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GROUNDWATER QUALITY STUDIES IN BELGAUM DISTRICT

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Preface

The intensive use of natural resources and the large production of wastes in modern society often pose a threat to groundwater quality and have already resulted in many incidents of groundwater contamination. Degradation of groundwater quality can take place over large areas. The quality of groundwater varies from place to place as well as from strata to strata. It may also vary with seasonal changes. Groundwater quality variation can be understood only by the regularly monitoring of quality of water. Due to rapid urbanization and wide variations of soil and geology in Belgaum district, the quality of water is poor in some of the villages. Water is either highly saline in nature and some of the villages are affected by fluoride. In the present study 52 samples have been analysed in the laboratory.

The present report based on the present analysis and available data from various central and state government organisation, an attempt is made to identify the areas which are facing water quality problems in the study area.

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Abstract

The ground water quality deterioration is a serious problem in many parts of Belgaum district due to various reasons such as urbanisation, industrial growth and induction of fertilisers and insecticides and also due to anthropogenic activities. Most individuals and an increasing number of communities whose well water is found to be contaminated are abandoning the use of the affected well and turning to an alternative water supply. If more and more wells are abandoned, the stress on other means of water supply will increase to an intolerable level. Therefore, some alternative means of dealing with the problem of encroaching ground water pollution are needed. In this regard, the foremost part is evaluation of water quality parameters which will throw a light on existing water quality conditions in the district.

In the present report, the results of the chemical analysis of ground water sample from both open and bore wells of Belgaum district have been presented. The study broadly covers the following aspects, (i) Groundwater quality evaluation of Belgaum district, (ii) identification of groundwater quality problems in various parts of the district, (iii) classification of groundwaters, and (iv) Application of DRASTIC model for assessing the vulnerability to groundwater pollution.

1.0. INTRODUCTION

1.1.General

The quality of water that we ingest as well as the quality of water in our lakes, rivers, streams and oceans is a critical parameter in determining the overall quality of our lives. Water quality is determined by the solutes and gases dissolved in the water, as well as the matter suspended in and floating on the water. Water quality is a consequence of the natural physical and chemical state of the water as well as any alterations that may have occurred as a consequence of human activity. The usefulness of water for a particular purpose is determined by the water quality. If human activity alters the natural water quality so that it is no longer fit for a use for which it had previously been suited, the water is said to be polluted or contaminated. It may be noted that in many areas water quality has been altered by human activity, but the water is still usable.

Water naturally contains a number of different dissolved constituents. The major anions are calcium, magnesium, sodium and potassium; the major cations are chloride, sulphate, carbonate, and bicarbonate. Although not in ionic form, silica can also be major constituent. These major constituents form the bulk of the mineral matter contributing to total dissolved solids. In addition, there may be minor constituents like iron, manganese, fluoride and nitrate. Trace elements such as arsenic, lead, cadmium, and chromium may be present in amounts of only a few micrograms per liter, but they are very important from a quality point of view.

Pollution of surface water frequently results in a situation where the contamination can be seen or smelt. However, contamination of ground water most often results in a situation that cannot be detected by human senses. Ground water contamination may be due to bacteriological or toxic agents or simply due to an increase in common chemical constituents to a concentration whereby the usefulness of the water is impaired(Fetter, 1990). In the past, water contamination was primarily due to microbiological agents. Although many advances in public health have been made, incidences of waterborne disease still occur in various parts of our country. Our understanding of toxicology of carcinogenic compounds has increased along with the analytical capacity to detect low concentrations of organic compounds in aqueous samples. Recent regulations have greatly increased the amount of ground water monitoring required. As a result, numerous instances of ground water contamination have been revealed. Legal cases involving groundwater contamination have resulted in corporations paying lakhs of rupees to clean up contaminated ground water as well as paying for damages to families suffering from illness and death alleged to have been caused by organic chemicals in well water ingested by the plaintiffs.

The chemical and microbiological agents, that adversely affect the quality of groundwater are coming from a variety of sources, including land application of agricultural chemicals; animal wastes; septic-tank disposal systems for sewage; sewage-treatment lagoons; land application of organic wastes; municipal landfills; toxic - and hazardous-waste landfills; leaking underground storage tanks; faulty underground injection wells, pits, ponds, and lagoons used for storage; treatment and disposal of various liquid compounds; and chemical and petroleum product spills.

The increasing demand for water to meet agricultural, industrial, and municipal need is placing greater emphasis on the development of ground water resources. In the recent years, ground water is becoming an important source of water supply in many regions since there has been a tremendous increase in the demand for fresh water due to growth in population. The rapid growth of urban areas has adversely affected the groundwater quality due to over exploitation of groundwater resources and improper waste disposal practices. Hence, there is an urgent need for the protection and management of groundwater quality. It is absolutely necessary to ascertain the potability of water before it is used for human consumption.

1.2 Sources of Groundwater Contamination

Sources of contamination can be divided basically into two groups, natural and cultural (those caused by man). The source can be further classified as either point and non-point source of pollution. Point sources enter the pollution transport routes as discrete, identifiable locations and can be measured directly or otherwise quantified, and their impact can be evaluated directly. Major point sources include effluent from industrial and sewage treatment plants, and effluent from farm buildings or solid waste disposal sites. The non-point sources include, effluents from agriculture activity, urban runoff, mining activities etc. Assessment of non-point sources are difficult and needs detailed field and laboratory investigations.

1.3 Scope of the Study

In our country, more than half of the population is dependent on groundwater and therefore, protection of groundwater from contamination is of great importance. Due to limited cost-effective options for treatment of polluted ground water, the affected resources are continuously used by the public for drinking and domestic purposes. This will pose a serious threat to the society and need an integrated approach so that necessary steps may be taken to control the problem. In order to understand such problems, it is necessary to undertake groundwater pollution monitoring and abatement programmes including identification of the kind of contaminating solutes, their sources and dispersal, the type pollution they generate, so that suitable measures could be effected to arrest , if not eliminate, the deleterious consequences of this rising menace

For adequate appreciation of the problems of groundwater and its deterioration, a succinct account of the occurrence and distribution of the ground water and its prevailing chemical quality is considered relevant and therefore, the present study will provide the status of water quality in Belgaum district and also ground water pollution potential in various taluks of the district.

1.4. Objective of the study

The present study has been carried out with the following objectives:

(i) Groundwater quality evaluation of Belgaum district,

(ii) identification of groundwater quality problems in various parts of the district,

(iii) classification of groundwater, and

(iv) Application of DRASTIC model for assessing the vulnerability to groundwater pollution.

2.0 REVIEW

Ground water quality studies have been actively initiated during the last few decades. Systematic surface water pollution investigations have been carried out by government organisations, universities and other non-governmental agencies. For groundwater pollution, the number of investigations carried out are very few and in most of the cases these have been limited to study of selected constituents. Now a days, people started understanding about the water quality problems due to increasing health problems. Various studies have been carried out elsewhere and also in our country. Some of the studies carried out in India are summarised below.

Review of studies carried out by different investigators of various agencies indicates that there is a wide spread ground water pollution in several parts of the country. Groundwater in several areas where sewage is being discharged without proper treatment has been adversely affected by contaminants associated with sewage. High levels of Potassium and Phosphate have been reported in groundwater from several places in Punjab, Haryana and Uttar Pradesh. Groundwater is moderately to highly saline in several parts of Rajasthan, Gujarat, Punjab, Haryana, Delhi and many other areas. Jacks (1973), observed that, as ground water is used for irrigation it is often subject to intense evapotranspiration and cations are removed from solution when the water is concentrated by this process. The ability of the soil to pick up cations is due to the formation of new clay minerals and the precipitation of calcite indicating that leaching has occurred to a greater extent in the past. In parts of Rajasthan, Southern Punjab, Haryana, Uttar Pradesh, Gujarat, Andhra Pradesh, Tamilnadu and Karnataka, high concentrations of fluoride in groundwater have been reported and there are cases of mottling of teeth, dental and skeletal diseases in many places. In certain exceptional cases like Sagalia in Gujarat, the fluoride concentration has been found to be 19 mg/l (Raghava Rao, 1977). Studies conducted by Central Ground Water Board and other agencies have revealed that there are high levels of nitrate in groundwater to the extent of several hundred mg/l in parts of Southern Punjab, Southern Haryana, Rajasthan, Uttar Pradesh, Maharashtra, Andhra Pradesh and in several other states. In Southern and South-Western Haryana, nitrate levels exceeding 500 mg/l at shallow depths have been reported from several places (Kakar, 1981). High concentrations of iron in groundwater have been reported from several areas, particularly those of high rainfall in West Bengal, North Eastern States and Kerala. In Assam, iron concentrations in groundwater to the extent of 20 mg/l has been reported.

Majumdar et.al. (1994) redeveloped and implicated the USGS model SUTRA on personnel computer and applied it to small alluvium stretch in Palar river basin.

Tamta (1994), reported high concentrations of fluoride in groundwater (1.5 mg/l) at number of network stations in northern district table land and eastern districts of Karnataka state comprising of Gulbarga, Bijapur, Raichur, Bellary, Chitradurga, Tumkur, Kolar, Shimoga, Dharwar and Belgaum. Groundwater high in fluoride concentration are observed carrying sodium as a predominant cation and also found oversaturated with respect to calcite suggesting adequate residence of groundwater with the calcium-sodium clays and fluoride bearing minerals. The study portrays, the need of fluoridation of ground water at number of network stations in the area as a measure towards oral health and hygiene for public water supplies.

Ravi Prakash and Krishna Rao (1994) have conducted groundwater quality studies of Paravada area, Visakhapatnam district (A.P.). The study reveals that pH values of groundwater shows an important indication of water quality. This is controlled by the amount of dissolved carbon dioxide, carbonate, bicarbonate and salinity contents. Also the concentrations and distribution of the carbonate and bicarbonate contents in the area are mainly dependent on carbon dioxide pressure, pH value, salinity content and the presence of white kankar formation in the soils. Surya narayana and Reddy (1994) have reported bromine and iodine in groundwater of eastern ghats (A.P.).

Mukherjee and Pandey (1994) have conducted studies on nitrate pollution in groundwater at Jaunpur and its environs (U.P.). They identified nitrate pollution in the study area which provided an important base for further investigations. Badrinath (1995) has developed the expert system named ESAQUAL to suggest the various tests to be conducted on waste water to examine the presence or absence of contaminants that may render the water unsuitable for human consumption. He suggested its utility for ground water quality monitoring in arid and semi-arid regions of the country.

Gogte Institute of Technology (Swapneel Bhadale, et al; 1996) has carried out groundwater quality studies for City Corporation of Belgaum and reported contamination in old Belgaum, Khade Bazar and Maruti Galli. In certain areas of the city, nitrate content is above the permissible limits. The high content of nitrate may be due to contamination due to surface water. Suresh, (1996) reported nitrate concentrations in certain patches of the city area.

Pollution due to domestic waste are studied in Karuvatta, Ezhamattur, and Kadika villages in Kerala state where coliform bacteria was noticed in groundwater. Wells in Semra village of Nion basin in Madhya Pradesh were found to contain E. Coli but no correlation between the bacterial contents and concentrations of inorganic ions was evident. Detailed studies carried out in and around of Semra village has revealed that pollution spread from the village in the form of plume in the direction of the groundwater gradient, and indicate that concentrations are only likely to return to background levels at a distance of 700-1000 meters south of the village. The pollution appears confined to the soft granular basalt - the layer penetrated by dug wells. Arsenic concentration in ground water has been found to be in excess of permissible limit of 0.05 mg/l in a number of localised patches in West Bengal. Population in the area is reported to be suffering from Arsenic Dermatosis' by drinking Arsenic rich ground water, (Sinha, et al. 1996).

Majumdar et.al. (1996) applied three dimensional finite difference model SWIFT III for Nargund - Navalgund region of Malaprabha command area which can be utilised for ground water quality assessment and remediation. National Institute of Hydrology has carried out groundwater quality investigations for Belgaum city (Purandara 1998).

3.0. DESCRIPTION OF THE STUDY AREA

Belgaum district lies in the northern part of Karnataka bordering Maharashtra (fig. 1). There are ten talukas in the district namely Athani, Bailahongal, Belgaum, Gokak, Hukkeri, Khanapur, Raibag, Ramdurg, Chikodi, and Saundatti. The elevation of the hills extends to more than 1000 m above msl. Of the total geographical area of 1346348 ha, 192776 ha is under forest, and 627328 ha which is nearly 50% of the geographical area is normally under crops.

Climate in the district is semi-arid in parts of Athani, Raibag, Gokak, Bailahongal, Ramdurg and Saundatti taluks. In other parts it ranges from sub-humid to humid. Nearly 95% of the annual rainfall is received during the period June to October, because of southwest monsoon.

Most of the remaining rainfall is received during November to December under the influence of Northeast monsoon. The district has two major river systems Ghataprabha and Malaprabha which are tributaries of river Krishna. There are two dams one across Ghataprabha at Hidkal (Hukkeri taluk) and the other at Naviluteerth across Malaprabha (Saundatti taluk).

3.1 Geology

Geologically Belgaum district may be divided into 4 regions (fig 2)

(a) Basal crystallines, which are mainly distributed in parts of Khanapur taluk,

(b) Meta sedimentaries and meta volcanic, observed in Bailahongal and Saundatti taluks

(c) Pre-Cambrian sedimentaries, distributed over Hidkal, Gokak and Ramdurg taluks, and

(d) Basalt with intertrappeans found in Belgaum, Chikodi, Raibag and Athani taluks.

3.2 Soils

Introduction of irrigation in an area must be proceeded by detailed field and laboratory investigations aimed at the classification of soils of the area for crop husbandry and to assess their suitability for irrigation. Detailed soil survey of the entire district has not been done systematically. From the data contained in various publications of the State Agriculture Department, there are mainly four types of soils in the district (fig 3).

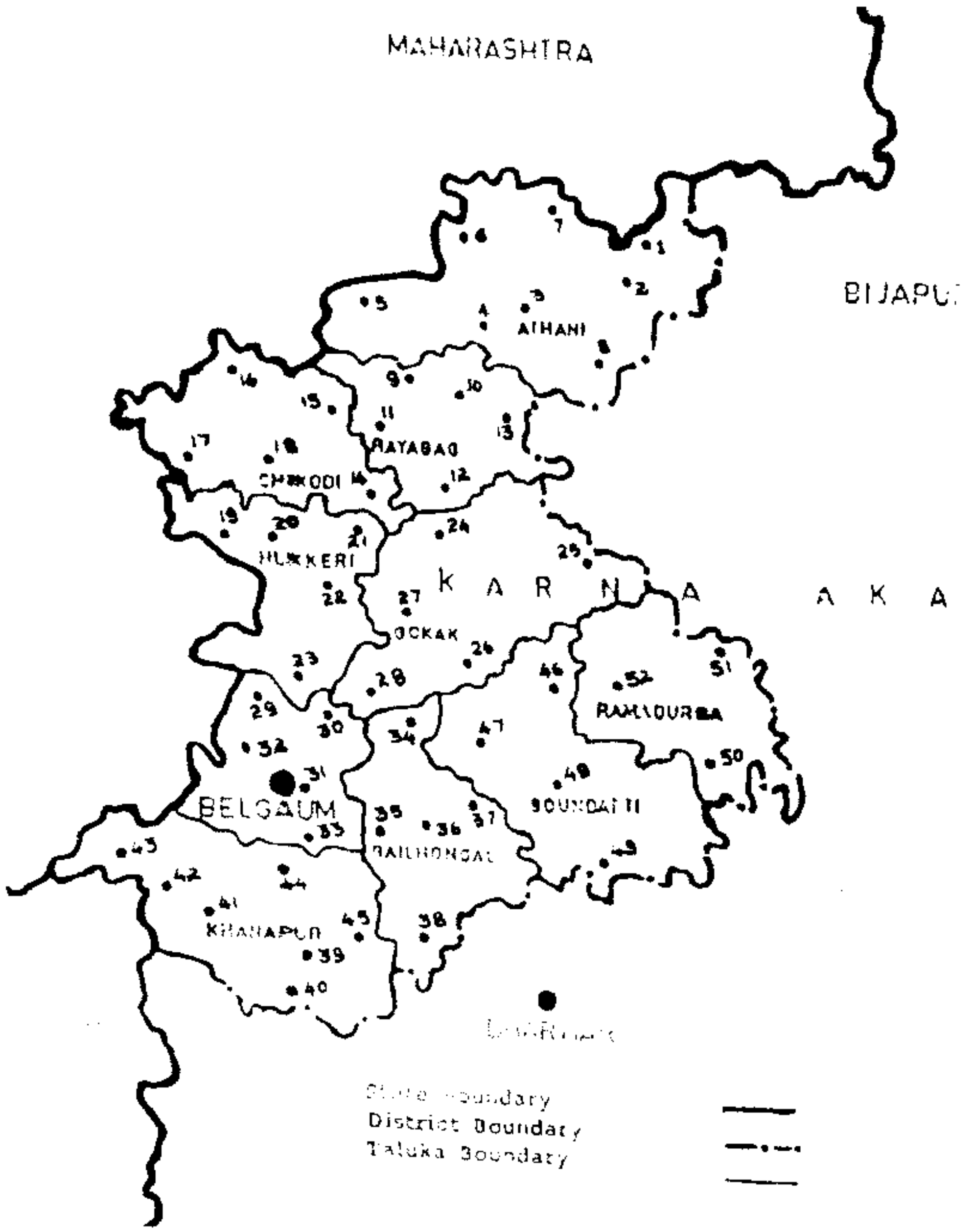

Figure. 1. Groundwater Sampling Locations

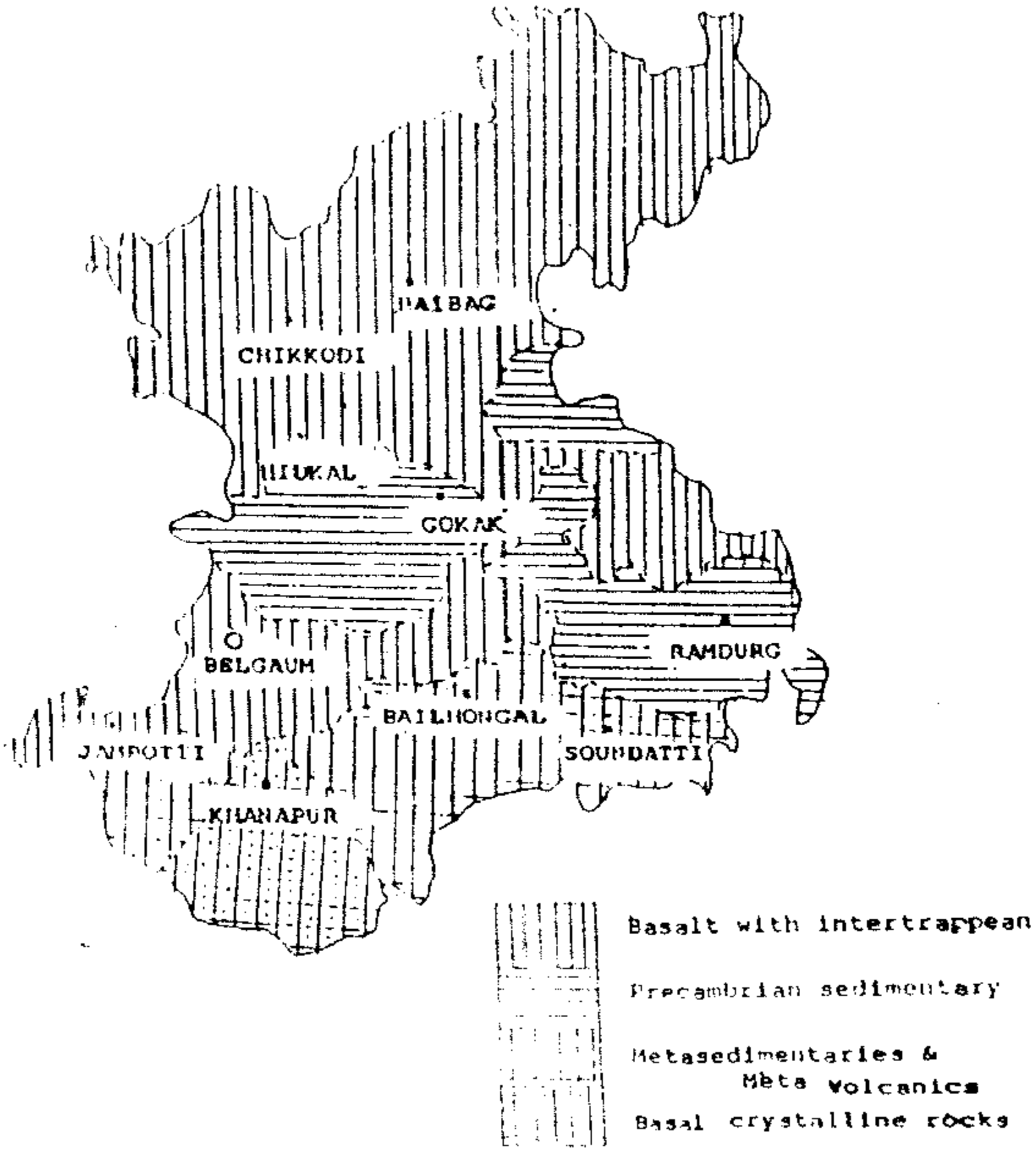

Figure. 2. Geology Map of Belgaum District

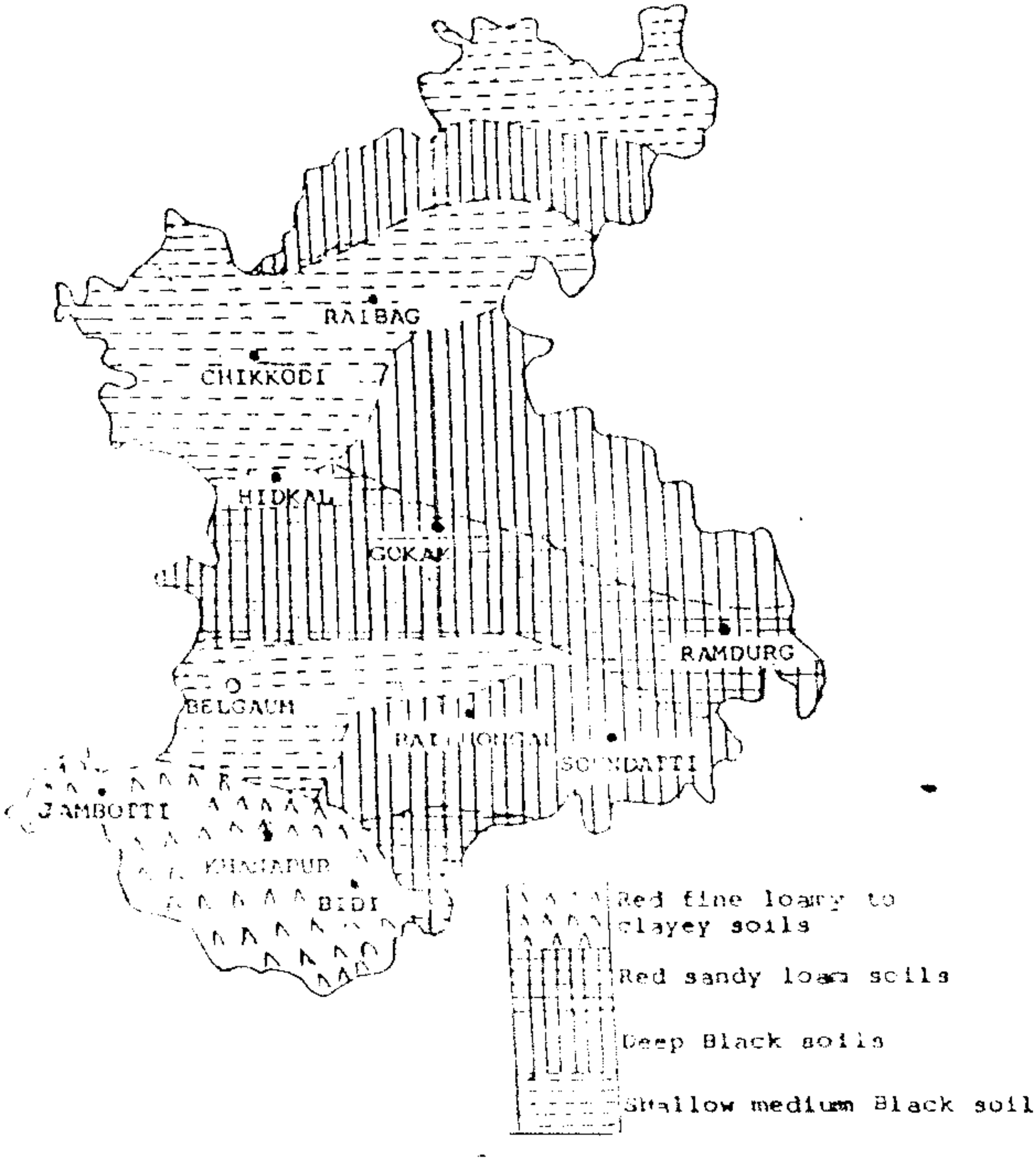

Figure. 3. Soil Map of Belgaum District

(i) Shallow medium black soils

(ii) Red sandy loam soils

(iii) Deep black soils

(iv) Red fine loamy soils

(i) Shallow medium black soils : Distributed in parts of Belgaum, Hukkeri, Chikkodi and Raibag taluks of Belgaum district. These soils are moderately deep, dark to very dark, grayish brown, dark reddish brown or black in color, usually calcareous cracking and clayey. These soils usually occur on very gently sloping mid-lands. They are highly retentive, neutral to alkaline in reaction and are well supplied with bases. These soils are fertile and produce good yields, when moisture is not the limiting factor. The crops grown on these soils under rainfed condition are jowar, wheat, millet, cotton, sunflower, groundnut, linseed, chillies, gram and other pulses.

(ii) Red sandy loam soils : Parts of Hukkeri, Gokak and Ramdurg taluks are covered by Red sandy loam soils. These soils are deep to very deep, reddish brown to dark reddish brown, loamy sand to sandy loam on the surface. They are neutral to acidic in nature and low to medium in cation exchange capacity and base saturation with medium to high water yielding capacity. Soils are well drained with moderate permeability. They respond well to irrigation , manuring and other water and land management practices.

(iii) Deep black soils : These soils generally occur on very gently sloping to nearly level or flat topography in low lands of Deccan trap and lime stone regions, in parts of Hukkeri, Gokak, Ramdurg, Bailahongal and Saundatti taluks. Deep black soils are also found on sedimentary rocks of mixed origin including transported soils occurring in the basins of major river valleys and depressions. These soils are very deep, dark brown, dark greyish brown to very dark grey or black in colour. These are highly retentive and fertile and are moderately well drained to imperfectly drained with slow to very slow permeability.

(iv) Red fine loamy soils : These are found in Belgaum and Khanapur taluks on hilly to undulating land on granites, granitic gneisses and Dharwar schists. Soils are very deep, dark brown to dark red, sandy loam to clay loam on the surface and loam to clay loam in the bottom layers. At places, there are gravelly sandy clay in the sub-surface horizon with distinct argillitic horizon. Soils are well drained with moderate permeability. Crops like wheat, jowar, millets, groundnut and pulses are grown under rainfed cultivation. Under irrigation, crops like paddy, sugarcane, chillies, sweet potatoes, vegetables and plantains are grown.

3.3 Land use pattern

In Belgaum district various types of land use pattern are followed. A major part of Khanapur taluk are covered by forest and shrubs. Agriculture land also occupies a good proportion of the Malaprabha catchment. However, in most parts of the other taluks forest cover is quite negligible, with relatively higher percentage of barren land. More than 50% of the region is covered by agriculture in these taluks. A general land use pattern(after Choubey et al. 1992) is given in figure 4.

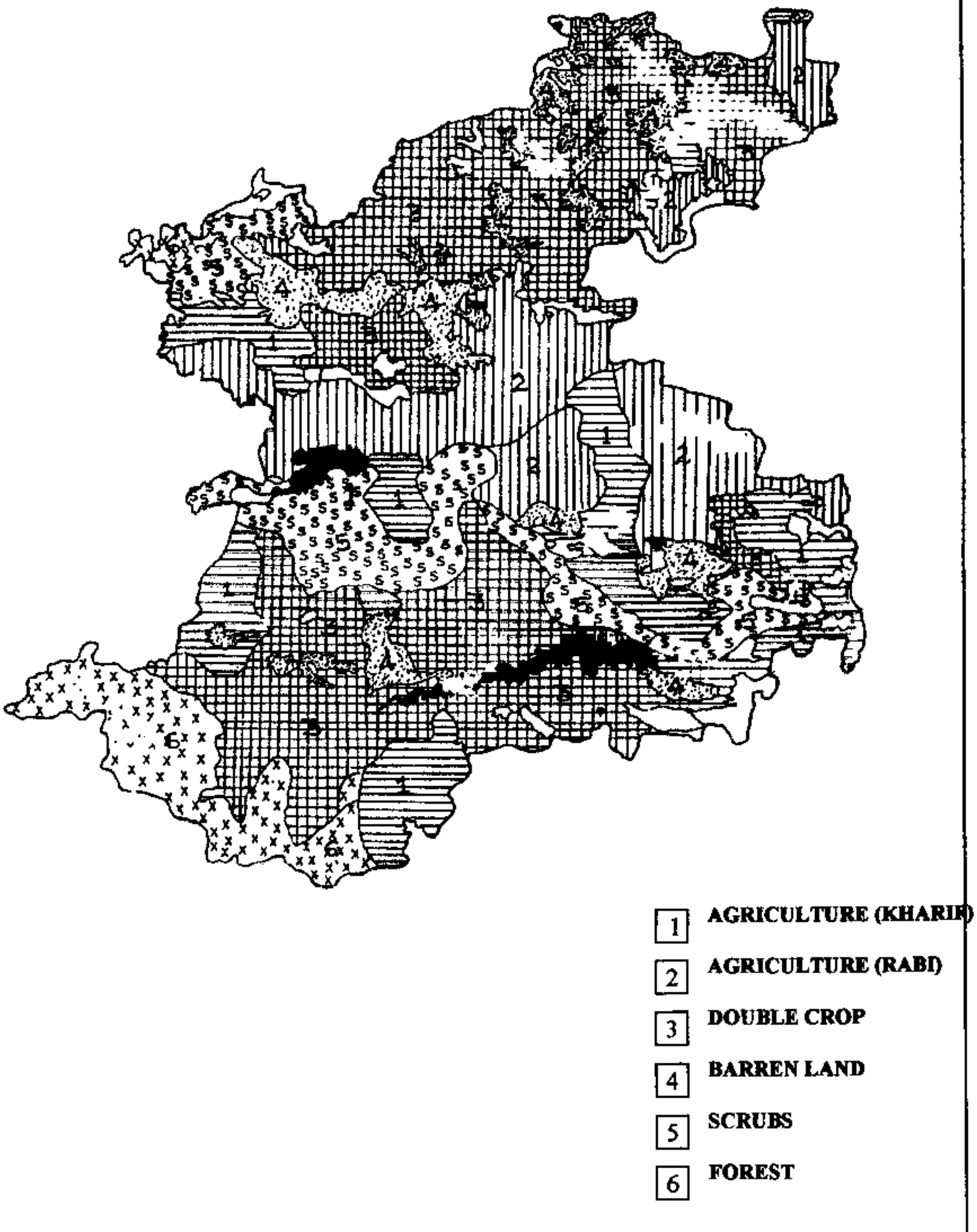

Fig. 4. Land use pattern of Belgaum District

4.0 METHODOLOGY

4.1 Sampling Techniques and Preservation

To understand the problem of groundwater quality in Belgaum district, More than fifty samples were collected from representative areas where from the problems of water quality were reported. To achieve the objective of the study, apart from collecting data from various State and Central government departments, groundwater samples were collected from the study area by dip sampling (or grab) sampling method during Post-monsoon season in the year 1998. Gridwise sampling locations are shown in figure 5. One sample from each grid has been used for DRASTIC indices estimation. The samples were collected from both open and bore wells, which are being extensively used for drinking and other domestic purposes. The depth of the water in the respective wells were also measured with hand held water level indicators. Samples were transferred to clean polyethylene containers fitted with screw caps. Some of the parameters like pH and temperature were measured in the field by using portable kits, at the time of sample collection.

Chemical parameters of the samples were analysed for pH, Specific conductance (EC), Temperature, Total Dissolved Solids, Alkalinity (carbonates and bicarbonates), Hardness, Fluoride and major cations and anions in the laboratory by standard.methods (APHA, 1985) and the methods suggested by Jain et al., 1987. The list of equipments used and methods of analysis are presented in the Table 1.

4.2 Diagrammatic Representation of Chemical Data

Geochemical studies often involve synthesis and interpretation of a mass of analytical data. The objective of interpretation may be to aid in the classification of waters of different geochemical characteristics for utilitarian purposes, solving problems of saline water intrusion, or ascertaining various factors on which the chemical cahracteristics of waters depend. The examination of tabular statements of geochemical data of a large number of samples is not only a tedious and irksome process, but also fails to bring geochemical aspects. Piper's diagram (fig 6) are extensively used to understand the problems of geochemical evolution of ground water. The diagram consists of three

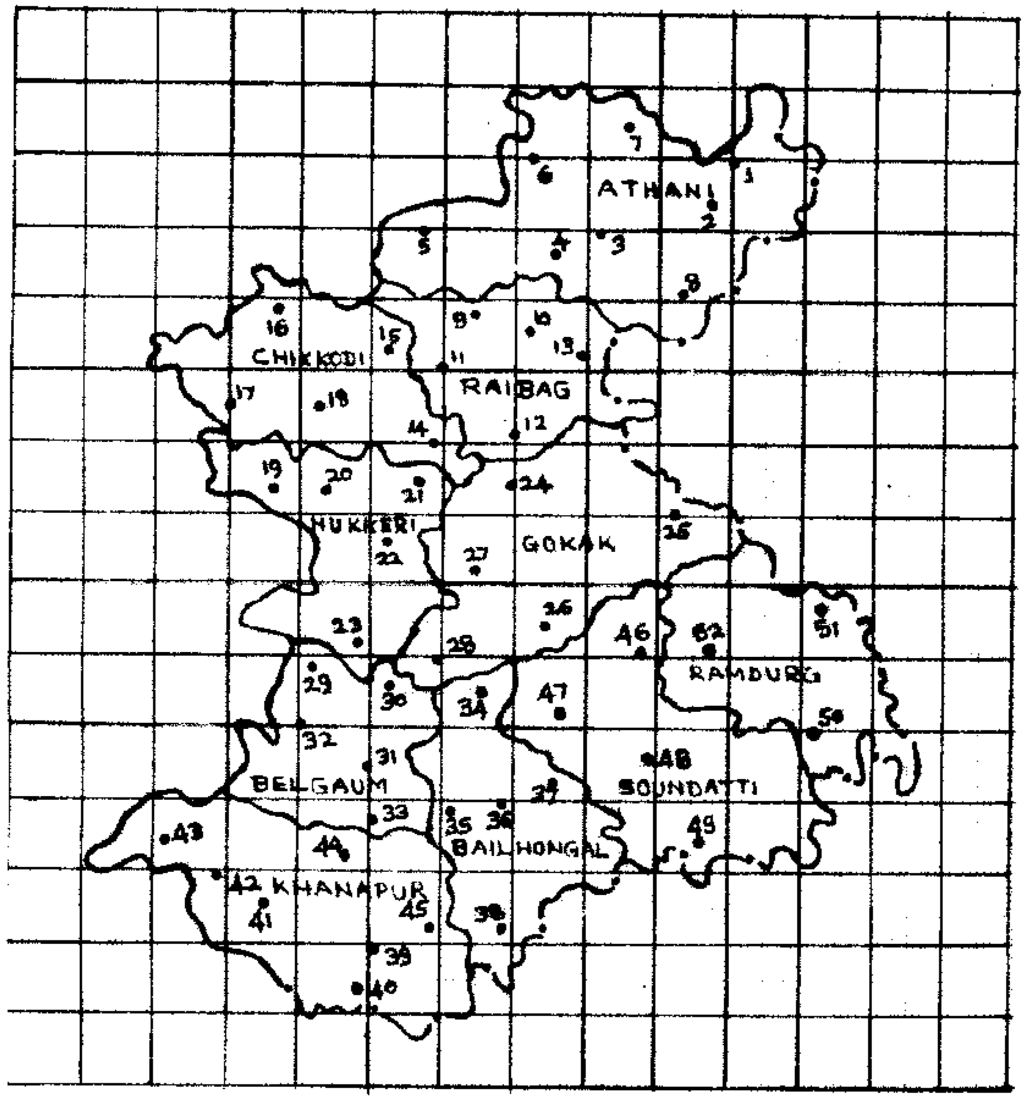

Figure. 5. Gridwise Locations considered for DRASTIC Model.

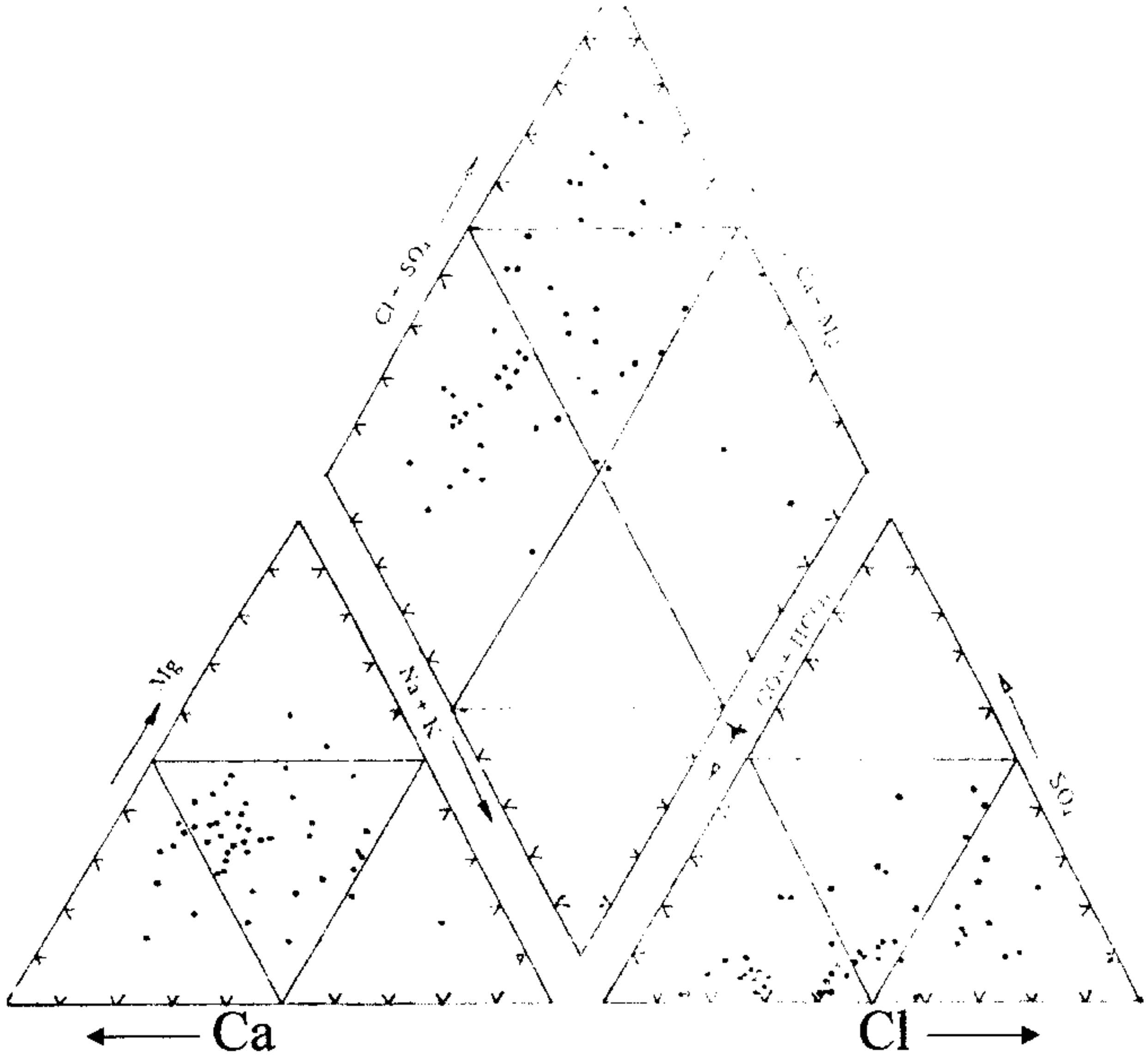

Figure. 6. Piper's Trilinear Diagram

distinct fields - two triangular fields and a diamond shaped field. In the triangular fields, plotted separately, are the percentage epm values of cations, Ca and Mg (alkaline earhs) and Na (alkali), and anions, HCO_3 (weak acid) and SO_4 and Cl (strong acid). The overall characteristics of the water is represented in the diamond-shaped field by projecting the position of the plots in the triangular fields. Minor alkalies like potassium, and strong acids like iodide, fluoride and nitrate are clubbed with the major ones.

Different types of groundwater can be distinguished by the position of their plottings occupy in certain areas of the diamond shaped field.

Area 1 - alkaline earths exceed alkalies

Area 2 - alkalies exceed alkaline earths

Area 3 - weak acids exceed strong acid

Area 4 - strong acids exceed weak acids

Area 5 - carbonate hardness exceeds 50 %,

Area 6 - non-carbonate hardness exceeds 50%

Area 7 - non-carbonate alkali exceeds 50%, i.e.chemical properties are dominated by alkalies and strong acids-ocean water and many brines plot near the right-hand vortex of the sub area.

Area 8 - carbonate alkali exceeds 50% - here plot the waters which are inordinately soft in proportion to their content of dissolved solids.

Area 9 - no one cation-anion pair exceeds 50%.

The Chadha's diagram shown in fig.7 is a somewhat modified version of the Piper diagram. In the Piper diagram the milliequivalent percentages of the major cations and anions are plotted in each triangle and the type of water is determined on the basis of position of the data plot in the respective cationic and anionic triangular fields. The plotting from triangular fields is extended further into the central diamond field, which provides the overall character of the water.

In contrast, in the Chadha's diagram, the difference in milliequivalent percentage between alkaline earths (calcium plus magnesium) and alkali metals (sodium plus potassium) expressed as percentage reacting values is plotted on the X axis and the

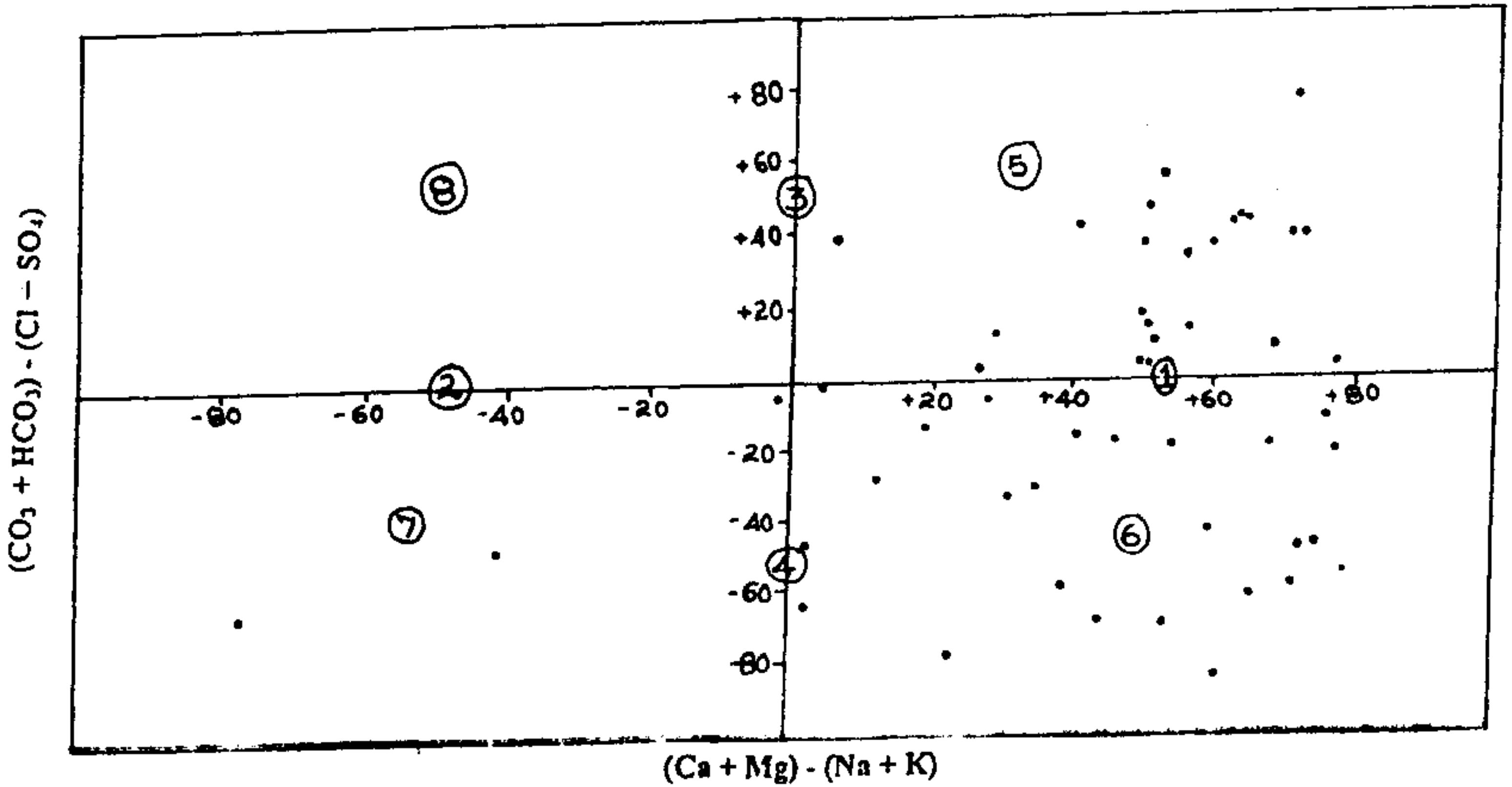

Figure. 7. Chadha's Diagram showing Geochemical Classification

difference in milliequivalent percentage between weak acidic anions (carbonate plus bicarbonate) and strong acidic anions (Chloride plus sulphate) is plotted on the Y axis. The resulting field of study is a square or rectangle depending upon the size of the scales chosen for X and Y co-ordinates. The milliequivalent percentage differences between alkaline earths and alkali metals and between weak acidic anions and strong acidic anions would plot in one of the four possible sub-fields of the proposed diagram.

The square or rectangular field describes the overall character of the water. The proposed diagram has all the advantages of the diamond-shaped field of the Piper diagram and can be used to study various hydrochemical processes, such as base cation exchange, cement pollution, mixing of natural waters, sulphate reduction, saline water (end product water) and other related hydrochemical problems. In order to define the primary character of water, the rectangular field is divided into eight sub-fields, each of which represents a water type as follows:

1. Alkaline earths exceed alkali metals.
2. Alkali metals exceed alkaline earths.
3. Weak acidic anions exceed strong acidic anions.
4. Strong acidic anions exceed weak acidic anions.
5. Alkaline earths and weak acidic anions exceed both alklai metals and strong acidic anions respectively. Such water has temporary hardness. The position of data points in the proposed diagram represent Ca^{2+} - Mg^{2+}- HCO_3^- type, Ca^{2+} -Mg^{2+}- dominant HCO_3^- type, or HCO_3^- - dominant Ca^{2+} -Mg^{2+}- type waters
6. Alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions. Such water has permanent hardness and does not deposit residual sodium carbonate in irrigation use.The positions of data points in the proposed diagram represent Ca^{2+} -Mg^{2+}-Cl^- type, Ca^{2+} -Mg^{2+}- dominant Cl^- - type or Cl^- - dominant Ca^{2+} -Mg^{2+}- type waters.
7. Alkali metals exceed alkaline earths and strong acidic anions exceed weak acidic anions. Such water generally creates salinity problems both in irrigation and drinking uses. The positions of data points in the proposed diagram represent Na^+-Cl^-- type, Na_2SO_4- type Na^+-dominant Cl^--type, or Cl^--dominant Na^+-type waters.

8. Alkali metals exceed alkaline earths and weak acidic anions exceed strong acidic anions. Such waters deposit residual sodium carbonate in irrigation use and cause foaming problems. The positions of data points in the proposed diagram represent Na^+- HCO_3^- - type, Na^+-dominant HCO_3^- -type, or HCO_3^- -dominant Na^+-type waters.

4.3 U.S. Salinity Laboratory Classification

Sodium concentration is an important criterion in irrigation-water classification because sodium reacts with the soil to create sodium hazards by replacing other cations. The extent of this replacement is estimated by Sodium Adsorption Ratio (SAR). The SAR is calculated from the formula

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

A diagram for use in studying the suitability of groundwater for irrigation purposes, named after Wilcox (1955), is based on the sodium adsorption ratio (SAR) and electrical conductivity of water expressed in µS/cm. The chemical analysis data of all the water samples have been plotted on Wilcox diagram,(fig. 8).

4.4 Estimation of DRASTIC indices

A numerical ranking system has been devised in order to assess the groundwater pollution potential in hydrogeologic settings using the DRASTIC faotors. DRASTIC is derived from the seven factors;

D= Depth of water in meters

R= Net recharge in meters

A = Aquifer media

S = Soil media

T = Topography (slope %)

I = Impact of vadose zone media

DRASTIC model contains three significant factors viz. weights, ranges, ratings

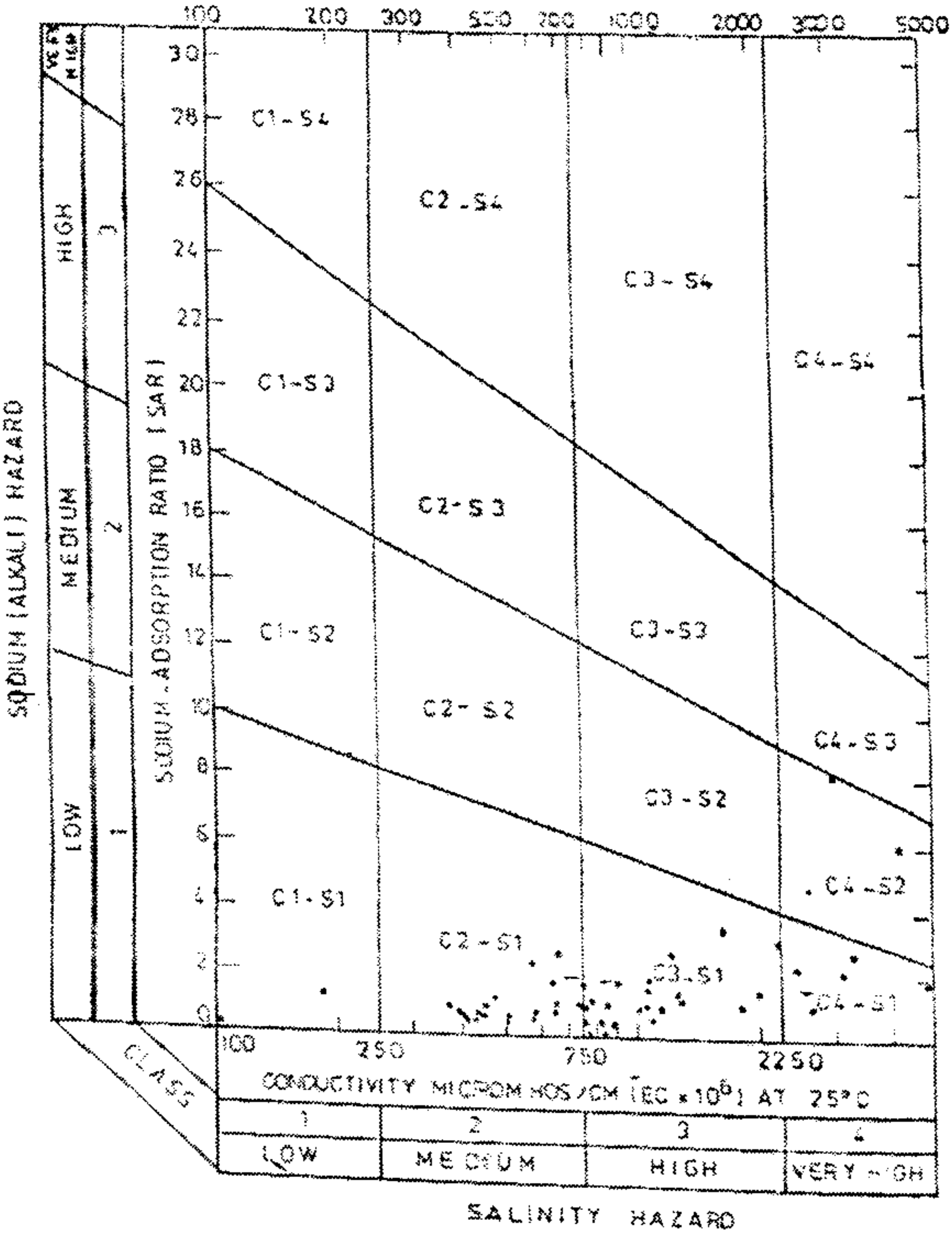

Figure. 8. US Salinity Diagram of Belgaum District

Weights (w) : Each of the DRASTIC parameters has been assigned a weight rating from 1 to 5 to describe relative importance in the Pollution processes as compared to other parameters.

Ranges : Each DRASTIC factor has been divided into either ranges or significant media types which have an impact on pollution potential

Ratings (r): The ratings vary between 1 to 10 for each range in DRASTIC factor. The DRASTIC factors have been assigned one value per range. The factors A and I have been assigned a typical rating and variable rating . The variable rating allows the user to choose either a typical rating and variable rating. The variable rating allows the user to choose either a typical value based on more specific knowledge.

Once all the factors have been assigned a rate, each rate is multiplied by the assigned weight and the resultant numbers are summed up to get what is called DRASTIC index or pollution potential. This model is formulated as an equation using a linear combination methodology.

DI = Dr Dw + Rr Rw + Ar Aw + Sr SW + Tr Tw + Ir Iw + Cr Cw = pollution potential

where, r = rating of the site, w = weight of the parameter

The index value computed by the model is considered as a relative indication of pollution potential. Higher scores indicate greater vulnerability. The index must, however, be interpreted within a specific hydrogeologic setting by reflecting the major geologic and hydrologic factors which affect and control groundwater movement into, through and out of an area. A mappable unit with common hydrogeologic characteristics, and as a consequence, common vulnerability to contamination.

Use of the index without reference to its hydrogeologic setting may lead to erroneous interpretation of results.

The design and information of DRASTIC was predicted on several assumptions, (i) the data required by the model are available, (ii) that variables included in the model are critically related to groundwater vulnerability, and (iii) the ratings, weights and mathematical relationships between variables are adequately set forth in the DRASTIC procedure. Furthermore, the model is to be used only for regional (not site specific) studies.

5.0 RESULTS

5.1 Athani taluk

In Athani taluk water quality problems are reported from villages viz. Birdi, Darur, Jambagi, Shivanur and Kagwad. Chloride concentration as high as 1820 mg/l is observed in the above villages. Total Hardness showed a maximum of 2000 mg/l. Water is highly turbid in this part of the district. Maximum turbidity reported is 2860 mg/l. Byadarahatti in Athani taluk is severely facing fluoride problem due to which fluorosis disease is reported. The analysis results have indicated that many chemical constituents do not show any consistent trend in variation in the taluk. In general, in most of the area of the taluk quality of groundwater is permissible to good for irrigation purpose. The area along the banks of Krishna and Agrani rivers and major part of the area constituting the Donihalla and Bhima river sub-basins, the groundwater is saline with higher concentration of Na and Potassium, chlorides and sulphates. These constituents are probably present in the soils as evaporates and contaminate the groundwater during its downward movement. Quality of water in these regions is in permissible to unacceptable limits. In some parts of these areas especially on the banks of the river Krishna, groundwater is used for irrigation only after admixing with river water.

Groundwater having total dissolved solids exceeding 2500 ppm is generally not suitable for irrigation and its usage may lead to soil salinity. Most of the water samples collected in the thick black soil covered zone are having TDS above 2500 ppm indicating that it cannot be directly used for irrigation.

Sodium concentration is important in classifying irrigation water because sodium reacts with soils to reduce its permeability. Sodium adsorption ratio varies from 0 to 14.32 in ground water samples. The data indicate that ground water quality is good in Athani taluk for irrigation purposes on elevated grounds and gentle slopes of the valleys. However, the quality is comparatively poor along the banks of Agrani and Krishna rivers which are covered by thick black soils.

It is also observed that in parts of Athani taluk the concentration of sodium, chlorides and sulphates are higher than the permissible limits. Therefore, it is suggested to admix the ground water with canal water for getting better result. Similar experiments were suggested by CADA for such regions.

Table 2 . Groundwater quality variation in Athani taluk

Sl no	Parameters	Minimum Concentration	Maximum concentration
1	pH	7.10	8.15
2	Iron	0.06	0.21
3	Fluoride	0.75	1.40
4	TDS	130.00	880.00
5	Electrical Conductivity	30.00	650.00
6	Turbidity	7.00	2860.00
7	Chloride	68.00	1820.00
8	Total Hardness	128.00	2000.00
9	Calcium Hardness	114.00	758.00
10	Total Alkalinity	88.00	300.00
11	Nitrates	7.72	22.80
12	Sulphates	16.00	92.00
13	Sodium	80.00	365.00
14	Potassium	0.65	64.00

5.2 Chikodi taluk

Ground water quality in Chikodi taluk indicate that there is a trend of degradation in water quality due to various reasons. Geologically, the region comprises of basaltic rocks found as parallel sheets of lava flows. Occurrence of bole bed horizons at the contact of two successive lava flows are common. Major types of soils found in the taluk are shallow sandy loam soils, medium to deep brown clay loam and very deep clay soils. The groundwater quality is characterised by high salinity (chloride concentration maximum observed is 1033 mg/l). Total hardness is also very high in this area (TH varies between 86 mg/l to 2064 mg/l). TDS and conductivity values also showed significant increase in black cotton soil areas.

Table 3. Ground water quality variation in Chikodi taluk.

Sl no	Parameters	Minimum Concentration	Maximum concentration
1	pH	6.60	9.15
2	Iron	0.001	0.30
3	Fluoride	0.70	1.30
4	TDS	140.00	2400.00
5	Electrical Conductivity	40.00	4190.00
6	Turbidity	6.0	130.00
7	Chloride	34.00	1409.00
8	Total Hardness	86.00	2064.00
9	Calcium Hardness	66.00	1033.00
10	Total Alkalinity	54.00	471.00
11	Nitrates	2.30	24.00
12	Sulphates	8.00	96.00
13	Sodium	44.00	490.00
14	Potassium	2.10	10.00

5.3 Raibag Taluk

Raibag taluk is covered by shallow medium black soils with a basement rock of basalts with intertrappeans. Groundwater is extensively used in this region for agriculture purpose. Ground water quality problems are quite common in Raibag taluk. Most problematic areas identified are Nasalpur, Yebratti, Beckeri, Gundwad and Shirgur. It is observed that the quality of water is good in most of the villages, except in the above mentioned places. Highly saline waters with higher fluoride concentration is also observed in some of the villages of Raibag taluk. Based on the reports from the publics, water samples have been collected and it is found that chloride concentration goes upto 1231 mg/l in the observed wells. Fluoride concentration upto 3 mg/l is noticed in some parts of the taluk. One of the most characteristic feature of the water is that the hardness is too high (more than 2000 mg/l). Sodium concentration varies between 16 mg/l and 400 mg/l. Sulphate concentration upto 2360 mg/l is observed at Yabaratti in Raibag taluk. Table 4 shows the variation of water quality parameters in Raibag taluk. Most sensitive problems are salinity, high hardness, turbidity, nitrate contamination and excess sodium concentration.

Table 4 . Groundwater quality variation in Raibag taluk

Sl no	Parameters	Minimum Concentration	Maximum concentration
1	pH	7.10	8.85
2	Iron	0.01	0.18
3	Fluoride	0.60	3.00
4	TDS	142.00	2790.00
5	Electrical Conductivity	35.00	2400.00
6	Turbidity	3.00	1800.00
7	Chloride	32.00	1231.00
8	Total Hardness	26.00	2006.00
9	Calcium Hardness	13.00	1148.00
10	Total Alkalinity	30.00	456.00
11	Nitrates	2.18	21.34
12	Sulphates	6.00	98.00
13	Sodium	16.00	400.00
14	Potassium	1.00	9.20

5.4 Gokak Taluk

The data of water quality of Gokak taluk indicate that the pH value varies from 7.15 to 8.85. The most highlighted constituent present in the waters of Gokak taluk are chlorides (32 - 1631 mg/l), carbonate (0 -180 mg/l), bicarbonate (75 - 610 mg/l), sodium (13-1920 mg/l) with a high potassium concentration (1.5 to 67 mg/l). In Gokak taluk major water quality problems are reported from Gad, G. Hosur, Dharmatti, Kuligod, Hunshyala and Yadwad. In Kuligod, fluoride concentration upto 3.34 mg/l is observed. Concentration of Fluoride is very high in the mining area of Gokak taluk. In Yadwad, high content of fluoride and iron are reported and also waterborne diseases are common. Range of water quality parameters are shown in table 5.

Table 5 : Groundwater quality variation in Gokak taluk

Sl no	Parameters	Minimum Concentration	Maximum concentration
1	pH	7.15	8.85
2	Iron	0.008	0.50
3	Fluoride	0.60	3.34
4	TDS	120.00	480.00
5	Electrical Conductivity	30.00	275.00
6	Turbidity	8.00	680.00
7	Chloride	32.00	1631.00
8	Total Hardness	86.40	730.00
9	Calcium Hardness	64.00	520.00
10	Total Alkalinity	75.00	435.00
11	Nitrates	4.43	40.00
12	Sulphates	8.00	1560.00
13	Sodium	13.00	1920.00
14	Potassium	1.50	67.00

5.5 Hukkeri Taluk

Hukkeri taluk is characterised by Pre-Cambrian sedimentary terrain with a typical red sandy loam soils. Ground water availability is comparatively less in this area. However, quality of ground water is reported to be good. (table 6). All parameters observed are within the permissible limits. Chloride concentration goes upto 606 mg/l in some parts of the taluk. Nitrate concentration varies between 3 mg/l and 21 mg/l . Higher chloride concentration is observed in water logged areas of the taluk.

Table 6 : Groundwater quality variations in Hukkeri taluk

Sl no	Parameters	Minimum Concentration	Maximum concentration
1	pH	7.00	9.15
2	Iron	0.001	0.093
3	Fluoride	0.70	1.300
4	TDS	120.00	400.00
5	Electrical Conductivity	30.00	310.00
6	Turbidity	5.00	46.00
7	Chloride	30.00	606.00
8	Total Hardness	80.00	992.00
9	Calcium Hardness	25.00	520.00
10	Total Alkalinity	48.00	495.00
11	Nitrates	3.10	21.14
12	Sulphates	3.00	62.00
13	Sodium	28.00	66.00
14	Potassium	0.0	3.30

5.6 Belgaum taluk

Belgaum receive an annual rainfall of about 1300 mm. The region is covered by black cotton soils and red loamy soils. Chemical quality data of Belgaum taluk shows that water quality is good for irrigation as well as for drinking purposes. However, it is reported that, there is a trend of deterioration in ground water quality (Suresh, 1996; Purandara, 1998). The present study also indicated a similar trend in groundwater quality. Major disturbed areas are Khasbhag, Khade Bazar, Maruti Galli, and Old Belgaum which are parts of Belgaum City. Water quality problems are also reported from Nilji, Alarwad, Desur and adjoining areas. Further, wells adjacent to Bellary nala also showed a degradation of water quality. Table below shows the variation in water quality in various parts of the taluk.

Table 7. Groundwater quality variation in Belgaum taluk

Sl no	Parameters	Minimum Concentration	Maximum concentration
1	pH	6.32	8.32
2	Iron	0.02	1.25
3	Fluoride	0.18	0.43
4	TDS	44.00	513.00
5	Electrical Conductivity	75.00	829.00
6	Turbidity	-	-
7	Chloride	22.00	239.00
8	Total Hardness	60.00	380.00
9	Calcium Hardness	34.00	240.00
10	Total Alkalinity	32.00	226.00
11	Nitrates	0.38	120.44
12	Sulphates	12.00	95.00
13	Sodium	9.20	117.00
14	Potassium	0.85	28.00

5.7 Khanapur Taluk

Khanapur taluk is characterised by Red fine loamy to clayey soils underlain by meta-sedimentaries and meta volcanic with a basement of crystalline rocks. The pH varies between 5.9 to 9.4, i.e., the water slightly acidic to highly alkaline in nature. Very high concentration of Iron is observed in certain patches of the taluk, especially at Gunji. Fluoride concentration varies between 0.17 mg/l and 2.73 mg/l. Sulphate concentration is very high during the post-monsoon season (485 mg/l). Sodium and Potassium also appears in significant quantity. Table 8 shows the water quality variation in Khanapur taluk.

Table 8 : Groundwater quality variation in Khanapur taluk

Sl no	Parameters	Minimum Concentration	Maximum concentration
1	pH	5.90	9.40
2	Iron	1.31	61.20
3	Fluoride	0.17	2.73
4	TDS	21.60	387.00
5	Electrical Conductivity	36.10	645.00
6	Turbidity	-	-
7	Chloride	7.10	90.40
8	Total Hardness	10.00	154.00
9	Calcium Hardness	6.00	72.00
10	Total Alkalinity	29.00	243.60
11	Nitrates	-	-
12	Sulphates	48.00	485.00
13	Sodium	3.40	69.00
14	Potassium	0.60	36.50

5.8 Bailahongal taluk

The average rainfall in the taluk is 709 mm. Bailahongal taluk is covered by Red sandy loam soils and deep black soils underlain by meta-sedimentaries and meta volcanics. In this part of the study area, water is highly alkaline and one of the most common problem is salinity. Salinity problem is observed especially at Dastikoppa and Holehosur areas. Conductivity varies between 780 mmhos/cm and 3800 mmhos/cm. Concentration of Sodium is very high specifically in bore wells. Maximum Sodium concentration observed is 396 mg/l. Potassium concentration also showed a high value of 149 mg/l which is highly uncommon. The general water quality trend in taluk is shown in table 9.

Table 9. Groundwater quality variation in Bailahongal taluk

Sl no	Parameters	Minimum Concentration	Maximum concentration
1	pH	7.60	9.60
2	Iron	0.79	41.20
3	Fluoride	0.85	2.44
4	TDS	512.00	2280.00
5	Electrical Conductivity	780.00	3800.00
6	Turbidity	-	-
7	Chloride	108.10	758.60
8	Total Hardness	48.00	828.00
9	Calcium Hardness	20.00	504.00
10	Total Alkalinity	121.80	580.00
11	Nitrates	-	-
12	Sulphates	40.00	275.00
13	Sodium	36.50	396.00
14	Potassium	1.00	149.00

5.9 Saundatti taluk

The average rainfall in the taluk is 610 mm. The entire taluk is chiefly composed of deep black soils intervened by red sandy loam soils in patches. Geologically, region is covered by meta-sedimentaries and meta-volcanics. The water is highly alkaline, i.e., pH varies between 7.9 and 9.7. Further, it is observed that in some of the villages in this taluk are facing water quality problem due to high Fluoride concentration. One of the villages identified in the present investigation is Ugargol which is worst hit by fluoride concentration. Fluoride concentration noticed in this part of the taluk is 3.85 mg/l which is quite higher than the normal value of 1.5 mg/l. Even in normal wells the minimum concentration observed is 1.6 mg/l. It is also noted that the potassium concentration is also very high (195 mg/l) in this taluk, in some places higher than the sodium concentration.

Table 10. Groundwater quality variation in Saundatti taluk

Sl no	Parameters	Minimum Concentration	Maximum concentration
1	pH	7.90	9.70
2	Iron	0.35	0.88
3	Fluoride	1.60	3.85
4	TDS	205.00	1792.00
5	Electrical Conductivity	342.00	2620.00
6	Turbidity	-	-
7	Chloride	48.00	274.00
8	Total Hardness	20.00	152.00
9	Calcium Hardness	37.20	358.00
10	Total Alkalinity	92.80	359.60
11	Nitrates	-	-
12	Sulphates	71.00	415.00
13	Sodium	20.00	108.00
14	Potassium	40.00	195.00

5.10 Ramdurg taluk

The average rainfall in the taluk is 573 mm. Major part of the taluk is covered by red sandy loam soils underlain by Pre-Cambrian sedimentary rocks. Water quality problems are reported from Chandargi, Katkol, Lingdal, Bennur, Thadas and Murkatnal. In some of the areas in Ramdurg taluk groundwater is slightly alkaline in nature. However, all the major anions and cations are within the permissible limits. Water is quite good for both drinking and irrigation purpose. However, to confirm the reports a detailed analyses is required. The present analysis of the available data did not show much variation in water quality. Table 11 shows the range of water quality parameters which are distributed over Ramdurg taluk.

Table 11 . Groundwater quality variation in Ramdurg taluk

Sl no	Parameters	Minimum Concentration	Maximum concentration
1	pH	7.49	8.30
2	Iron	-	-
3	Fluoride	0.35	0.56
4	TDS	320.00	1300.00
5	Electrical Conductivity	580.00	2670.00
6	Turbidity	-	-
7	Chloride	21.00	567.00
8	Total Hardness	310.00	1200.00
9	Calcium Hardness	180.00	760.00
10	Total Alkalinity	146.00	256.00
11	Nitrates	25.00	500.00
12	Sulphates	15.00	156.00
13	Sodium	23.00	78.00
14	Potassium	0.0	4.20

6.0. Discussion

6.1 Statistical Analysis of chemical Parameters

The chemistry of natural water is often termed hydrochemistry. This deals with the origin of chemical constituents in water and the processes by which they become dissolved in water or removed from the water by precipitation. The quality of water in the zone of saturation reflects that of the water which has percolated to the water table and the subsequent reactions between water and rock which occur. The factor which influence the solute content include the original chemical quality of water entering the zone of saturation, the distribution, solubility, exchange capacity and exchange selectivity of the minerals involved in the reactions and flow path of the water. All the physical and chemical properties can be assessed through statistical relationships. In the present study an attempt is made to relate the various chemical properties with each other. Some of the interesting results obtained based on data of three taluks viz. Khanapur, Bailahongal and Saundatti taluks are discussed below.

It is a known fact that sodium and potassium are abundant elements in the earth's crust and chloride is the most common element attracted towards sodium and potassium. Though potassium is common, its occurrence is very limited in the groundwater. It shows a simple relationship with sodium and chloride i.e.,

Na = C* Potassium^ b Chloride^a ($R^2 = 0.90$)

C = 1.417, b = 0.004 and a = 0.739.

Similarly, abundance of sodium and chloride can be related by the following equation

Sodium = C*Chloride^a ($R^2 = 0.90$)

C = 1.444 and a = 0.738.

Hardness of water is a common problem in the natural groundwater especially in black cotton soil area and responsible for high alkalinity. Therefore, alkalinity depends upon hardness and thereby with the bicarbonate content.

Alkalinity = C* Hardness^a*Bicarbonate^b.

(R^2 = 0.87) C = 2.656, a = 0.05, b = 0.754.

In the study area, calcium, magnesium and sulphate show mutual affinity. Therefore, these parameters can be related as

Calcium = C*sulphate^a*magnesium^b

(R^2 = 0.95)

where C = 0.797, a = 0.472 and b = 0.860.

It is also observed that there is a low level correlation between potassium and fluoride concentration. Correlation coefficient is near to 0.5. This marginal correlation may be due to the fact that the source of fluoride may be partially from potassium rich rocks.

Another important factor which affects the quality of water is porosity and permeability which in turn may be related with water level fluctuations in the zone of saturation. In particularly, if the water table exists at a shallow depth, then losses by transpiration, and possibly evaporation will increase when it rises. This means that the salt content increases. This is true in some areas where the water is drawn from shallow aquifers.Generally, the upper most layer of rocks and soil act as a purifying agent and filters the water when it passes through these layers. This depends on size of pores, the proportion of argillaceous and organic matter present and the distance traveled by the water involved. It is also observed that certain parameters such as bicarbonate, sodium and sulphate has showed marked correlation with rainfall recharge, porosity and permeability.

6.2 Classification of Waters

Piper's (1944) diagram has been widely used to study similarities and differences in the composition of waters and to classify them into certain chemical types. The water types demonstrated by the Piper's diagram, as described by Karanth (1987) show the essential chemical character of different constituents in percentage reacting values, expressed in milligrams equivalent. Based on Piper's diagram, (fig. 6) it can be classified basically under three major categories, i.e., Area 4, representing strong acids exceed weak acids and Area-5, which represent carbonate hardness exceeds 50% i.e. chemical properties of the water are dominated by alkaline earths and weak acids and, Area 6 having non-carbonate hardness exceeding 50%. Piper diagram is highly useful as it allow comparisons to be made among numerous analyses but this does not portray actual ion concentration. The distribution of ions within the main field is unsystematic in hydrochemical process terms so the diagram lacks certain logic. Piper suggested the method of encircling the plotted points in the central diamond field with its area proportional to the absolute concentration. This method is not very convenient when plotting large volume of data.

Based on the Chadha's diagram (figure 7), the groundwater samples in the entire area can be separated into two distinct groups, 5 & 6. The Group 5 indicate that alkaline earths and weak acidic anions exceed both alkali metals and strong acidic anions, respectively. Such water has temporary hardness. The majority of the samples fall under Group 6 which shows that alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions. Such water have permanent hardness and does not deposit residual sodium carbonate in irrigation use. From the present study, it is revealed that the parts of northern and eastern areas of Belgaum covering parts of Athani, Raibag, Chikodi, Hukkeri, Gokak and Ramdurg are the regions which exhibit high hardness values. This is attributed to the source rocks and also due to the excessive irrigation activities taking place in these taluks. The Chadhas diagram seems to be an essentially a good method for classification of groundwater.

6.3 Salinity Hazards

It is evident from the figure 8, that, all the samples in the study area can be grouped under medium-sodium hazard to high sodium hazard zone, however, the conductivity varies considerably from low to very high.

The chemical quality of water abstracted from igneous or metamorphic rocks is nearly always excellent with salt concentration commonly below 100 mg/l and seldom over 500 mg/l. Exceptions are found in arid areas where salt may be concentrated in the recharge water by evaporation.

6.4 Groundwater Chemistry with reference to study area

The pH value of water is an important indication of its quality. It influences to a great extent the growth of both plant and soil micro-organisms since it affects the suitability of water for irrigation.

A pH value of 7.5 to 8.0 usually indicates the presence of carbonates of calcium and magnesium. This is true in the present study that the waters with the above pH values shows a high bicarbonate concentration whereas water with a pH of 8.5 and above indicates appreciable exchangeable sodium. The results of the present study shows clearly the dominance of bicarbonate and sodium. It is also noticed that the pH value varies between 7 and 9 with bicarbonate as the most dominant species. The carbonate ion is dominant when pH is above 10. However, carbonate in most of the samples is absent. But where the pH is above 9, quantity of carbonate is comparatively high. In actual groundwater systems, the situation is more complex. The pH and carbonate speciation are interdependent, a function of not only the ionization equilibrium for the carbonate species and water but also strong bases added through the distribution of carbonate and silica minerals

In natural groundwater, the generation of net positive charges through the dissolution of carbonate and silicate minerals is always greater than the contribution of net negative charges from the ionization of strong acids. This is one of the major reason, why the ground water are alkaline in nature. Strong acids are rare in natural waters and when they do occur are the result of contamination. In these cases, the charge due to the strong base which create mineral acidity. Incoming alkalinity increases the net positive charge and is matched by an increase in the concentration of negatively charged species that comes from the ionization of bicarbonate to carbonate. This also shows an increase in pH. This behaviour is commonly observed as groundwater evolves by dissolving minerals along a flow path.

The electrical conductivity is an useful parameter of water quality for indicating salinity hazards. In general waters with conductivity values below 750 μmhos/cm are satisfactory for irrigation except for salt sensitive crops that may be adversely affected by the use of such waters. Irrigation waters having conductivity values in the range 250 - 750 μmhos/cm are widely used and satisfactory crop growth is obtained under good management and favourable drainage conditions.

Water naturally contains a number of different dissolved inorganic constituents. The major cations are calcium, magnesium, sodium and potassium; the major anions are chloride, sulphate, carbonate and bicarbonate. These major constituents constitute the bulk of the mineral matter contributing to total dissolved solids. The natural quality of groundwater varies substantially from place to place. It can range from total dissolved solids of 100 mg/l or less for some fresh groundwater to more than 100,000 mg/l for some brines found in deep aquifers. In the present study, in Belgaum district, TDS values varies between 21.60 mg/l (Khanapur taluk) and 2790 mg/l (Raibag taluk). The high concentration of TDS could be attributed to higher agricultural activities taking place in the command areas. In the catchment area which is also mainly covered by red soils the TDS concentration is minimum. This indicate that the agricultural areas are prone to erosion and soils are carried away with the overland flow to open wells which are not having parapets. Based on the above observations the whole district can be divided into two distinct zones, based on soil type, i.e., (i) the regions covered by black cotton soils, and (ii) regions covered by all other types of soils (red soil, brown soil etc).

It is observed that waters of high electrical conductivity values are predominant with sodium and chloride ions. This is evident in various taluks like Athani, Chikodi, Raibag, Gokak, and Bailahongal. Such problems were reported from almost all taluks, however, the problems are severe in the above taluks. Further it is observed that saline waters also have relatively more calcium, magnesium and bicarbonate ions. Potassium and carbonate ions, if present, are mostly confined upto a range of 5 % of the total salt concentration. It is rather difficult to draw a general conclusion on the ionic composition of the water in relation to geographical conditions. In general, waters in areas of high rainfall, i.e. above 75 cm per annum and with good drainage are of good quality. This is clear from the present study that, in the upstream where the rainfall is more the quality of water is good whereas in the downstream area various parameters exceeds the acceptable limits.

The deterioration of chemical quality in groundwater is mainly due to unstable equilibrium between various ions such as carbonate, silicate and alumino-silicate minerals. These constituents will continue to dissolve in the saturated zone. Because of their relative abundance, reasonably fast reaction rate with H^+, and reasonable solubilities, these reactions increase the cation concentrations, alkalinity, and pH. The concentrations of cations increase due to the continued hydrolysis of the biotite and plagioclase as does the alkalinity. An important source of calcium is the dissolution of small quantities of carbonate minerals. In the deeper parts of the system, montrimorillonite occurs in addition to kaolinite as a weathering product of plagioclase.

The most important exchange reactions are the natural water softening reactions, which take Ca^{2+} and Mg^{2++} out of water and replace them with Na^+. The main requirement for this process is a large reservoir of exchangeable Na^+, which is most often provided by clay minerals deposited. When ion exchange takes place, its effects on the cation chemistry of water should be unmistakable. However, an equivalent increase in Na^+ concentration that is matched by an increasing Cl^- concentration may mean that other processes are at work. It is observed that in most of the study area soils are dominated by clay minerals which are responsible for the exchange reaction taking place in the area.

The reduction that oxidise organic matter all generate CO_2 is redistributed among $H_2CO_3^-$, HCO_3^- and CO_3^{2-}. In aquifers where Ca^{2+} and Mg^{2++} are exchanged onto clay minerals for Na^+, the possibility exists for carbonate dissolution and even higher bicarbonate dissolution. With CO_2 generated by redox reactions, ion exchange, and carbonate dissolution, the water will evolve chemically to a sodium bicarbonate.

In general, Na^+ and HCO_3^- concentrations increase in the direction of flow as observed in the present study. Dominico and Schwartz (1990) also observed similar condition. In contrast to this, sulphates behaves oppositely with the highest concentrations in the recharge area and a systematic decrease down gradient in the confined part of the aquifer. In the present case, it is observed that sulphates are one of the dominating anions in the upstream region. This higher concentration of sulphate could be due to the higher recharge capacity.

HCO_3^- and Na^+ dominant water normally indicates ion-exchanged waters, although the generation of CO_2 at depth can produce HCO_3^- where Na^+ is dominant under certain circumstances. This refers to the enrichment of bicarbonate concentration in areas dominated by sodium ions. In the present case, in order to arrive at definite conclusion, it is necessary to observe the chemical quality of soil column which may have influence over water quality.

The whole of our study area is underlain by unconsolidated to consolidated effusive sedimentary, metasedimentary and meta volcanic rocks, basalt, crystalline, and unclassified crystalline rock types. The studies carried out by CGWB, reported that the aquifers in the study area comprises of kaolinite clay, basalt, sandstone, shale, limestone, dolomite, phyllite, schist, granite-gneiss and intrusives. Silt, sand and clay occurs only along the stream courses to a limited extent. The groundwater chemistry depends mainly upon the lithology and hydrogeological conditions.This is evident from the Piper's diagram, in which, the field 5 and 8 indicate possible groundwater evolutionary paths and suggest the presence of zeolite in basalt. Similar observations were reported by Chadha (1999). Sodium clays at places encounter recharging water from limestone, sandstone, and other aquifers and these clays play a key role in the evolution of sodium bicarbonate type water.

Like sodium, potassium is highly soluble and therefore is not easily removed from, except by ion exchange. Although, the abundance of potassium in the earths crust, is similar to that of sodium, its concentration in groundwater is usually less than one tenth of that of sodium. The geology shows that, the basin area is covered by intertrappean clays. Under suitable conditions clay minerals may release exchangeable sodium ions. This causes higher concentration of sodium in areas where intertrappean clays are found. Concentration of potassium may be higher due to agricultural activities and excessive application of fertlisers. In addition to this, basement rocks comprising of minerals such as feldspars and mica, also contributes potassium to the groundwater. This is evident through the present results that potassium shows relatively higher concentration in regions covered by meta sedimentaries and meta volcanics.

The chloride content of groundwater may be due to the presence of soluble chlorides from rocks. Further, chloride is a widely distributed element in all types of rocks in one or the other form. Its affinity towards sodium is high. Therefore, its concentration is high in groundwater where the temperature is high and rainfall is less. Soil porosity and permeability also play a key role in building up the chloride concentration. High content of chloride observed at various places, especially in black cotton soil areas could be due to low permeability, less rainfall and comparatively higher temperature.

In igneous and metamorphic rocks calcium is supported by feldsper, pyroxenes and amphiboles and the less common minerals such as apatite and wollastonite. Despite the higher solubilities of magnesium sulphate and magnesium chloride, magnesium usually occurs in lesser concentration than calcium. This is probably due to the fact that the dissolution of magnesium rich minerals is slow process and that calcium is more abundant in the earth's crust. Sedimentary rocks such as shales and clays may contain pyrites or marcasite from which sulphur can be derived. However, most sulphate ions are probably derived from the solution of calcium and magnesium sulphate minerals. Groundwater in limestone, sandstone and many other aquifers in recharge areas is dominated by HCO_3^- and Ca^{2+}, whereas groundwater in lavas and gypsiferous deposits in recharge areas may have a $CaSO_4$ - type chemical composition.

A specific water quality problem in hard rock areas is due to high fluoride concentrations. Fluoride mainly found in dark primary minerals, e.g. in biotite gneiss. However, if anorthite is also present enough, calcium will be released to check the fluoride concentration in the water. In ground water discharge area where kankar is formed, fluoride will also be precipitated. Hence, high fluoride concentration are sometimes found in kankar layers. Fluoride can enter through exchange of zeolite in basalt. The most important occurrence of fluorides are fluorspar CaF_2 and cryolite of $NaF.AlF_2$. Fluorspar forms the cementing material in some sandstones. This is evident from the present investigation that the fluoride concentration is very high in such areas dominated by the above geology (typical zone in Saundatti taluk)

7.0 Evaluation of Groundwater Pollution Potential Using DRASTIC Model

The DRASTIC model is applied for the systematic determination of groundwater pollution susceptibility of any hydrogeological setting on the basis of available data. Hydrogeological setting incorporates the major hydrogeologic factors, which are used to infer the potential for contamination to enter groundwater. This model is used for the present study as a part of the groundwater modelling.

1. Parameter Estimation

Based on the relative importance of various hydrogeological parameters in characterizing ground water quality, certain weights are assigned for each factor to calculate the DRASTIC index for each taluk. Assigned weights are given in table 12.

Table 12 : Assigned Weights for DRASTIC Features.

Features	Weight (w) used in the study
Depth of Water	5
Net Recharge	4
Aquifer Media	3
Soil Media	5
Topography	3
Impact of Vadose zone	4
Hydraulic Conductivity of the Aquifer	2

(i) Depth to Water Table

The depth to water table is important in any hydrological pollution study, primarily because it determines the depth of material through which a contaminant must travel before it reaches the aquifer. In general, there is a greater chance for attenuation to occur as the depth to water increases because deeper water levels require long travel times (table 13)

Table 13 : Rating for Depth to Water

Talukas	Rating
Athani	6
Bailhongal	6
Belgaum	6
Chikkodi	7
Gokak	7
Hukkeri	5
Khanapur	7
Raibag	8
Ramdurg	6
Soundatti	5

(ii) Net Recharge

For estimating the net recharge, infiltration data (Purandara et al, 1995) has been used. It indicates the amount of water per unit area of land, which penetrates the ground surface and reaches the water table. It expresses the transportation mechanism of contaminant vertically to the water table and horizontally within the aquifer (table 14).

Table. 14 : Rating for Net Recharge

Talukas	Rating
Athani	1
Bailhongal	3
Belgaum	8
Chikkodi	2
Gokak	6
Hukkeri	4
Khanapur	9
Raibag	2
Ramdurg	5
Soundatti	5

(iii) Aquifer Media

Aquifer parameters were estimated for different types of aquifers **based on the** data provided from State and Central Groundwater Departments (table 15).

Table 15: Rating for Aquifer Media

Talukas	Rating
Athani	9
Bailhongal	9
Belgaum	8
Chikkodi	8
Gokak	6
Hukkeri	9
Khanapur	8
Raibag	8
Ramdurg	6
Soundatti	6

(iv) Soil Media

Soil media refers to uppermost portion of the vadose zone characterized by significant biological activity. Major soil types distributed in the study area are black cotton soils, Lateritic soils and mixed soils (table 16).

Table 16 : Rating for Soil Media

Talukas	Rating
Athani	7
Bailhongal	3
Belgaum	6
Chikkodi	10
Gokak	6
Hukkeri	10
Khanapur	6
Raibag	6
Ramdurg	10
Soundatti	10

(v) Topography

Topography refers to the slope and slope variability of the land surface. Topography influences a pollutant to remain on the surface longer enough to infiltrate or to wash away. The slope of the study area varies between 0 and 8 % (table 17).

Table 17: Rating for Topography (Slope %)

Talukas	Rating
Athani	7
Bailhongal	4
Belgaum	9
Chikkodi	7
Gokak	8
Hukkeri	8
Khanapur	5
Raibag	7
Ramdurg	7
Soundatti	8

(vi) Impact of Vadose Zone

The vadose zone is defined as the zone above the water table, which is unsaturated. The type of vadose media determines the attenuation characteristics of material below the typical soil horizon and above the water table(table 18).

Table 18: Rating for Impact of Vadose Zone Media

Talukas	Rating
Athani	9
Bailhongal	5
Belgaum	4
Chikkodi	8
Gokak	6
Hukkeri	6
Khanapur	2
Raibag	8
Ramdurg	6
Soundatti	6

(vii) Hydraulic Conductivity

Hydraulic conductivity data has been collected from State Groundwater Department (table 19).

Table 19: Rating for Hydraulic Conductivity

Talukas	Rating
Athani	2
Bailhongal	6
Belgaum	8
Chikkodi	3
Gokak	6
Hukkeri	4
Khanapur	10
Raibag	4
Ramdurg	6
Soundatti	5

Fifty two (52 numbers) stations were considered for the entire district for estimating the DRASTIC index. The groundwater analysis results were compared with the DRASTIC index. It is noted that, the evaluated DRASTIC indices indicate that the pollution potential in well waters of Athani, Chikodi, Raibag, Gokak, Belgaum and Saundatti taluks are higher when compared to other taluks in the district. The results obtained through DRASTIC indices methodology matches well with the field and laboratory investigations. DRASTIC Indices for various taluks are given below(table 20).

Table.20 DRASTIC Indices for Belgaum District (Talukwise).

Sl No	Taluks	Index Value
1	Athani	172
2	Bailahongal	160
3	Belgaum	175
4	Chikodi	176
5	Gokak	171
6	Hukkeri	154
7	Khanapur	168
8	Raibag	171
9	Ramdurg	155
10	Saundatti	171

From the above estimated index values, it is concluded that, if the Index value exceeds 170 mark, the area is highly prone to pollution. Further, the DRASTIC index ranging between 170 - 160 may be considered as marginal, which indicate that immediate steps should be taken to control the pollution activities. The index less than 160 is considered as relatively least vulnerable regions to pollution.

In order to arrive at definite conclusion., it is necessary to evaluate all the hydrogeological parameters through intensive field and laboratory investigations. Modification of DRASTIC by incorporating other factors such as landuse, land cover, chemical applications, well density, irrigation type and intensity, are essential for accurate evaluation. Groundwater vulnerability studies carried out in United States commented that the DRASTIC approach is only one of many possible approaches to modelling groundwater vulnerability. Jayakumar(1996) also opined that DRASTIC model is an useful tool for identifying groundwater pollution in an area.

8.0 Conclusions

Precipitation, which is the purest of natural waters, is the most dominant source of ground water recharge. The chemical composition of precipitation is, therefore, of considerable importance in understanding the chemistry of ground water. Substantial increase in concentration of dissolved salts may be brought about in the soil zone due to high evaporation rate. In taluks like Athani, Chikodi, Raibag, Gokak and Bailahongal the evaporation is very high. Therefore, an increase in the salt concentration may occur in the zone of aeration by dissolution of soluble minerals, especially carbonates of calcium and magnesium. Solutions of calcium and magnesium are rich in humus. On the otherhand, in arid, and semi-arid regions, precipitation of calcium and magnesium carbonates in the soil zone is the dominant feature. Extensive pans of lime , locally known as kankar are found in some of the study area at shallow depths above the water table. The enrichment of calcium, could be due to the precipitation of calcium and magnesium within the zone of aeration. This is quite common in arid to semi-arid regions of the study area.

In general, a progressive change in the chemical character of the ground water is noticed from the point of recharge to point of discharge. During the prolonged contact of ground water with the reservoir rocks, physico -chemical processes lead towards attainment of equilibrium between the mobile constituents of the rock minerals and solutes in the ground water. The most striking change in the composition of ground waters, especially in semi-arid to arid regions is brought about by evaporation. Evaporation of ground water, in areas where the capillary fringe intercepts the land surface , cause salinisation of soils and formation of saline crusts, accompanied by concentration of dissolved solids. Progressively salts are precipitated in the reverse order of solubilities, which are as follows:

Calcium carbonate, magnesium carbonate, calcium sulphate, sodium bicarbonate, sulphate, and carbonate; sodium chloride, magnesium sulphate and chloride; calcium chloride, followed by chloride and nitrate of potassium. Which of these will be precipitated is dependent upon the initial concentration of the salts and duration of evaporation and climatic factors.

However, to conclude the reasons for salinisation, a detailed study is required. In the present study, limited data is available due to which no solid conclusion can be drawn.

9.0 Recommendations

In view of reported ground water pollution in several parts of the district, there is an imminent danger of extensive damage to the ground water resources. For effective protection of ground water quality from deleterious effects of pollution, there is an urgent need to establish ground water quality monitoring system covering the whole study area with sampling points selected with regard to water supply systems, mode of waste water supply schemes in pollution prone areas where the ground water is the only the major source of supply, it may be necessary to carry out monitoring on top priority basis to delineate affected areas.

One of the immediate measure required in all the villages of the district should be provided with good sanitation facility and sewerage channels so that there may not be any accumulation of biodegradable elements. Wherever, the water supply is from the tanks water should be supplied after chemical treatment. In all villages the waste disposal sites should be located at a suitable place based on scientific technique so that there is no effect of dump sites on water quality in a long run.

9.1 Planning a Ground-water Monitoring program

The science of ground water sampling has advanced greatly in recent years, not only in our understanding of the techniques to be used, but in the development of materials and equipment used in the sampling process. The first step in designing a ground water monitoring program is to determine the purpose. There are at least four major reasons to monitor ground water: to determine the water quality and chemistry of a region, to determine the water quality and chemistry of a specific water supply well or well field, to determine the extent of ground water contamination from a known source, and to monitor a potential source of contamination to determine if the groundwater becomes contaminated(Fetter, 1990).

If the purpose of the study is to evaluate the existing water quality and chemistry of a region, then it is likely that only existing wells would be sampled. In this event, it is necessary to know the construction details of the well and pump. One needs to know what aquifer the well is drawing water from in order to interpret the chemical analyses Wells that tap more than one aquifer should not be used in these studies, which are usually designed to map the distribution of ions in specific aquifer. A good geographical distribution of wells is needed. In studies of Chemical hydrogeology, wells located in both recharge and discharge areas should be sampled. One must be careful that the water sample collected has not been altered by the well system. A common occurrence with existing private wells is that all of the water softener, which changes the water chemistry. If the water quality of a potential well site is being investigated, nearby wells may be sampled to establish regional water quality. In most cases it is desirable to construct a test well before a permanent well is installed.

The selection of monitoring network should take into account the hydrogeological units, heterogeneity and anisotropy of the aquifer properties, proximity to sources of indirect recharge, hydrogeological continuity and boundary conditions. The representative wells selected for the purpose should also satisfy the following conditions:

(I) The well should be so selected as to be representative of the hydrogeological situation in the area.

(ii) The well should be in good condition, not silted up or collapsed

(iii) The aquifers tapped in the well should be identifiable.

(iv) The well should not be subject to heavy withdrawal, so that static water levels may be monitored.

(vi) It should have sufficient water column, as not to dry up in summer or in drought years

(vii) It should be accessible in all seasons

Apart from the above criteria, authors suggest the following criteria for groundwater quality monitoring:

(a) Basin/ watershed delineation in a region or a district unit.

(b) Classify the units into existing landuse types including cropping pattern

(c) Classify the soils according to structure, texture, colour and porosity.

(d) Identify the lithology and confirm the number of aquifers which are tapped in the area

(e) Public opinions should be gathered before finalising the monitoring well

(f) Domestic and industrial effluent discharge sites should be taken into consideration irrespective of quantity.

Once the classification based on above factors are ready, from each location two to three wells should be selected based on aquifer system (in a single aquifer areas, it is better to go for both open well and borewell monitoring). There is no need of rigid criteria for observation well density once the above factors are taken into consideration for groundwater quality monitoring.

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Table 1: Analytical Methods and Equipments used in the study

Sl.No.	Parameters	Methods	Equipments
1.	PH	Electrometric	pH Meter (AQUA LYTIC)
2.	Total Dissolved Solids	Electrometric	Ion Meter (JENWAY 4320)
3.	Conductivity	Electrometric	Ion Meter(JENWAY 4320)
4.	Temperature	Thermometric	T 100 N LCD - Thermometer
5.	Calcium	Titration by EDTA	Volumetric glassware
6.	Magnesium	Titration by EDTA	Volumetric glassware
7.	Sodium	Flame emission	Flame Photometer (Model Chemito 1000)
8.	Potassium	Flame emission	Flame Photometer (Model Chemito 1000)
9.	Carbonate	Titration	Volumetric glassware
10.	Bicarbonate	Titration	Volumetric glassware
11.	Chloride	Titration by Silver nitrate	Volumetric glassware
12.	Sulphate	Turbidimetric	Photoelectric Colorimeter (Model AE - 11S, Erma.Inc)
13.	Fluoride	Electrometric	Ion Meter (JENWAY 3340)
14.	Hardness	Titration by EDTA	Volumetric glassware

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