Ceruloplasmin is a blue protein present in mammalian serum. It helps in RBC formation, development of bones and connective tissues. Beyond permissible limit, Cu causes many diseases like oliguria, haematuria, albueminuria, uremia, kidney damage, paralysis of limbs followed by drowsiness, coma and even sometime death. Symptoms start with metallic taste, increased salivation and burning pain in the stomach. Cu toxicity increases in the presence of Ca and Mn (Mathias and Cumming, 1973). In aquatic systems, the toxicity of Cu also depends upon some factors like total hardness, pH, etc. (Dixit and Witcomb, 1983). Cu can form complexes with humic acids (Srivastava, 1995), which may deposit on the sediment and may affect plant growth. The high concentration of Cu in drinking water is toxic to humans and causes hypertension and effects on brain tissues (Sharma et al., 1988).

**Iron (Fe).** Fe may be introduced from different industrial activities. In water and soil, Fe exists as Fe (II) and Fe (III). Some amount of Fe is essential for human health, since it is the most important component of many heme and non heme enzymes (Huheey, 2002) of human body. High amount of Fe has adverse effects on humans or animals. It is proved that the metal iron precipitates on the mucous secretion of the gills. Subsequently
respiration is arrested in fish. It is a micronutrient necessary for maintenance of chlorophyll in plants. It also takes an important part in oxidation reduction reactions in the plants. Water having large amount of Fe can not be used in domestic purposes. Excess amount of Fe causes staining of cloths and utensils. It interacts with the tannins of tea and coffee to produce a black inky appearance with metallic taste. Potatoes also turn black on boiling in water containing large amount of Fe. It may also cause vomiting.

**Mercury (Hg).** Elemental Hg is fairly inert and non toxic. It is excreted without serious damage if swallowed, but the vapour of Hg is quite toxic. It enters the brain through the blood stream, leading to severe damage of the central nervous system. Hg in the form of Hg^{+2} is non toxic but Hg^{+2} is fairly toxic, due to its high affinity for sulphur atoms. It can easily attach itself to the Sulphur containing amino acids of proteins. It also forms bonds with hemoglobin and serum albumin. The most toxic species of Hg is CH_{3}Hg^{+}, which is soluble in fat, the liquid fraction of membranes and brain tissue. The covalent Hg-C bond is not easily disrupted and CH_{3}Hg^{+} is retained in cells for prolonged period of time. It can move through the placental barrier and enter fetal tissues. Hg inhibits active transport of sugars across the membranes and allows the passage of K to the membrane. CH_{3}Hg^{+} leads to segregation of chromosomes, chromosome breakage in cells and inhibit cell division. All the symptoms of Hg poisoning is seen in blood levels of 0.5 ppm of CH_{3}Hg^{+}. The EPA has recognized mercuric chloride and methyl mercury as possible human carcinogens.

**Manganese (Mn).** Mn has three possible oxidation states in soils, +2, +3 and +4. Mn^{+2} is the only stable form in soil solution and natural water (Ramteke and Moghe, 1986; Trivedy and Goel, 1984). It is an essential element for most of the organisms. Plants require Mn in the process of photosynthesis (Huheey, 2002). It involves in glucose utilization (Forstner and Wittmann, 1983). Large amount of Mn may results in pneumonitis (Manivasakam, 1987), which affects the central nervous system (Meena et al, 1969). Above 0.15 ppm, Mn in water stains plumbing fixtures and laundry. At higher concentration it causes an undesirable taste to beverages. Mn toxicity is often observed in acid soil. Low pH favors the reduction of insoluble Mn Oxides and an increased solubility of Mn^{+2}, which is toxic to plants. As a result, Mn solubility within any particular soil can fluctuate tremendously over time, sometimes ranging from deficient to toxic levels. Mn toxicity is a serious threat to human health. It causes akinesia, trembling hands, emotion instability, bronco and lobar pneumonia, insomnia, etc. Another disease called sclerosis amyotrophic lateralis, which is
reported from Japan has been linked to high Mn content in soil and food chain (Mohammed et al., 1995).

**Nickel (Ni).** Ni is an essential heavy metal present in natural water in trace quantity. It is considered as a borderline element between hard and soft acid acceptors in chemical interactions towards donor atoms. The $+2$ oxidation state is the only stable form of Ni in soil environments. Solubility of Ni decreases markedly at higher pH, rated as medium in acid soils, becomes very low in neutral to alkaline solution. Toxicity of Ni to plants is found in acid soil. Ni is a strongly phytotoxic element, being several times more toxic than copper. It occurs commonly in industrial wastes at appreciable level and may reach level toxic to plants in waste treated soil. From soil, natural water is also affected. The common adverse health effect of Ni in human is an allergic reaction. It may affect muscle, brain, lungs, liver, and kidney and may also cause cancer (Datar and Vashistha, 1990). Nickel carbonyl is the most toxic compound of nickel.

**Lead (Pb).** Pb is a non essential toxic element to plant and animals. Pb is the most extensively studied heavy metal due to its probable adverse effect on nervous system and other parts of our body (Nriagu, 1988). After the accumulation of Pb, it is released very slowly from our body; hence poisoning effect can occur without exposure to major doses. It is reported that Pb is a cumulative polytrophic poison which acts on central and peripheral nervous system (Kehoe, 1969). It enters the human body by inhalation or through the ingestion of contaminated food and water. Lungs retain Pb more efficiently than the gastro-intestinal tract. From our blood stream, it is transported to all parts of the body primarily by the red blood cells, though its incorporation into tissues apparently occurs through the blood plasma. It is distributed to liver and kidney within a few hours and ultimately about 90% of the inorganic Pb in the body is deposited in the bones where it replaces calcium. Organic Pb does not accumulate in the bones but tends to concentrate in the lipid tissues, including those of central nervous system. In brain and liver, concentration of Pb is often high. Pb is considering as one of the most serious neuro-toxins in the environment due to its widespread subtle and insidious impact on man. Even at low levels, it causes hypertension, anger, depression, impaired memory, and high blood pressure and IQ loss in children. It has been reported that there is a finier relationship between blood Pb level and hypertension in adults (Herlan et al., 1985; Pirkle et al., 1985). In soil, Pb exists mainly in $+2$ oxidation state. It is the least mobile heavy metal in soil,
especially under reducing or non-acid condition. It generally enters the soil through the automobile exhaust and mining activities. The major biochemical effect of Pb is its interference with heme synthesis, leading to hematological damage. It inhibits several of the key enzymes involved in the overall process of heme synthesis.

**Selenium (Se).** Se enters air from burning coal or oil. Much of the selenium in air is attached to fly ash and to suspended particles. The elemental Se that may be present in fossil fuels forms selenium dioxide when burned. Selenium dioxide can then form selenious acid with water. Selenium compounds that dissolve in water are very mobile. Water containing selenium may seep from abandoned-coal-mining areas into groundwater, or into rivers or streams. This can eventually enter into drinking water systems. About 150,000–460,000 tons of selenium per year are deposited in coal fly ash (Andren and Klein 1975; Doran 1982). Selenium from fly ash settling ponds and hazardous waste sites could reach surface water via runoff or could reach groundwater via leaching. In humans and animals, selenium is an essential nutrient that plays a role in protecting tissues from oxidative damage as a component of glutathione peroxidase. But inadequate and excessive selenium intake can cause adverse health effects. Selenium deficiency has been associated with two endemic diseases found in selenium-poor regions of China: a cardiovascular condition characterized by cardiac enlargement, abnormal ECG patterns, cardiogenic shock, and congestive heart failure, with multifocal necrosis of the myocardium. The other disease is characterized by atrophy, degeneration, and necrosis of cartilage tissue, and occurs primarily in children between the ages of 5 and 13 years. Less than 1% of the daily intake of selenium is estimated to come from drinking water. The seriousness of the effects of excess selenium depends on how much selenium is eaten and how often. Intentional or accidental swallowing of a large amount of sodium selenate or sodium selenite could be life-threatening. Even if mildly excessive amounts of selenium are eaten over long periods, brittle hair and deformed nails can develop. In extreme cases, people may lose feeling and control in arms and legs. These health effects, called selenosis, are seen in villages in China where people are exposed to foods high in selenium for months to years.

**Tin (Sn)**

**Vanadium (V).** In soil solution, V exists predominantly in the +5 and +4 oxidation states. At low pH, it is likely that vanadate anions bound on oxide and silicates most effectively...
following the pattern of phosphate and many other oxy anions. Consequently, V solubility should be quite high at high pH, but lower if the soil is more acidic. The mobility of V under reducing or acid conditions is probably moderate to low.

**Zinc (Zn).** It is an essential trace metal in human body. It is essential for the normal activity of DNA polymerized and for protein synthesis. Above desirable limit, it may be toxic, especially to the aquatic biota (Nriagu, 1980). Excess amount of Zn can cause stomach cramps, nausea, vomiting, central nervous system disturbances, dyspepsia, digestive problems, colic with constipation, paralysis etc. In soil +2 oxidation states is the only one possible state and does not undergo reduction reaction in nature due to its electropositive nature (Krauskopf, 1972). Under acidic oxidizing condition, Zn$^{+2}$ is one of the most soluble and mobile of the trace metal cations. At low pH it does not complex tightly with organic matter. Acid-leached soils often have Zn deficiency because of depletion of this element in the surface layer. Toxicity of Zn to plants is most likely to appear in acidic soils that have not been subjected to prolonged acid leaching.

### 1.7 Fate of solid wastes and contaminants in effluents

All types of industries produce different types of solid wastes and waste water. Disposal of solid waste has now become a challenging problem for the environmentalist (Aurangabadkar et al. 2001). Improper and inadequate disposal method of wastes can cause serious health hazards even leading to death. At Minamata Bay in Japan in 1953-60 more than 100 people lost their lives and many thousands were permanently paralyzed from eating mercury contaminated fish. The source of Hg was the effluent discharged into the Bay from a vinyl chloride plant, Minamata Chemical Company. Hg was deposited on the bottom of the Bay and remained there since 1950s. In the mid 1970, another disaster occurred in Hopewell known as Kepone case. Kepone is an insecticide, used to kill tobacco wire worm, ants and cockroaches. It is a very toxic compound and may cause cancer. The plant was connected to the Hopewell sewage system as a result of which many fish and aquatic animals died in this case. The plant had to be closed. A number of other incidents have been reported where leachates have contaminated the surrounding soil and ground water (Nicholson et al. 1983, Jaroslave. 1985, Vogl et al. 1985; Belevi and Baccini 1992).

In case of coal mining, suspended particles may pollute the environment. Coal contains pyrite ore along with it and thereby increases the Fe, Sulphide and Sulphate content in nearby water and soil. It also contains minerals like Cu, Mg, etc. (Golden 1983, Theis and
Gardner 1990) and trace elements like Ba, Cu, Mo, Be, Cd, Pb, Zn, Hg, etc. (Klein et al., 1975, Fulekar 1993). Several recent studies have been reported by a number of scientists on the effect of industrial effluent on water and soil (Dutta and Mookherjee 1980, Ruby 1997, Warrin et al. 1971). The effluents that are dumped on the ground ultimately reach the ground water and thus pollute it (Saether et al., 1997). The polluted water is not suitable for drinking or other domestic uses. Even this type of water cannot be use for irrigation. It has been widely reported that effluent irrigation adversely affects the soil system and thus the growth of plants (Anand et al. 1969, Karande et al. 1993, Madhappan 1993, Rao et al. 1993). The leaching of liquid waste through the soil changes the fertility of the soil and thus it becomes unsafe for agriculture (Chandekar et al. 1996, Inamul 1998).

1.8 Pollution studies on water and soil system

The growth of literature and data based on water and soil qualities have been really tremendous during the last few decades throughout the world. Internationally many reports are there on studies of soil and water systems. Only a few examples are given here. Vesely et al. (1998) have studied the water chemistry of acidified Bohemian Lakes from 1984 to 1995. Brass (2000) has studied the drinking water standards program in the United States. Nicole et al. (2001) have studied the concentration of some heavy metals in the Rain and Stream water of two contrasting watersheds in Western Maryland. Al-Awadi et al. (2002) have studied the presence of trace constituents in the ground water of Kuwait. Jurdi et al. (2002) have reported the water quality of the Qaraoun reservoir of Lebanon. Lee et al. (2003) have studied the water quality and heavy metals in the bed and suspended sediments of Anyang River, Korea. Rodriguez et al. (2003) have reported the variation of Arsenic in the ground water in the aquifer system of Zimapan Valley. Casper et al. (2003) have reported the contamination of surface soils, river water and sediments by trace metals from copper processing industry in the Churnet River Valley, Staffordshire, U.K. A few other notable studies are: Charlatchka and Cambier (2000), Neal et al. (2000), Cooper and Gillespie (2000), Foust et al. (2003).

1.9 Review of the literature on Coal mining area

Worldwide study has also been observed on the water and soil quality of coal mining areas of different coal fields. Sharma and Ram (1993) have reported some data about coal in, Introduction to geology of Coal and Indian coalfields. Thomas et al. (1994) have focused some problems of mining wastes. Rybicka, (1996) have studied the impact of mining in Poland.; Friese et al. (1998) have studied the biochemistry of Fe and S in sediments of an acidic mining lake in Lusatia, Germany.; Buttner et al. (1998) have reported the geochemistry of surface sediments in an acidic mining lake.; Dharmappa et al. (2000) have worked on the application of cleaner production principle in the coal mining industry. Chemical evolution of coal mine drainage in a non acid producing environment in Wasatch Plateau, Utah, USA, was also studied by Mayo et al. (2000). Ernest et al. (2000) have worked to control acid drainage in a Pyritic mine waste rock. Zabowski et al. (2001) have studied the impact of mining on trace metal content of water, soil and stream sediments in the Hei River basin, China; Black and Craw (2001) have reported the occurrence of As, Cu and Zn at the Wangaloa coal mine, southeast Otago, New Zealand. Peplow and Edmonds (2003) have worked on the health risk associated with the contaminated ground water by abandoned mines near Twisp in Okanogan Country, Washington, USA.. Douglas et al. (2003) have reported the changes of water quality due to abandoned underground coal mines in Uniontown Syncline, USA.; Charlotte et al. (2003) have studied the metal geochemistry in a mine polluted estuarine system in Spain.

However, despite the Assam coalfields being in operation for a very long time, only a few reports are found here and there. Ghosh et al. (1994) have mentioned some data with respect to Hg content of Assam coal. Tiwary (2001) worked on the impact of coal mining on the water regime of Assam including the Northeast coalfield area. It was therefore proposed to undertake this study with the following principal objectives.

1.10. Objectives of the present study

The following objectives have been considered while undertaking the present work:

1) To collect water samples from different sources of water like river, rivulet, pond, well, tube well and municipal supply water in the coalfield area.
2) To collect soil samples from paddy field and other areas and from bed sediments of water bodies likely to have received effluents from the coalfields.
3) The physicochemical characterization of water and soil samples.
4) To find out the heavy metal concentration of water and soil samples.
5) To carry out metal speciation of certain significant heavy metals in soil samples for identifying the chemical forms in which the metals are present.
6) To find out the soil composition as oxides and to determine the minerals present in clay.
7) Evaluation of the overall impact of the mining operations on water and soil by statistical computations and other means from the collected data.
8) 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.
9) To suggest ways for remediation measures and damage control.

It was proposed to utilize the generated data to find out the various statistical intra and inter relations among the parameters. Data will be used to establish the role of different parameters towards mobility and to find out the station-wise and season-wise variation of concentration of different geochemical parameters.