CHAPTER I

GENERAL INTRODUCTION
1.1 INTRODUCTION

Human invasion on natural resources for the advancement in the quality of life has posed several environmental challenges to the society. Constructive approach to these challenges is not to minimize technological innovations; it is rather minimizing environmental hazards, leading to an eco friendly life i.e. conserving natural resources so that their essence is also experienced by future generations. Increasing pressure from natural and anthropogenic activities threaten the naturality and aesthetic quality of our environment.

Vast areas of land throughout the world are rendered unproductive by human activities (Choi and Wali, 1995). The situation is particularly alarming in tropical areas where forest loss and degradation, as well as degradation of land that earlier supported forest, are proceeding at unprecedented rates (Parrota et al., 1997). Ecosystem destruction by mining, quarrying for minerals, and other processes to meet demands of industries, is an inevitable part of civilization (Bradshaw, 1983). The necessity of these mineral resources accelerates further degradation of natural habitats, as forests previously occupy most mines, leads to loss of biological diversity and creates several other environmental problems (Singh et al., 2002).
Mining operations, disposal of mine tailings, mine water etc are serious sources of environmental contamination to the surrounding environment (Adriano, 1986; Larsen et al., 2001; Armienta et al., 2003; Ali et al., 2004). Apart from the local disturbance of the soil profile and structure, a more widespread contamination of soils, vegetation and water courses by toxic metals can trigger (Wilmoth et al., 1991). The magnitude and significance of environmental pollution caused by mining depends on the type of minerals, method of mining and beneficiation, processing plants and concentration of mining activities, geological features of the area etc. Removal of large quantities of material from mining sites and deposition of waste can drastically alter the physical characteristics of the area including topography, hydrology, vegetative cover, wildlife habitat and susceptibility to erosion. The direct effect is loss of cultivated land, forest or grazing land, and the overall loss of production (Wang et al., 2003). The indirect effects include air, water pollution and siltation of water body. This eventually leads to the loss of biodiversity, amenity and economic wealth. As a result of mining, significant areas of land are degraded and existing ecosystems are replaced by undesirable waste materials in the form of dumps, tailing dams and ash dams (Piha et al., 1995). The mineral extraction process drastically alters the physical and biological nature of a mined area, destroys vegetation, causes extensive soil destruction and alters microbial communities (Corbett et al., 1996). In the process of removing desired mineral material, the original vegetation is inevitably destroyed and soil is lost or buried by waste (Bradshaw, 1997). On the freshly excavated dumps, which serve as a new substrate for plants comprise of various mixtures of topsoil and substrate rock. The fresh unweathered rocks that are brought to the surface, may release elements to the soil in
greater concentrations, than existed in original soil and therefore may affect the growth of plants (Ebens and Shacklett, 1982).

Similarly, mining and related activities cause drastic perturbation to terrestrial ecosystems, leading to severe soil degradation. Consequently, there is a severe loss of soil organic carbon (SOC) by soil disturbance through mining operations, due to enhanced mineralization, erosion, and leaching (Lal et al., 1998). Mining causes compaction, changes in soil texture, loss of soil structure and reduced water infiltration. In addition, steep sided soil piles are prone to erosion (Grunwald et al., 1988). Unreclaimed or poorly reclaimed lands are often barren, as problematic soil material left on the surface after mining does not support plant growth. This creates problems, as waste dumps are unsightly and subject to erosion and leaching if left unvegetated. Under these circumstances, extreme degradation easily spreads beyond the disposal site. This necessitates initiation of restoration of the degraded environment.

Mining is one of the primary sources of metal pollution and environmental degradation (Kabata-Pendias and Pendias, 1989). Mining and consequent environmental pollution through trace elements disturbs ecological balance and enhances the biosphere degradation. Mineral utilization by humans mainly causes trace element pollution and is of ecological, biological and health significance. As mine wastes weather, they release acid rock drainage into ground and surface waters, polluting them imparting acidity, toxic elements, and salinity (Ernst, 1988; Pentreath, 1994). Many ores that are rich in metals consist of sulfide minerals, form stable sulfide complexes with heavy metals (Schnoor, 1996). However, if sulfides (e.g., pyrite) interact with atmospheric oxygen and water, sulfuric acid is formed. In addition, if other sulfides are oxidized, metals are released (Holstrom, 2000). Thus,
acid elements drain from the site and spread into the environment. Mine tailings or waste possesses enormous levels of trace or heavy metals which pose environmental hazards in mining areas (Simon, 2005; Lee et al., 2005; Kim et al., 2005; Li et al., 2006; Pandey et al., 2007). These elevated metal levels can be found in and around metalliferous mines due to discharge and dispersion of mine wastes into the nearby agricultural soils, food crops etc (Thornton, 1995; Jung and Thornton, 1996; Kim et al., 1998; Steinborn and Breen, 1999; Kim et al., 2002; Aslibekian and Moles, 2003). Eventually they may pose a potential health risk in the vicinity of mining areas (Jung, 2001).

Environmental degradation has an impact not only on human beings but also on all species and most natural systems. Mining processes such as crushing, grinding, washing, smelting etc. used to extract and concentrate metals generate a large amount of waste rocks and tailing, are often unstable and make elements environmentally mobile through normal biogeochemical pathways, to sink, such as sediments, soils or biomass (Davies, 1980; Davies, 1983).

Indeed, metal ions are essential all across the kingdoms of life, but their role in biology is ambiguous: small amounts of metals like iron, manganese, zinc, copper and nickel are essential. However, serious damage occurs when any heavy metal is accumulated in excess or distributed incorrectly within an organism. Therefore all life forms possess a tightly knit and intricately regulated network of metals.

The term trace element is widely used and designates elements occurring in natural system in minute concentrations. It is a general consensus that an element is considered trace in natural materials when present at levels less than 0.1%. Trace elements occur in natural and perturbed ecosystems in small amounts and that when present in
sufficient concentration are toxic to living organisms. Synonymous terms such as trace metals, heavy metals, micronutrients, micro elements, minor elements and trace inorganics may also be used. The use of micro nutrients is usually applied to those elements required by higher plants (Zn, Mn, Cu, Fe, Mo, B). The term heavy metal is usually referred to elements having densities greater than 5.0 (Ramesh and Anbu, 1996).

Trace elements though present at very low concentrations have a potential function in life and can influence environment or the food chain (Cornells, 2002). The mobility, bioavailability, storage, retention and toxicity of trace elements in living systems, food and the environment depends on the chemical form in a system and the final form in which it is present. The form, or species, clearly governs its biochemical and geochemical behaviour. It is also possible that an element is leached into the environment at low concentrations but can cause toxicity at greater concentrations. The element may subsequently be transformed into one or more toxic forms through the intermediary of living organisms at the bottom of the food chain, only to reach dangerously toxic levels in the top predators. The chemical form of the element is decisive for the short term and long term injuries they may inflict. Therefore the detection of the trace elements and representative sampling from natural environments is indeed a significant task.

Heavy metal pollution by mining is widespread and poses a threat to drinking water resources, food chain safety and air quality. The clean up of metal polluted soils is thus of great interest economically as well as for the protection of human and environmental health. It is a daunting task to explore plant species that accumulate metals specifically in their tissues while thriving on metal polluted soils. This could serve as a basis for the development of new plant based and cost effective technologies for cleanup or stabilization of metal contaminated
As plants are sedentary or immobile, they efficiently compartmentalize toxic metals into plant tissues and organelles of cell where damage due to their accumulation is least. However certain metal tolerant plant species growing on metal enriched soils markedly concentrate metals in their tissues (Baker, 1981; Brooks, 1987). Plant species endemic to metalliferous soils accumulate metals at extraordinarily high levels (>1% and upto 10%) in contrast to normal plant concentrations. These plants, termed hyperaccumulators, contain in excess of 1000 mg g⁻¹ (dry weight) of metal for Ni, Cu, Co, Cr, Pb, or 10,000 mg g⁻¹ for Zn or Mn (Baker and Brooks, 1989). Vegetation plays a crucial role in the restoration of such degraded areas, as it prevents wind blow of contaminated particles and reduces water pollution (Tordoff et al., 2000). Nevertheless, trace element uptake by plants implies several hazards such as introduction into the food chain (McLaughin, 2001). Thus, a study of soil properties and vegetation development is necessary to evaluate the effectiveness of remediation measures on ecosystem ecology and risk posed by the trace element content of a soil. Establishment of vegetation cover can fulfill the objectives of stabilization, pollution control, visual improvement and removal of threats to human beings (Freitas et al., 2004).

Barite mining operations at Mangampeta affect precious natural ecosystems. Though mining of barites is associated with Mangampeta since 1975, scarce information is generated on its ecological impacts. The most potential hazard is the contamination of trace metals, as the area is more mineralized. Trace metals are associated with barite bearing rocks, which enter the nearby environment and adversely affect them (Sirish Chandra, 2000). The biota and the waters of the area are vulnerable to mining hazards. Many involve long term and cumulative impacts on the ecosystems.
Mining produces tremendous volumes of waste rock and tailings, which introduce high concentrations of acids, sulfate and metal into groundwater. Unless waste sites are protected from oxidation and metal release, these sites represent a source of serious contamination to groundwater for potentially several years affecting the nutrient cycles in the aquifers and ultimately the hydrological cycle. In addition the groundwater entering the open cast mine, where the actual mining is in progress is of prime concern. This water experiences interaction with metal enriched substrate, which is constantly pumped through pipelines and percolates through narrow channels and finally gets stored in the form of artificial tanks. These tanks possibly recharge the groundwater aquifers within the mining region and threaten ground water resources. This enhances the migration of contaminants to different provinces within the aquifers. In addition, these tanks are frequently exposed to the particulate matter generated due to transportation of mine tailings after the refining processes. Hence there is a need to understand the relationship between mining activities and environmental problems in detail for their management.

In this context to be aware of the increasing complexity of environmental degradation and as a system of considerable conservation value, terrestrial and aquatic ecosystems at Mangampeta barite mining area and surrounding virgin area have been investigated. However since ancient times man has been well familiar with the importance of plant cover as an indicator of ecological or hydrological or mineral purposes. Varahamihira (505–587 A.D.), the great Indian astrologer, astronomer and mathematician has described in 125 slokas (verses) several features of vegetation, termite mounds, soil and rocks that may help in locating groundwater sources and mineral deposits (Biswas, 2006). The present
investigative work comprised the assessment of physical and textural properties along with the trace element distribution in termite mound; in addition the chemical constituents in groundwater of the mining and non-mining areas have also been assessed. Apart from these, the phytochemistry of trace elements in plant and soil ecosystems has been investigated. The distribution of species over the earth’s surface has some correlation with the elemental contents present hidden beneath the earth’s crust. The biological method for prospecting minerals involves visual survey of the vegetation to detect the presence of minerals by observing plant distribution, the presence of indicator plants and morphological or mutational changes caused by the presence or excess quantity of certain elements in the substrate (Brooks, 1972). The metals are commonly determined to monitor the pollution levels in both environmental and biological matrices such as plants, foods, vegetables, fruit, and other similar samples (Yaman, 2000; Divrikli et al., 2003). Environmental monitoring programs are common tools to control pollution in a particular area (Morselli et al., 2002; Chang et al., 2003). These programs assess the contribution of a potential contaminant source on the environment. As they are easily collected and stored, soil and vegetation are standardized environmental monitors (Moraes et al., 2002; Klumpp et al., 2003). Soil and vegetation are widely used as cumulative matrices of long term and short term exposure, respectively, to environmental pollutants (Domingo et al., 2001; Schuhmacher et al., 2003; Nadal et al., 2004).

1.2 Introduction to Barites

Barite (BaSO₄) is the mineral name of barium sulphate and was derived from the Greek word barus meaning heavy. Barium sulphate is the most important barium compound and the mineral barite, also called
heavy spar or barite, is by far the most important barite mineral. It is generally white to light grey, relatively soft mineral with a specific gravity of 4.5 g/cm³. Barite occurs in veins, in association with sedimentary rocks, and as concretions. The spiralling oil prices and the unsteady oil market, during the early seventies resulted in the search and exploration for oil and allied raw materials like barites all over the world. The principal use of barite is to add weight to drilling muds in oil and gas exploration. Other uses include chemical manufacture, in fillers and extenders, glass making etc.

Barite is a common mineral and makes very attractive specimens. It is often an accessory mineral to other minerals and makes a nice backdrop to brightly colored crystals. At times bladed or tabular crystals of barite form a concentric pattern of increasingly larger crystals outward. This has the appearance of a flower and when colored red by iron stains, these formations are called Desert Roses. As barite is very common, it is confused for other minerals. Celestite (SrSO₄) has the same structure as barite and forms very similar crystals. The two are indistinguishable by ordinary methods, but a flame test can distinguish them. By scrapping the dust of the crystals into a gas flame the color of the flame confirms the identity of the crystal. When the flame is pale green it is barite and when it is red it is celestite.

1.2.1 Physical Characteristics

Color is variable, colorless or white is common and also occur as blue, green, yellow and red shades.
Luster is vitreous.
Transparency crystals are transparent to translucent.
Crystal System is orthorhombic; 2/m 2/m 2/m
Crystal Habits include the bladed crystals dominated by two large pinacoid faces top and bottom, small prism faces forming a jutting angle on every side. There are many variations of these faces, but the flattened blades and tabular crystals are the most common. If the pinacoid faces become diminished or are absent, the resulting prismatic crystal has a rhombic cross section. Also scaly, lamellar, and even fiberous. Cleavage is perfect in one direction, less so in another direction. Fracture is conchoidal. Hardness is 3 - 3.5. Specific Gravity is approximately 4.5 (heavy for translucent minerals) Streak is white. Associated Minerals are numerous but significant associations are with chalcopyrite, calcite, aragonite, sulfur, pyrite, quartz, vanadinite, cerussite and fluorite among many others.

1.2.2 Release Patterns

Barium metal does not occur free in nature. The most common ores are barite (sulphate) and witherite (carbonate). Barium is released into water and soil by different sources, during the discharge and disposal of drilling wastes, from the smelting of copper, and the manufacture of motor vehicle parts and accessories. Barium enters the atmosphere mainly from mining, refining, and production of barium and barium based chemicals, and as a result of combustion of coal and oil.

1.2.3 Environmental Fate

In water, the more toxic soluble barium salts are likely to precipitate out as the less toxic insoluble sulphate or carbonate. Barium is less mobile in most soil systems. Adsorption of barium is observed in sandy and sandy loam soil at levels closely corresponding to those to be
expected for field conditions. In general, sludge solutions increase the mobility of elements in soil. This could be due to complexation of dissolved organic compounds, high background concentration and high ionic strengths of the soil solution.

1.3 Mangampeta – Study area

The Andhra Pradesh Mineral Development Corporation (APMDC) is involved in the exploration and commercial exploitation of barite at Mangampeta village since 1975. The barite deposit extends over 160 hectares and is located in Obulvaripalle mandalam (Lat 14°01' N and Long 79°19' E) of Cuddapah district (Toposheet No. 57 N/8), Andhra Pradesh (Fig 1a). A glimpse of the mines and the waste dumps are represented in plates 1 and 2 respectively. This deposit with its estimated reserves of over 65 million tonnes of barites holds about 98% of the total reserves in the Cuddapah basin and 87% of the country's reserves. Its origin is unique and represents the single largest deposit in the world with over 25% of reserves.

1.3.1 Geology of the Deposit

Significant occurrence of barites in India is confined to the Cuddapah basin. Studies conducted by the geological survey of India have established that all the barite deposits in Cuddapah basin are of the vein type with the single exception of the bedded barite deposit at Mangampeta. The barites is characterized with significant properties like high specific gravity, low hardness, chemical inertness and stability that renders it suitable as an essential raw material in oil drilling, paint and chemical industries etc. The granular barites beds are overlain by a zone of lapilli barites and constitute economically significant deposits (Neelakantam and Sabyasachi, 1979). Barite is mined from the open cast
mine and waste overburden is removed and dumped in the nearby region. The dumps are invariably associated with pockets of soil/carbonaceous tuff, which basically comprises of pyrite, dolomite and quartz. At Mangampeta the rock types are shale, quartzite and dolomite with numerous quartz and a few scattered barite veins (Neelakantam, 1987). Rock types associated with the deposit are dolomite, crystal and devitrified glass tuff (Kurien et al., 1977). Various geological aspects like origin, evolution, composition and types of rocks, barite mineralization, distribution, mode of occurrence and genesis of barites etc., are reported by several researchers (Murthy, 1950; Karunakaran, 1970; Kurien et al., 1976; Karunakaran, 1976; Kurien et al., 1977; Murthy et al., 1978; Neelakantam and Sabyasachi, 1979; Neelakantam, 1987; Basu, 1997).

The Mangampeta barite deposit occurs within the Upper Carbonaceous horizons of the tuff sequence of the Pullampet Formation (Cumbum Formation) of the Nallamalai Group of the Cuddapah Supergroup. Tuff (Shale) interbedded with dolomite and quartz crystal tuff (quartzite) constitute the rock types of the Pullampet Formation. The general strike of the formations in NNW-SSE with gentle dips of about 15°-30° towards ENE. The rocks are folded with their regional fold axes trending NNW-SSE and cross folded at places along ENE-WS axis. The barite deposit occurs as two lensoid bodies: one near Mangampeta termed the “Northern Lens” (Plate 1) and the other at about 700 m south of the Northern Lens designated as the “Southern Lens”.

**Northern Lens**

This lensoid body forms the bulk of the barites deposit at Mangampeta. Most of this deposit occurs under a thick overburden of tuff. The lens has a strike length of 1220 m, a maximum width of 900 m
Fig 1a Geology of the study area with groundwater sample locations
and covers an area of about ¾ sq km. A generalized lithological succession of this deposit is given in Table 1.1.

**Southern Lens**

It has a strike length of 300 m and a width of 70 m with steep dips towards ENE. A generalized sequence of the beds in the lens is given in Table 1.2. The rock units are similar to those in the Northern Lens, though they occur at different stratigraphic levels.

**Structure of the Northern Lens**

The beds in the Northern Lens trend NNW-SSE and have gentle dips (10 - 25°) towards ENE. Due to the folding, variations in the strike and dip, beds gently roll (5 - 11°) either towards NNW or SSE. These are cross folded along ENE-WSW axis into gently plunging, open folds plunging 30-40° either towards ENE or WSW. Monoclinical folding of the beds is observed at certain places. The lens itself is folded into a broad doubly plunging symmetrical syncline with a number of rolls.

**Structure of the Southern Lens**

The strike of the beds in the Southern Lens varies from N60°W - S60°E in the northwestern end of the lens to N10°W - S10°E in the southeastern end. In the northwestern part of the lens, the barites beds and the associated rocks are folded into an overturned anticline. The western limb is overturned. The fold axis trends NW-SE and plunges at 40° towards SE. The intensity of folding seen in the northwestern part of the lens does not extend to the southeastern part where the sequence is normal.
Table 1.1 Generalized lithological succession of the beds in the Northern lens

<table>
<thead>
<tr>
<th>S. No</th>
<th>Litho units</th>
<th>Thickness range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soil</td>
<td>0.00 - 3.00</td>
</tr>
<tr>
<td>2</td>
<td>Quartz veins</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>&quot;Tuff (partly weathered)&quot;</td>
<td>1.70 - 180.00</td>
</tr>
<tr>
<td>4</td>
<td>Carbonaceous tuff with lapilli</td>
<td>0.50 - 6.00</td>
</tr>
<tr>
<td>5</td>
<td>Tuff with quartz and barites lapilli</td>
<td>0.25 - 3.00</td>
</tr>
<tr>
<td>6</td>
<td>Tuff with barites lapilli</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Alternate bands of lapilli barites and tuff</td>
<td>0.30 - 22.00</td>
</tr>
<tr>
<td>8</td>
<td>Lapilli barites</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Granular barites</td>
<td>1.30 - 35.00</td>
</tr>
<tr>
<td>10</td>
<td>Carbonaceous tuff</td>
<td>2.00 - 76.00</td>
</tr>
<tr>
<td>11</td>
<td>Tuff (partly weathered)</td>
<td>5.25 (max)</td>
</tr>
<tr>
<td>12</td>
<td>Carbonaceous tuff with lapilli</td>
<td>83.85</td>
</tr>
<tr>
<td></td>
<td>Dolomite with thin black tuff bands</td>
<td>(bottom not reached)</td>
</tr>
<tr>
<td></td>
<td>Alternate grey and black tuff with dolomite bands</td>
<td></td>
</tr>
</tbody>
</table>

*The term 'Tuff' refers to a combination of altered glass and crystal fragments or "mixed tuff".

Table 1.2 Generalized geological succession of the beds in the Southern lens

<table>
<thead>
<tr>
<th>S.No</th>
<th>Litho units</th>
<th>Thickness range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soil</td>
<td>0.50 - 2.00</td>
</tr>
<tr>
<td>2</td>
<td>Tuff (partly weathered)</td>
<td>2.00 - 51.00</td>
</tr>
<tr>
<td>3</td>
<td>Quartz pyrites lapilli tuff</td>
<td>1.60 (max)</td>
</tr>
<tr>
<td>4</td>
<td>Barites lapilli tuff</td>
<td>4.50 (max)</td>
</tr>
<tr>
<td>5</td>
<td>Granular barites</td>
<td>1.00 - 12.50</td>
</tr>
<tr>
<td>6</td>
<td>Barites lapilli tuff</td>
<td>0.20 (max)</td>
</tr>
<tr>
<td>7</td>
<td>Tuff (carbonaceous)</td>
<td>11.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(bottom not reached)</td>
</tr>
</tbody>
</table>
Mode of Occurrence

Barites in Mangampeta area occurs within the carbonaceous beds of the Pullampet Formation as (1) bedded, grey, granular (2) lapilli or rosette (3) vein or fracture filling and (4) replacement types. The bedded granular and lapilli varieties constitute the bulk of the deposit. The vein type of barites is negligible and the replacement variety is purely of academic interest. The mineral occurs as granular (A grade) and lapilli-rosette types (B, C, D grades) of barites. The granular barite is quantitatively and economically significant due to its high specific gravity (4.32 g/cm³) and BaSO₄ content (94%). It possesses light grey color, massive, bedded, granular/saccharoidal and occupies the bottom portion of the barites bed. The lapilli rosette barites overlying the granular type are commercially differentiated into three categories based on specific gravity and barite type which is represented in the table 1.3. The ratio of barite ore to waste by volume worked out to be 1:7.1 and the ratio of barite ore to waste by weight works out to 1:3.6.

Table 1.3 Mineable Reserves

<table>
<thead>
<tr>
<th>Grade</th>
<th>Barite mineral bed in tonnes</th>
<th>Specific gravity</th>
<th>Barite type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>56,90,170</td>
<td>4.32</td>
<td>Granular</td>
</tr>
<tr>
<td>B</td>
<td>16,54,768</td>
<td>4.22 to 4.32</td>
<td>Lapilli-rosette</td>
</tr>
<tr>
<td>C</td>
<td>26,14,205</td>
<td>4.0 to 4.22</td>
<td>Lapilli-rosette</td>
</tr>
<tr>
<td>D</td>
<td>12,79,472</td>
<td>3.6 to 4.0</td>
<td>Lapilli-rosette</td>
</tr>
<tr>
<td>Total</td>
<td>112,38,615</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Granular Barites

A light to dark grey, massive, well-bedded, fine grained, saccharoidal, granular type forms the lower zone of the barites body. It is usually uniform in nature and carries thin intercalations of grey/black tuff (Plate 1). The specific gravity varies from 4.0 to 4.45 g/cm³, the average being 4.21 g/cm³. Its hardness on Moh's scale ranges between 2.4 to 2.5. It occupies the central part of the northern lens with an average thickness of 17 m. The granular barites exhibit a fine grained, granular mosaic texture with euhedral to subhedral crystals of barites. Thin tuff laminations are present at certain places which consist of light yellow to buff coloured argillised glass, pyrite, angular to sub-angular quartz, sericite and barites. The rock is almost mono mineralic containing a few grains of pyrite and quartz.

Lapilli/Rosette barites

These barites consist of elliptical, oval or nearly circular lapilli varying from about 1 mm to 10 mm in size and made up of aggregates of radiating plates or laths of barites set in a tuffaceous matrix. In some instances, the lapilli are flattened parallel to the plane of bedding. A layer containing lapilli of different sizes of matrix of yellow to black tuff generally occurs on the top of the lapilli barite beds. The beds of barites lapilli tuff are followed downwards by a zone of alternate layers of barites lapilli tuff and bedded tuff. This is followed further downwards by a zone of massive lapilli barites, which contains numerous lapilli barites of both macroscopic and microscopic sizes associated with a little tuff material. The lapilli size decreases and its incidence increases with depth. Lapilli barites of the Northern Lens have an average thickness of 7000 m and its specific gravity varies from 3.12 to 4.16 g/cm³.
Lapilli barites exhibits round to oval shaped lapilli composed of quartz and barites set in a matrix of clay (argillised glass). The lapilli are made up of radiating plates of barites with wavy outlines, tapering towards the centre with inclusions of euhedral microlites of fresh feldspar, quartz and dark dust. Some of the feldspar inclusions have brownish isotropic cores. Occasionally pyrite, tourmaline and zircon are also found as inclusions. Traces of bedding planes in the tuff swerve around the lapilli, indicating that the curving of tuff laminae is caused due to the impact of the falling lapilli.

**Vein Barites**

The vein type of barites consists of white, impure white or earthy crystalline aggregates of barites, often coated with brownish limonitic material. It is associated with quartz, calcite and occurs within dolomite, tuff and granular and lapilli barite beds. The veins are usually very thin and occur as irregular network. At certain places they appear to follow NNW-SSE and ENE-WSW trends which coincide with the major trends and cross fold axes. Small stringes and veinlets of barites cutting across the tuff and barites beds are noticed in some mine sections, which are of hydrothermal origin.

**Replacement Barites**

Replacement of quartz and pyrite grains by barites along grain margins in tuff constitutes this type.
1.3.2 Quality of the Barites

Quality wise, the lower beds of the deposit are of the highest grade, often almost pure barium sulphate, readily marketable, or even fit to serve as "sweetner" for off grade ore. The upper beds containing lower grade are not readily suitable for industrial purpose, though the percentage of barium sulphate is as high as 70 to 90 percent. To extract the underlying high grade ores, the overlying low grade ores should be necessarily removed. Thus, in the interest of conservation of this valuable asset, as also for bringing down the mining costs, beneficiation and upgrading of these low grade ores should become an integral part of the overall long term exploitation of the deposit (Neelakantam and Suthanandam, 1981).

1.3.3 Genesis

Important bedded deposits are mainly confined to the Archaean and Palaeozoic rocks with the exception of the Mangampeta deposit in India, which is Middle Proterozoic in age. These deposits are usually grey and are associated with Cu, Pb, Zn and generally of low grade, rarely analyzing 50% BaSO₄.

The Mangampeta barite deposit with interlayer of carbonaceous shale was formed under fluctuating euxinic and oxidizing conditions in a partially enclosed ocean basin fed by thermal springs enriched in barium derived from the Cuddapah volcanic activity (Balasundaram, 1971). A volcanic nature is suggested for the deposit (Karunakaran, 1973). Further, in 1976 he suggested that the sulphur in the barites and the associated pyrite was derived from the sea water sulphate by bacteriogenic reduction and barium was contributed by volcanic
exhalations. Neelakantam and Kopresa Rao (1980) also suggested a volcanic sedimentary origin to the deposit. The rocks closely associated with barites in Mangampeta area are welded vitric crystal tuffs of eruptive origin (Sastry and Viswanath, 1979). The Mangampeta barite deposit is genetically a consanguineous linkage to the widespread contemporaneous acid volcanic activity in the Cumbum (Pullampet) times corresponding to the fourth phase of igneous activity in the Cuddapah basin (Nagaraja Rao et al., 1987). Based on the detailed field and petrographic studies, Neelakantam (1987), opines that a major part of the Pullampet sequence comprising shale, quartzite and dolomite, with the exception of dolomite, is perhaps of volcanogenic origin. Barium is believed to be concentrated in minute quantities in volcanogenic rocks. Circulating meteoric waters extract a part of this barium from vast tracts of such rocks and sulphur in the sea water gives rise to chemical precipitates of barium sulphate (Devore, 1981).

1.3.4 Distribution of Barites

Barite is non metallic in nature and therefore commonly exploited and used based on purity and economic considerations. These mineral deposits are distributed in the Asia and Pacific region. Barite is an important commodity in oil and gas exploration and also used as filler. Most of the large barite deposits in the world are in China, though India also has large deposits. The barite deposits are sedimentary, but barite also occurs in veins. Bedded barite deposits consist of barite interbedded with sedimentary rocks. The deposits commonly are spatially associated with sedimentary zinc-lead deposits. The sedimentary Mangampeta deposit, India is the single largest barite deposit in the world.
1.3.5 Topography

The Mangampeta region forms an undulating plain dotted with hills trending NW-SE with relief varying from a few metres to over 300 metres; the ground elevation being about 180 metres above mean sea level. The hills are generally composed of crystal tuff (quartzite), and the plains and low lying mounds are composed of dolomites and tuffs (shales). The Velikonda and the Seshachalam ranges lie to the east and west of the area respectively. The bedded barites mineralization is noticed in the plains.

1.3.6 Climate, Rainfall and Drainage

The climate of the district is of the hot steppe type characterized by hot summers and mild winters. Maximum and minimum temperatures of 46°C and 14°C are recorded during the summer (March to June) and winter (December to February) months respectively. The district is influenced by both southwest and northeast monsoons. The region falls within semiarid to arid belt associated with high temperatures and hence classified as a drought prone area. The average rainfall of the district is 685.5 mm over half of which is received during June–October (south west monsoon). The ground water table is about 4-5 metres below the ground level. Minor tanks form chief sources of water for irrigation.

1.3.7 Soils and Vegetation

The district comprises of different soil types, the important soil types are black cotton, red loamy, red earthy and red sandy soils. Black cotton soil occurs in the Kunderu-Pennar plain and Patagunjana-Cheyoyeru plain, and it is well developed in Jammalamadugu and Proddatur taluks and partly in Kamalapuram, Cuddapah, Sidhout and
Rajampeta taluks. Red earth occurs in the southern part of the Sagileru plain and in the Rajampet-Pullampet plain. It is well developed in Sidhout and Rajampet taluks and to some extent in Badvel taluk. Red sandy soil is well developed in Badvel taluk. Alluvium is exposed along all the major streams occupying an aggregate area of 340 Sq kms. The confluence of the Kunderu and Papaghni with the Penner is marked by a wide expanse of sandy tract. The maximum depth of alluvium exceeds 70 m in the Penner at Repalle, 60 m in Chitravati at Obannapeta and 32 m in Pagaghni at Peddacheppalle. It comprises pebbles, sand and clay. The Penner alluvial at Kottagullakunta was mined for diamonds.

The district is generally characterized by scanty vegetation due to the unfavorable conditions of climate, rainfall and poor fertility of soils. The vegetation is mostly shrubs and thorny bushes covering the hills as well as some of the plains. Forests cover the hilly tract which forms 32 percent of the district. There are a few palm, bamboo, devadaru, tamarind and neem trees in some parts of the district. In several areas, grapes and citrus family fruits are grown. In the agricultural lands of the district mainly dry crops, such as millets, pulses, and groundnut are grown. Paddy is cultivated at a few places where the water is abundant. The chief commercial crops of the district are mangoes, oranges, betel leaves and ground nut.
1.3.8 Previous Literature on the Study Area

The literature on geological aspects of this region is extensive whereas environmental aspects are scanty and scattered. Literature pertinent to Mangampeta barite mines is presented below.

- Karunakaran (1970) suggested a sedimentary origin to Mangampeta barite deposit. Karunakaran (1973) made petrographic studies and attributed the genesis of the deposit to volcano exhalative process with the barium content being derived from the acid volcanic activity. The study states that mineralized sequence comprises layers of granular barites and rosette barites set in a matrix of tuff of pyroclastic origin. Karunakaran (1976) based on sulphur isotope studies on the barites and associated pyrite, concluded that the sulphur in the barite and pyrite was derived from sea water sulphate by bacteriogenic reduction and barium might have been contributed by volcanic or submarine exhalative sources.

- Bose and Vaidyanathan (1979) conducted gravity surveys around Mangampeta, delineated the ore body and estimated the reserves of the barites deposit to be over 60 million tonnes.

- Sastry and Viswanath (1979) reported 'vitric crystal tuffs' (welded tuffs) of domalkaline to peralkaline composition associated with granular barites and assigned an eruptive origin to them.
1.4 Biogeochemical Study

Extensive research studies are carried out in the field of geology / petrology/ geochemistry / geophysics in Mangampeta area. However, the biogeochemical aspects of this area need investigations. Therefore the present study is aimed to conduct a thorough biogeochemical investigation in and around Mangampeta barite deposit. Biogeochemical prospecting is a rapidly developing, cost effective technique to explore economically significant mineral deposits. Biogeochemical methods include the chemical analysis of elements in vegetation and underlying soils. It is a complex science involving the interaction of organic and inorganic processes controlled by a host of physico-chemical parameters. Notwithstanding these complexities careful and systematic collection and preparation of vegetation samples can provide cost effective and new insight, not readily obtainable by other means, to the chemistry of the substrate. The assumption is that the plant accumulates an element from the soil or bedrock in a reproducible manner and that consequently, abnormal amounts in the vegetation indicate anomalies in the substrate. With this approach, in addition to plants, termite mounds are also studied to distinguish the trace element mineralization in this region.

In the present study, the biogeochemical aspects of the study are classified into two categories. The termite mounds constitute the first category and the study of vegetation and its associated soils constitutes the second category.

1.4.1 Termite Mounds

Termites carry the mineral particles from sub soil formations to construct their mounds on the ground surface. As soil particles are
recycled, thus bringing changes in soil properties, it is significant to investigate the changes by analyzing the physical, chemical and textural properties in the termite mound soil and the adjoining surface soils. Several researchers have discussed the usefulness of termite mounds in mineral exploration (West, 1965 and 1970; Watson, 1972; d'Orey, 1975; Pomeroy, 1978; Prasad and Vijayasaradhi, 1984, 1985 and 1986; Suryaprakash Rao and Raju, 1984; Prasad and Sankaranna, 1987; Gleeson and Poulin, 1989; Gopalakrishnan, 1993; Sankaranna and Prasad, 2000).

In the present investigations physical properties (bulk density and organic matter), textural properties (sand, silt, clay proportions and grain size parameters of sand size fractions) and the distribution of trace elements (Ba, Sr, Mn, B, Cu, Zn, Pb, Ni, Co and Cr) in termite mounds and the adjoining natural surface soils are studied in Mangampeta barite mining and surrounding regions.

1.4.2 Plant Biogeochemistry

For successful use of plants in biogeochemical prospecting a reproducible uptake of soil elements by plants of the same species is an essential prerequisite. Plants depend on the soil for nutritional elements; the elemental content of their tissues reflects excess or deficiency of the elements in the substrate. These studies are extremely important, as this form the basis for remediation of the affected area due to barite mining operations. The plant species are selected on the basis of their dominance and abundance in this area. The important plant species considered for experimental studies include *Prosopis juliflora*, *Calotropis gigantea*, *Lantana camera*, *Dodonea viscosa*, *Acacia leucophloea* and *Azadirachta indica*. These studies reveal the plant-soil relationship in
virgin and mining areas and assist in identifying their accumulation potential and their ability to remediate the contaminated areas.

1.5 Hydrogeochemistry

The natural occurrence of barite and leachate from the mine waste in Mangampeta potentially threaten local ground water resources. Due to the lack of surface water, ground water is the only resource for drinking and agriculture. Little attention has been given to this issue. To be aware of the increasing complexity of environmental degradation, this study represents an initial effort to characterize the extent and nature of contamination in ground water, as it potentially relates to the barite mining and processing. Various chemical constituents are determined using reliable methods and techniques, to rate the suitability of ground water for drinking and agriculture. To substantiate the study, the sampling strategy involved collection of representative ground water samples from Mangampeta mining and the surrounding virgin areas.

1.6 Scope and Objectives

There is a need to understand the relationship between mining activities and environmental problems in detail for their management. The mining and metallurgical processing of barite (BaSO₄) ores generates vast quantities of mine rock and mine tailings scattered over an area of 4–6 square kilometers. The mine waste from barite mines chiefly comprises of tuff matter. Unchecked dumping of mine waste and other processes generate dust; pulverizing mills and a few chemical industries in Mangampeta cause pollution threatening the ecological balance. Toxic trace elements Ba, Sr, Mn, B, Cu, Zn, Pb, Ni, Co, Cr, etc are associated with barite bearing rocks, which affect the environmental ecosystems. Since the study area is highly mineralized, environmental ecosystems are
at high risk. This necessitates initiation of restoration of the degraded environment. The clean up of metal polluted soils is thus of great interest economically as well as for the protection of human and environmental health. Vegetation plays a crucial role in the restoration of such degraded areas, as it prevents wind blow of contaminated particles and reduces water pollution. Therefore it is a significant task to explore plant species that accumulate metals specifically in their tissues while thriving on metal polluted soils. However certain metal tolerant plant species growing on metal enriched soils markedly concentrate metals in their tissues. This could serve as a basis for the development of new plant based and cost effective technologies for cleanup or stabilization of metal contaminated soils. Thus, a study of soil properties and vegetation development is necessary to evaluate the effectiveness of remediation measures on ecosystem ecology and risk posed by the trace element content of a soil. Establishment of vegetation cover can fulfill the objectives of stabilization, pollution control, visual improvement and removal of threats to human beings. Therefore the detection of the trace elements and representative sampling from natural environments is indeed a significant task. The metals are commonly determined to monitor the pollution levels in both environmental and biological matrices. As they are easily collected and stored, soil and vegetation are standardized environmental monitors and are widely used as cumulative matrices of long term and short term exposure, respectively, to environmental pollutants.

Though the probable risk of contamination of aquatic and terrestrial ecosystems has been recognized at Mangampeta, environmental studies are scanty. As a system of considerable conservation value and lack of ecological studies has prompted to take up plant – soil interactions, termite soil - natural soil relationships and finally aspects related to quality of ground water in mining and surrounding virgin areas. These studies are useful to understand the
mineral deposits, understand the pollution levels and suggest plant based management options to rehabilitate areas affected by barite mining operation.

An investigation was undertaken to determine the effects of a large barite mining operation on the environmental ecosystems and to delineate plant – soil – water relationships near Mangampeta, Cuddapah district, Andhra Pradesh, India.

1. To delineate the distribution of trace elements in the termite mound soils and their adjoining natural surface soils and to explore the viability of the termite mounds as biogeochemical indicators.

2. To screen certain dominantly growing plant species in the mining region, analyze the plant tissues and associated soils for trace elements, study the accumulation potential of these plants and suggest them for environmental restoration of the contaminated areas.

3. To assess the groundwater quality in the mining and surrounding virgin areas by analyzing the major chemical constituents and to determine the suitability of these waters for drinking and agricultural purposes.