CHAPTER I - INTRODUCTION

Water is one of the most essential constituents of the human environment. Man needs it, in the first place of his physiological existence just as every living organism does, and secondly for many other purposes such as industrial water supply, irrigation, aquatic life, generation of power etc. The oceans contain about 97.2% of the total world water supply. The balance is fresh water of which 2.15% is in ice caps and glaciers, 0.625% in soil and groundwater, 0.017% in surface water and only 0.001% in the atmosphere.

Groundwater is one of the most precious natural resources. It also plays an important role in satisfying the need worldwide, for drinking, irrigation, industry etc. But man has brought about changes, whether through urbanisation and growth of population or by introduction of industries and employment of auxiliary means in agriculture, which have disturbed or even destroyed the natural healthy quality of groundwater. Groundwater become unsuitable for many beneficial uses for which they have utilised earlier. Furthermore, there is a worldwide increase in the demand for good quality water. It has become imperative to protect and conserve groundwater as well as surface water of the world for their prospective uses.

The studies on quality and chemistry of groundwater is a developing branch, which explains the suitability of water for various purposes, classification of hydrochemical types and the mode of origin of groundwater. From the standpoint of water quality or hydrochemistry, there are many variations. There are waters with extremely low concentrations of a few ions and other which have high concentrations of ions. Thus the quality of water for various purposes and chemical nature of them are also differing. The physical characteristics determine how important a groundwater source will be for drinking, industrial and agricultural purposes. Groundwater chemistry was initially studied in relation to the suitability of groundwater for different purposes. As the overall knowledge of groundwater has increased, the hydrochemical aspects have been interpreted with respect to chemical evolutionary processes and quality criteria. Here, in this thesis, an attempt has been made to study the water quality and hydrochemistry of groundwaters in mine areas of the Cuddapah Basin, Andhra Pradesh.
STUDY AREA

The study has been conducted in three major mine areas located in the Cuddapah Basin. These are the areas covering the mines of asbestos, uranium, baryte and base metals such as copper, lead and zinc. The physiography and climate of the Cuddapah Basin are narrated below.

CUDDAPAH BASIN

Physiography and Climate

The middle Proterozoic Cuddapah Basin in the Peninsular India is crescent shaped with its concave side facing the east. It is 340 km long with a maximum width of 145 km about the middle and with an area of 42,000 sq. km.

The annual rainfall in the basin is 500-700 mm and the annual range of temperature is from 30°C to 40°C and the maximum is around 46°C.

The basin is well known for its rich mineral deposits, particularly base metals like lead, copper and zinc, and then asbestos, baryte and uranium deposits. These mineral rich zones have great influence on the quality and chemistry of groundwater. Mining operations and mine-waste disposals in these areas may disturb the natural characteristics of groundwater. Therefore, three major important mine areas selected for the present study. They are,

1. Brahmanapalle-Vemula area (asbestos-baryte-uranium mine area),
2. Mangampeta area (baryte mine area) and

The first two areas are located in Cuddapah district and the last one is located in Guntur district of Andhra Pradesh. Figure 1.1 shows the locations of the study areas in the Cuddapah Basin. The location and accessibility, topography, and climate of the mine areas are described as follows.
Fig. 1.1. Location map of the study areas in the Cuddapah Basin.
1. BRAHMANAPALLE-VEMULA AREA

Location and Accessibility

Brahmanapalle-Vemula area is located in the southern part of the Cuddapah Basin, lying between latitudes 14°19'00" and 14°29'30", and longitudes 78°08'00" and 78°23'00" falling in the Survey of India toposheet nos. 57 J/3 and 57 J/7. The mines of asbestos, barite and uranium are existing in this area. Mines (subsurface) of asbestos are located in the Brahmanapalle-Ipatla range; white crystalline barite at Vemula and Erumarapalle; and uranium mine at Tummalapalle. The area is located 70 km west of Cuddapah town which is easily accessible by road. The location map of the area is given in figure 1.2.

Topography

The topography of the area is hilly and marked by moderate strike ridges composed of quartzites, dolomites and traps. The area is bounded with Palkonda Hills in the southern side and Mogamareru river in the northern side. South of Brahmanapalle village, there is a long ridge which divides the area into three parts by two shallow valleys. The western section of Brahmanapalle forms a prominent hill. The southwestern part of Ipatla, the hills with a height of 1170 m are found traversed by small streams. In the northwestern part of Ramanuthnapalle village, hills have a height of 1130 m and tops are occupied by Pulivendla quartzites.

Climate

The climatic conditions of the area are characterised by hot summer with annual temperature in between 40°C to 42°C. In winter the minimum temperature is about 15°C to 18°C. Average rainfall in the area is 650 mm.

2. MANGAMPETA AREA

Location and Accessibility

Mangampeta area lies in between latitudes 14°00'00" and 14°05'30" and longitudes 79°15'30" and 79°21'30", falling in toposheet no. 57 N/8 of Survey of India. The area is bounded by Gunjanavagu, a small stream in the east and south-central railway line in its western side. The area is approachable from Cuddapah town, about 60 km towards Tirupathi. The location map of the area is given in figure 1.3.
Fig. 1.2. Location map of Brahmanapalle-Vemula area.
Fig. 1.3. Location map of Mangampeta area.
Topography

The topography of the area can be stated to be almost flat to gently rising towards north and northeast. The area comprises hillocks in the central and northeastern parts, and tanks are distributed all over the area. The highest hill (365m.) is situated at Mangampeta. The area around Mangampeta forms an undulating plain dotted with hills trending NW-SE with relief varying from a few metres to over 300m; the ground elevation being about 180m above the mean sea level. The Velikonda and the Seshachalam ranges lie to the east and west of the area, respectively.

Climate

The climate of the area is characterised by hot summer with maximum temperature ranging between 40°C and 42°C and in winter the temperature reaches minimum of about 13°C to 14°C. Average rainfall is about 700mm, but generally the area is dry.

3. BANDLAMOTTU-AGNIGUNDALA AREA

Location and Accessibility

The Bandlamottu-Agni bundala area is located in the northeastern part of the Cuddapah Basin and lies in between latitudes 16°05'00" and 16°13'30" and longitudes in between 79°38'30" and 79°46'00", falling in toposheets 56 P/12 and 56 P/16. The area is bounded by Kuppukonda extension reserved forest in the western side, Nallakonda reserved forest in the northern side and Guttikonda in the northeastern side. Agnigundala is located in the southwest of Bandlamottu, about 10 km. away, where copper mining was in the past. Lead and zinc mines are located in Bandlamottu. Bandlamottu is located near Vinukonda and is easily accessible from Guntur town by road for about 100 k.m. distance from Guntur. The location map of the area is given in figure 1.4.

Topography

The topography of the area is highly undulated, surrounded by the hillocks Kuppukonda, Moddulakonda, Nallakonda, Guttikonda. The plains of Vinukonda area is marked by circular hills, ridges around Vellaturu (granite dome) and Nayudupalem.
Climate

The climate of the area is tropical with hot summer and mild winter. The maximum temperature during summer is 45°C and the minimum temperature is down to 16°C. The rainy season is restricted to July and September and the average annual rainfall is 850 mm.

OBJECTIVES

The main objectives of the present investigation are:

1. Assessment of groundwater quality for drinking and irrigation purposes.
2. Study on the distribution of major parameters and trace elements.
3. Comparative study on the water quality parameters from the three mine areas.
4. Study of seasonal variation of various parameters.
5. Representation of hydrochemical data using various diagrams.
6. Comparative study of hydrochemistry of the three mine areas.
7. Application of FACTOR analysis to identify the hydrochemical facies and their distribution.
8. Comparative study of the hydrochemical facies among the three mine areas and seasonal variation.

To achieve the above objectives the following methodology is adopted.

METHODOLOGY

The methods of study comprise the collection of groundwater from borewells and mine pits, major and trace metal analysis, discrimination of hydrochemical facies using multivariate analysis, assessment of water quality for drinking and irrigation purposes etc. The various methods utilised in the present study are given below.

Hydrochemical Sampling and Monitoring Programme

Hydrochemical sampling and monitoring will be unique. In monitoring programme, sequential sampling is often only performed twice annually for full analyses where groundwater conditions undergo significant seasonal effects (Lloyd and
Fig. 1.4. Location map of Bandlamottu-Agnigundala area.
Heathcote, 1985). Hence, two seasonal samplings have been conducted in the study areas to find the seasonal variations in the quality and chemistry of groundwater.

The water samples have been collected from mine pits and then bore-wells existing in the adjacent areas to the mines. The collection of samples have been done during May 1993 (pre-monsoon) and December 1993 (post-monsoon). Sample bottles were carefully cleaned with conc. HCl, then rinsed strongly with tap water and finally with distilled water. Contamination was further avoided before sample collection at the sampling site by rinsing sample bottles with the water to be sampled. One litre sample has been collected from each sampling point and kept in polythene bottles. For selected sample locations, 500 ml. of sample collected separately and preserved in 5% HNO₃ medium, to keep the metals in dissolved form, for trace metal analysis.

Forty two samples have been collected for each season from Brahmanapalle-Vemula area, in which most of them were from bore-wells and the remaining from mines of asbestos (10 samples), baryte (6 samples), and uranium (5 samples). Thirty two samples have been collected in each season from Mangampeta area, in which ten samples were from baryte mines and the rest were from bore-wells and thirty six have been collected in each season from Bandlamottu-Agnigundala area, in which five samples from lead-zinc mine area and the rest from bore-wells of adjacent areas. Among those samples, nineteen samples from Brahmanapalle-Vemula area, sixteen samples from Mangampeta area and thirteen samples from Bandlamottu-Agnigundala area were subjected for trace metal analysis.

**Analytical Methods**

The amount of time and expense devoted to chemical analysis should be proportional to the level of interpretations required (Lloyd and Heathcote, 1985). The choice of a particular programme should be dictated by the following factors, as sample and method (Edmunds, 1981).

1. Sample: Collection, storage and pre-treatment conditions: available volume; distinction between dissolved and particulate matter.

2. Method: Specificity; sensitivity; precision; accuracy and time (cost of analysis).

The measurement of certain parameters of groundwater is carried out for the purpose of convenient rapid assessment and to provide control for laboratory
measurements. Of the two objectives, control for laboratory measurements are the most important in that physical condition of a sample may change between the time of sampling and the laboratory measurements. The changes that occur most frequently effect the carbonate chemistry leading to carbonate mineral precipitation that can also induce co-precipitation of metals and other changes. The field parameters normally measured are electrical conductivity (EC), temperature (T), hydrogen-ion activity (pH) etc., which are having temporary variations. These analyses were done in the field by using 'ELICO water quality (kit) analyser'.

The chemical analysis of water samples have been carried out in the laboratory by standard analytical techniques (APHA, 1985). Analytical accuracy is the most important factor after correct sampling in hydrochemical studies. Modern rapid analytical techniques are capable of giving very precise results, although sometimes at the expense of accuracy, and this may be apparent, for example, in a monitoring programme where changes in chemistry vary with a change in analyst. The sample matrix may seriously affect the accuracy of the result and matched standards should be used where appropriate; it is also wise to use standard addition techniques at regular intervals (Lloyd & Heathcote, 1985).

As a guide to hydrochemical analytical techniques generally in use, tables are included below for the major parameters and trace metals studied in ground water of the study areas (Table 1.1).

**Major Ions (Parameters)**

The major parameters examined in the present study are hydrogen-ion activity (pH), electrical conductivity (EC), temperature (T), total hardness (TH), total alkalinity (TA), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), bicarbonate (HCO₃), carbonate (CO₃), chloride (Cl), nitrate (NO₃), sulphate (SO₄), fluoride (F) and total dissolved solids (TDS). APHA (1985) has given the standards of analysis of many of the major and minor ions in water leaves much to the desired; of major ions the greatest range in results appears to be for Mg, HCO₃ and SO₄. Analytical methods are rapidly improving and the techniques are listed in table 1.1 should prove reliable. Titrimetric, flame-photometric and Ultraviolet/Visual Spectrophotometric methods were used for the analyses.
<table>
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<tr>
<th>S.No.</th>
<th>Chemical Parameter/ Method/ Instrument</th>
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<tr>
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<td>Total Alkalinity (TA)</td>
<td>Volumetric method</td>
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<td>Phenolphthalein**</td>
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<td>Methyl Orange**</td>
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<td>Ultraviolet Spectrophotometric method</td>
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* Reagent, ** Indicator
Trace Metals

Trace metals such as copper (Cu), manganese (Mn), iron (Fe), barium (Ba), cobalt (Co), nickel (Ni), chromium (Cr), zinc (Zn), lead (Pb), aluminium (Al) and cadmium (Cd) have been analysed in the study areas. Uranium (U) has been analysed for Brahmanapalle-Vemula area.

The requirement of high sensitivity, low detection limit, high sample throughput and multi-element capability poses severe problems for trace analysis. In most cases the problems of high sensitivity and low detection limit can be partially overcome by the use of pre-concentration techniques in the laboratory or field. Those of high throughput and multi-element capability can be overcome by the application of the numerous instrumental methods that have been developed during the last few years, many of which are amenable to automation. Some of the techniques that are widely using for trace analyses are given in table 1.1. Atomic Absorption Spectrometry (AAS), and Laser Fluoridimetric methods have been used for the present analyses.

Hydrochemical Data Presentation

The physico-chemical analyses and calculations provide a plethora of hydrochemical parameters on which interpretations can be based. In the procedure of representing data for interpretation, it is recommended that a two fold approach be adopted which should consist firstly of maps of distribution of pertinent parameters and secondly of relevant parameter relationship diagrams.

The various diagrams used for the interpretation in the present study are discussed in the following chapters, in which frequency-concentration diagrams, ion-distribution diagrams, hydrochemical diagrams are given. Frequency-concentration diagrams representing the frequency distribution of parameters, ion-distribution diagrams are prepared for major and trace elements explains their distribution. Hydrochemical diagrams in the present study include Piper trilinear diagram, Durov diagram and salinity diagram.

Multivariate analysis

Nowadays statistical procedures are becoming a powerful tool to relate analyses to each other and means of extrapolating data in space and time. Data sets can be fitted into different frequency distributions. These have certain characteristics called as
statistical parameters such as mean, variance, co-variance, standard deviation, standard error etc. These statistical procedures are useful in knowing the nature of raw data.

Bivariate techniques like correlations, regressions and multivariate techniques like principal component analysis, factor analysis, cluster analysis are also commonly used to understand the data obtained.

In the present study, hydrochemical data has been subjected to the multivariate method, factor analysis. A number of computational procedures are commonly employed in factor analysis. These share the common objective of attempting to reveal simple underlying structure that is presumed to exist within a set of multivariate observations. Factor methods operate by extracting the eigen values and eigen vectors from a square matrix produced by multiplying a data matrix by its transpose.

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