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GROUNDWATER QUALITY STUDIES IN BELGAUM CITY

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Contents

List of Figures

List of Tables

Abstract

In many groundwater assessment studies, evaluation of the quality of groundwater is as important as the quantity because the usability of groundwater available is determined by its chemical, physical and bacteriological properties. Considering the significance of water quality in water resources management, especially, in city like Belgaum where the water scarcity is a major problem, the City Corporation of Belgaum is meeting the quantity of water for municipal water supply through selected wells of the City area. Therefore, in the present study an attempt has been made to understand the status of ground water quality in Belgaum City. It is observed that, though most of the major anions and cations are within the permissible limits, there is a trend of deterioration. Nitrate is one of the major contaminant which is affecting the ground water. Higher concentration of Sodium and potassium are also observed in some of the localities. Therefore, the study stresses the need for taking immediate steps to control the groundwater pollution.

1.0 Introduction

In most parts of the world groundwater has generally been considered to be readily available good quality source of water for drinking and for agricultural and industrial uses. Therefore, in many groundwater assessment studies, evaluation of the quality of groundwater is as important as the quantity. 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 is determined by the purpose for which it is used. 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 should 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 inorganic constituents. The major cations are calcium, magnesium, sodium, and potassium; the major anions are chloride, sulfate, carbonate, and bicarbonate. Although not in ionic form, silica can also be a major constituent. These major components form the bulk of the mineral matter contributing to total dissolved solids. In addition, there may be minor constituents present, including iron, manganese, fluoride, nitrate, strontium, and boron. 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 due to their toxicity.

The majority of ground water pollution incidents reported in scientific literature were discovered some time after subsurface contamination began and, in most cases contamination of water supply wells was the first indication of the groundwater pollution problem. 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 alternate water supply. If more and more wells are abandoned, the stress on other means of water supply will increase to an intolerable level. Therfore, some alternate means of dealing with the problem of encroaching groundwater pollution are needed.

In India, where more than half of the population is dependent on ground water, pollution of groundwater is a serious matter. Due to a limited cost effective treatment options for polluted groundwater, the affected resource is generally lost for drinking purposes and other utilities. The serious implications of this problem necessitate an integrated approach in explicit terms to undertake groundwater pollution monitoring and abatement programmes including identification of the kind of contaminating solutes, their sources and dispersal, the type of pollution they generate, so that suitable measures could be effected to arrest, if not eliminate, the deliterious consequences of this rising menace.

The specter of ground water contamination looms over industrialised, sub-urban, and rural areas. Due to rapid rate of urbanisation and industrialisation in several parts of the country resulting in several fold increase in generation of waste water. Though domestic sewage is partly treated in some cities, at most of the places it is discharged without any treatment. In cases of industrial units, effluents in most of the cases without proper treatment are discharged into pits near factories or passed through unlined channels to move to low lying depressions on land resulting in pollution of groundwater. Indiscriminate use of fertilisers in certain areas in quantities for excess of optimum requirement has resulted in very high concentrations of some of the constituents in groundwater. The problem of groundwater pollution in several parts of the country has become so acute that unless urgent steps for detailed identification and abatement are taken, extensive groundwater resources may be damaged.

1.1 Process of Ground water Pollution

The process of surface water pollution is rapid and becomes evident in comparatively short time from perceptible changes in colour, taste, odour and at times by dead aquatic life. The mechanism of groundwater pollution is different from surface water and time lag between pollution discharge at land surface and when the pollutants reach groundwater may be several years or decades. Some of the factors which control groundwater pollution include: reactions in top soil and vadose zone, effect of soil moisture deficiency, laminar flow of pollutants, specific gravity and viscosity effects and also movement of effluents.

The important processes that take place in the top soil and vadose zone are biological degradation, filteration, sorption, oxidation and reduction, buffering etc. Due to these reactions several constituents may be removed from or added to percolating water depending on the characteristics of pollutants present and nature of strata through which infiltration takes place. Storage capacity and moisture characteristics of vadose zone play important role in controlling percolation of waste waters. Considerable amount of pollutants may remain in soil and vadose zone and undergo attenuation as a result of various reactions.

In sharp contrast to often turbulent flow of surface waters, ground water flow through strata is mostly laminar. Several investigators have found that recharge water with pollutants appears to maintain a bulb like mass as it moves downward to the lower part of surficial aquifers, then horizontally through the aquifer material to discharge point. It has also been observed that a small ribbon of polluted water injected into groundwater flow will move in a defined stream line with a minimum of lateral or vertical diffusion. Differences in specific gravity and viscosity of effluents from that of natural waters also restrict diffusion of effluents with groundwater.

The flow of groundwater and pollutants that it may contain is very slow as compared with flow on land surface. As a result of this, it may take considerable time for contaminants to move away from source of pollution and degradation in groundwater quality may remain undetected. However, when ground water is polluted, rectification cannot be achieved by stopping the pollutants from source as process of purification by leaching takes more time than initial period of pollution.

1.2 Sources of Ground water Pollution

The major sources of groundwater pollution include:

(i) Urban and domestic wastes: The forms of domestic wastes which can adversely affect ground water quality are sewage and solid wastes. As in case of many cities sewage is discharged on agricultural lands without adequate treatment, groundwater may be polluted. At many places solid wastes are disposed in open dumps or land fills. Unless disposal sites are selected taking hydrogeological conditions into consideration, precipitation recharge passing through dumps and land fills may leach pollutants resulting in ground water pollution.

(ii)Industrial Pollution

Several of the inorganic and organic constituents present in industrial effluents are toxic. Generally the industries discharge their effluents without adequate treatment near their factories. These effluents are either discharged into pits or are passed through unlined channels to nearby depressions where several toxic constituents percolate into groundwater system. Solid wastes are mostly discharged into dumps or landfills which as in case of urban and domestic solid wastes, are potential sources of ground water pollution. Leaks from storage tanks and pipelines particularly in case of hydrocarbons are often sources of ground water contamination. Though leaks may be in the form of trickle, the cumulative effect can be substantial and small amount of hydrocarbon may render the groundwater unfit for consumption.

(iii) Agricultural Pollution

Ground water pollution due to agricultural sources is mainly derived from fertilisers, irrigation salts, animal wastes and crop waste disposal. Though use of fertilisers in optimum levels depending on fertility status of soils is essential, indiscriminate use leads to groundwater pollution. High levels of potassium and nitrate in ground water in several parts of the country can be attributed to excessive application of fertilisers. Several insecticides which are applied can also be leached into groundwater systems. Excess of irrigation water as a result of leaching of salts from soils may also increase several constituents in ground water.

(iv) Induced groundwater pollution

Movement of contaminated or saline water front in inland aquifers sea water intrusion due to excessive withdrawals in coastal aquifers and recharge of water contaminated by air pollution may also adversely affect ground water quality.

(v) Radiological pollution

As a result of increase in nuclear plants for power generation, contamination of groundwater by radiological sources may take place. Operations like mining and milling of radioactive ores, chemical reprocessing and radio active waste disposal can be sources for radio-active pollution. Leaks or accidental releases from storage tanks or pipelines may also cause radio active pollution of groundwater.

2.0 Review

Urban environment will soon be the environment of most people. The term urban refers to area that have most of the physical and economic characteristics of cities, but they need not lie within city boundaries. On the other hand city shall be a relatively dense grouping of large number of people and structures, unified by and located within a definite political boundary, and whose primary concern is not connected with agriculture. Furthermore, ideally a city is characterised by social heterogeneity and the opportunity for rich cultural, economic and political experience and exchange. Even in non-industrialised countries like India, where bulk of the population remains rural, the large cities that do exist are expanding rapidly. The urban population in India increased from 26 million in 1901 to 274 million in 1995 which is expected to cross over to 326 million in year 2001 (Raju, 1987*). There are 212 class I cities (population 1 lakh and above) which include 12 metropolitan cities and 241 class II towns (population more than 50,000 to less than 1 lakh), in the country. Nearly 60% urban population lives in metropolitan cities (Kantawala, 1995*). If current trend of organisation persist, it may well be that within 100 years from now, 95% of the World's population will be urban. This seemingly inevitable increase and urbanisation of the worlds population has numerous, diverse ramifications that present the human race with major social economic, political and environmental problems whose satisfactory solution is both imperative and urgent. Apart from groundwater quality and pollution problems emanating due to activity of man, there are water quality problems due to natural causes in several areas of the country.

Ground water is moderately to highly saline in several parts of Rajasthan, Gujarat, Punjab, Haryana, Delhi and many other areas. Fluoride concentrations in ground water are high in several parts of the country particularly in semi arid and arid tracts. In parts of Rajasthan, Southern Punjab, Haryana, UP, Gujarat, A.P., Tamil nadu and Karnataka, high concentrations of fluoride in groundwater have been reported and there are cases of mottling of teeth, dental and skeletal diseases at many places. In certain exceptional cases like Sagalia in Gujarat, the fluoride concentration has been found to be 19 mg/l (Raghava Rao, 1977). High concentrations of iron in ground water 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. Tamta (1994), reported high concentrations of fluoride in ground water(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, Chithradurga, Tumkur, Kolar, Shimoga, Dharwar and Belgaum. Ground water high in fluoride concentrations are observed carrying sodium as a predominant cation and also found oversaturated with respect to calcite suggesting adequate residence of ground water with the calcium-sodium clays and fluoride bearing minerals. The study portrays 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 ground water 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 conducted bromine and iodine in ground water of eastern ghats (A.P.). Gogte Institute of Technology (Swapneel Bhadale et al., 1996) has carried out ground water quality studies for City Corporation of Belgaum and reported contamination in Old Belgaum, Khade Bazar and Maruti Galli. In certain areas of the city NO_3 content is above the permissible limits. The high content of nitrate may be due to contamination due to surface water. Suresh, (1996) reported NO_3 concentrations in certain patches of the city area.

3.0 Study Area

Belgaum which is one of the important city of Karnataka, is located at longitude 74° 30' and latitude 15°57'. The city is distributed in 3 river catchments namely Bellary Nala (53.35 %), Markandeya river catchment (31.65%) and Mongetri nala catchment (14.98%). Belgaum municipality was established in the year 1951 and in 1977 it was given the status of municipal corporation. In the latter years Kudchi, Kanbargi, Alarwad and Yamunapur are merged with corporation of city Belgaum (Suresh, 1996). The population of the city is more than 5 lakhs including cantonment population. The city gets its water supply from Rakaskop barrage across Markandeya river located about 25 km west of Belgaum city. The area falls under semi-arid climate with an average annual normal rainfall of 1324 mm. Nearly 95% of the annual rainfall is received during the period June to October through south-west monsoon.

3.1 Accessibility

The National highway no.4 is passing through corporation and connects to Poona in the north and Bangalore in the south. The South Central Railway links CCB with Bangalore towards south and Miraj towards north. The CCB is well connected with good all seasonal and motorable roads within and surrounding sub areas/ villages (fig. 1).

3.2 Geology and Soils

The Belgaum corporation area is in the form of depression with elevated portions on north, west and south. Fig. 2 represents a hypothetical geological cross-section across the study area. The eastern part is open. The central and eastern portion is almost silted with black cotton soil due to weathering and erosion, the drainage generally follows easterly direction.

The area comprises of Black soil, Red soil, Laterites, Weathered basalt, Basalt and Kaladgis in the N-E portions.The laterite and weathered basalt are the only litho units which are water bearing. The thickness of black cotton soil are quite fine. Red soils in most parts are granular. The laterites of the CCB varies from purple to pink red to whitish brown in

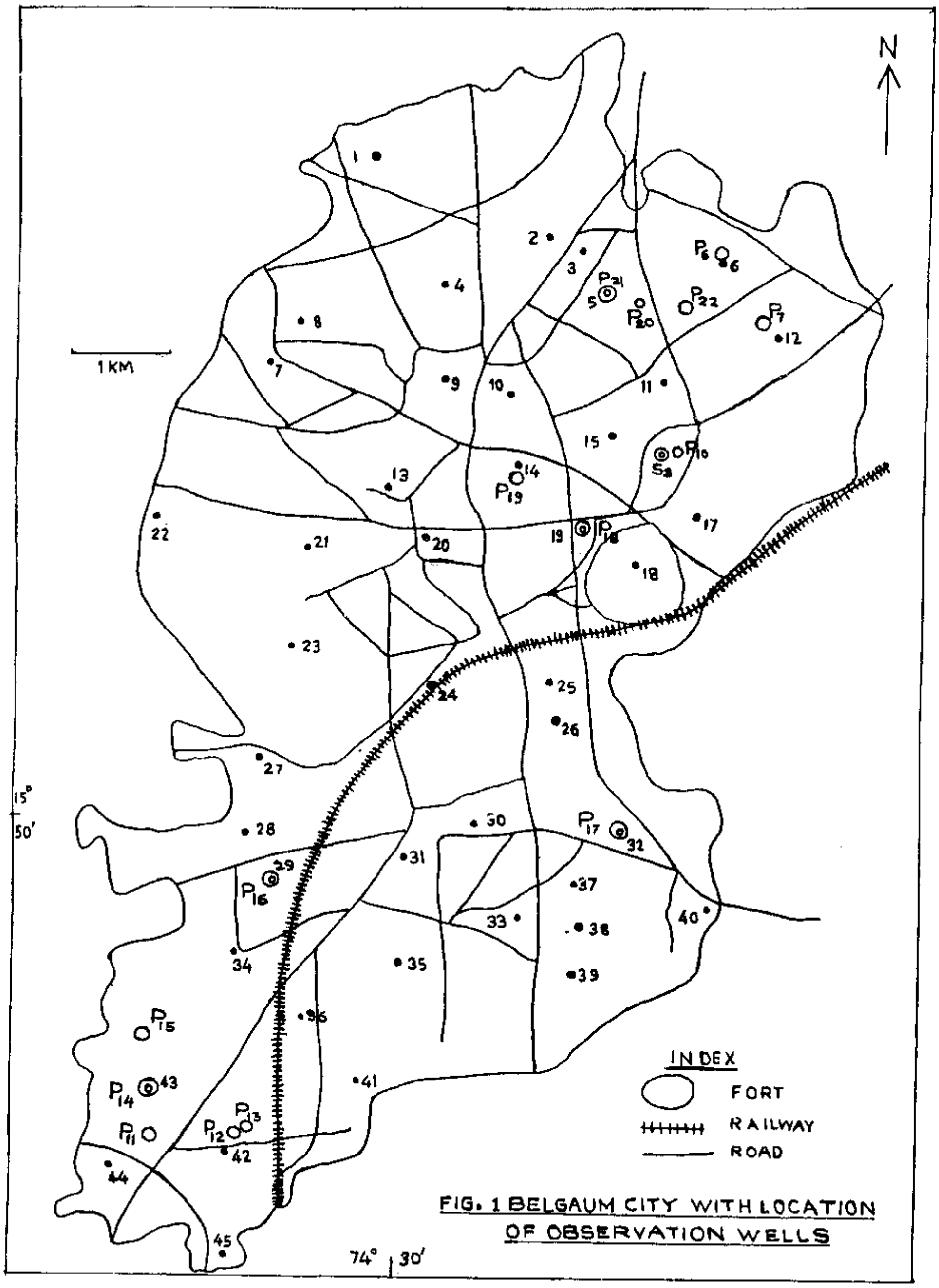


FIG. 1 BELGAUM CITY WITH LOCATION OF OBSERVATION WELLS

Fig. 1. List of observation wells considered for the study

1) Market yard
2) JNMC
3) Nehru nagar
4) Sadashiv nagar
5) Shivabasava nagar
6) Malmaruti
7) Race course
8) Vishweshwariah nagar
9) Civil Hospital
10) Police station
11) HUDCO colony
12) Milk dairy
13) Union Gymkhana
14) DC's office
15) Shivaji nagar
16) Kotikere tank
17) Gandhi nagar
18) Fort
19) CBT
20) Bogarves
21) Cantonment
22) Laxmi hill
23) Cantonment
24) Railway station
25) Hosur
26) Jakkeri tank
27) Nanawadi
28) Maratha colony
29) Tilakwadi
30) Valtakwadi
31) Hindwadi
32) Khasbagh
33) Adarsh nagar
34) Vaccine -institute
35) Bhagya nagar
36) Chidambara nagar
37) Bharat nagar
38) Madhavpur
39) Vadgaon
40) Old Belgaum
41) Angol
42) Udyambagh
43) Industrial Estate
44) GIT campus
45) Majgaon

(Data obtained from GIT, Belgaum)

Locations of present study within the CCB (City Corporation of Belgaum)

1. P6 - Rukmini nagar
2. P7 - Anjaneya nagar
3. P10 - Dhobhighat
4. P11- Udyambhag(ow)
5. P12 -Udyambhag (BW)
6. P13 - Industrial estate(BW)
7. P14 - Industrial estate(OW)
8. P15 - Chennamma nagar
9. P16 - Tilakwadi
10. P17 - Khasbhag
11. P18 - Jatimat
12. P19 - Shettigalli
13. P20 - Shivabasava nagar
14. P21 - Shivabasavanagar(BW)
15. P22 - vaibhav nagar
16. S3 - Kotekere tank
17. S2 - Bellare nala

O Locations showing both bore and open well samples
Samples Collected from Outskirts of City area

1. P1 - Kakati
2. P2 - Kakati (BW)
3. P3 - Gogte Textile mill
4. P4 - Mutanahatti
5. P5 - B. K. Kangrali
6. B. K. Kangrali (BW)
7. P9 - Indal nagar

Locations in and around INDAL campus

1. Yamunapur Well
2. Basavanakol Well
3. Open well inside Indal Campus(Under Construction)
4. Bore well near E type Quarter
5. Small pond near E type Quarter
6. Open well near INDAL Quarter (behind guest house)
7. Open well in Kanabargi

* Locations outside the CCB area is not marked in the Study area map.

(Data available include those from GIT, Belgaum, University of Goa and Regional Centre, NIH)

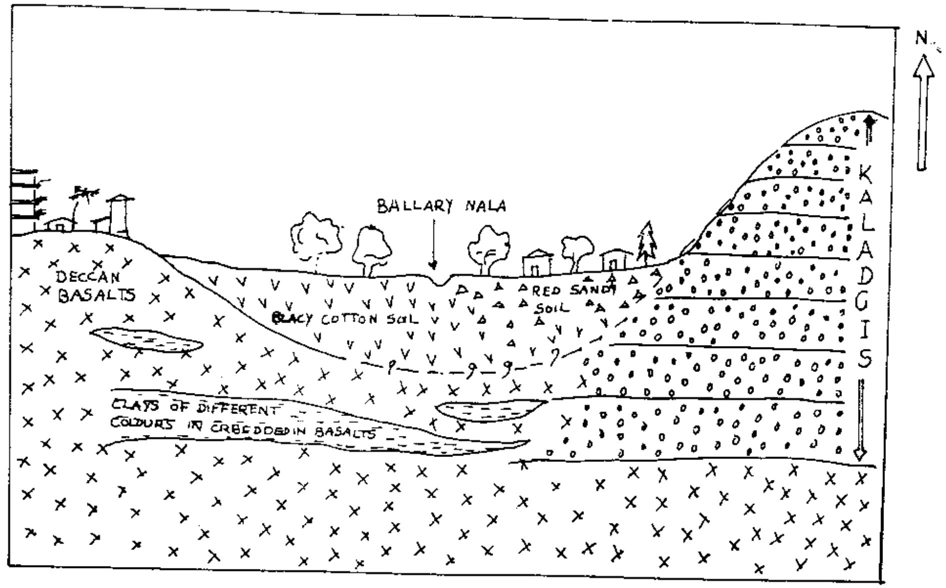


FIG 2 HYPOTHETICAL GEOLOGICAL CROSS SECTION ACROSS STUDY AREA (NOT TO SCALE)

colour. The laterites outcrop is with soil cover.Their thickness varies from a few meters to 50 meters. They are highly porous and perforated with innumerable, irregular and sinuous and tabular cavities. These cavities vary in diameter from 0.05 cm to 2.5 cm. At places the cavities are filled with white buff coloured clays. These clays are often stained to yellow and brown because of peseolatry iron solution. The cavities act as water bearing and transporting openings.

The top crust of laterites upto a depth of 2 to 3m generally very hard and highly ferruginous. This gradually grades into soft lithomarge and mottled clay laterite. This further grades into highly altered layer before merging into basalt, the hard top crust of laterite may be due to the dehydration and soft laterite at depth of subsurface water.

The basalts and outcrops in the northern, part of southern side and in western part of CCB. However, basalt are encountered at the depth, i.e., below 30 - 40 meters in the central part of the CCB. The basalt are generally weathered but also fresh at few places. They are highly jointed and fractured. Basalt at many places exhibit numerous vesicles. These basalts are amygdaloidal, (quartz calcite). These formation lie below the porous laterites which have an excellent character for transmittive infiltering water (fig. 3).

4.0 Statement of the Problem

The Belgaum city generates a sizable amount of liquid and solid waste. The solid waste amounts to about 80 tonnes per day. There are 2 waste disposal sites in the Belgaum city. The soild waste is directly dumped into these depots located within the corporation limits. Air pollution, anaesthetic conditions in the vicinity of dump sites and water contamination are commonly observed. The most damaging waste in the Belgaum city is in the form of sewage. The city uses about 8 mgd of both surface and ground water considering 20% loss about 6 mgd of sewage is generated in the area. There are no sewage treatment plants and recycling facilities within the city area. The entire sewage is directed to Bellary nala which is linked through gutters and sewer lines. The Bellary nala once a perennial stream carrying fresh water has now turned into a sewer drain all along its course of about 30 kms. This Nala passes through a highly fertile black cotton soil which is underlain by a very good aquifer probably by now this fresh water aquifer might have been contaminated with the influx of sewage. The farmers along this nala pump out the sewage water for irrigating sugarcane, paddy, vegetable etc.,thereby passing the toxic contaminants into the food chain. Farmers themselves get affected physically while irrigating with sewage water charged with heavy contaminants and disease causing bacteria. Besides contaminating rural and urban water sources the aesthetic beauty of the countryside which was once being a land with

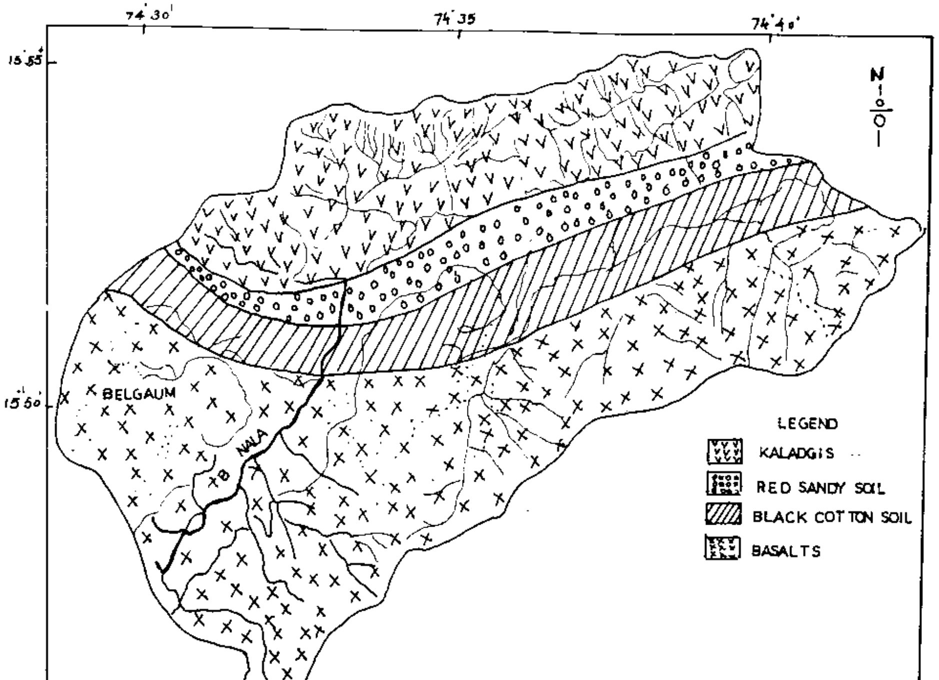


FIG 3 LOCATION MAP OF THE DRAINAGE NALA AND GEOLOGY AROUND BELGAUM

perennial source of fresh water has been severely affected. The cattle drink and bath the same water, the rural children play and take bath in this dirty water out of their ignorance of its after effects and the entire stretch of nala stinks. The outlet of this nala is constrained due to hilly terrain and gentle slopes of the ground . After the growth of the Belgaum city and spread of its utilities the contribution of surface runoff to this nala is decreased many fold and every year the vast stretch of fertile land on either side is flooded for several weeks during rainy seasons. This causes enormous damages to the standing crops on this fertile land thereby depriving the farmers of their fruits of labour and investments.

4.1 Present work

Considering the above factors, in the present study, 15 groundwater samples have been analysed from selected wells in the city area 7 samples have been collected from various locations from the outskirts of the city. INDAL, is one of the Aluminium factory situated close to the Belgaum city which engaged in aluminium processing. Seven samples have been analysed from the factory area to understand the quality of water in and around the INDAL factory area which covers about 1500 acres. Samples have been analysed for the major chemical constituents such as pH, Electrical conductivity, TDS, Nitrite, chloride, Alkalinity, Fluoride, dissolved Carbon dioxide , Ca, Mg, Na, K and Nitrate (as N). Further data have been collected from various studies conducted by various organisations. Information pertaining to water quality and well details are presented in table 1.

5.0 Material and Methods

5.1 Sampling techniques and Preservation

Sample collection in the water column varies in degree from the simplest of hand sampling procedures at a single point to the more sophisticated multipoint sampling technique. However, for the present study water samples have been collected mainly from open wells during the post-monsoon season of 1995 and Pre-monsoon season of 1996. Data have been collected for bore wells.

The samples are drawn from both open and bore-wells. The water samples are collected in plastic container (PVC 2 litre) and sealed. Samples are analysed for major cations and anions. The depth of the water in the respective wells was also measured while collecting samples using graduated steel tap. The quantity of water collected from each well is given as follows.

Table. 1 : Field data of some of the obsaervation wells in Belgaum City area

Station	M.P	PMSWL	TD	DWC	POWSWL	W.Ty	WD	WC	WQ	Purpose
KG	0.86	3.41	42.7	39.29	2.6	OC	4. 35	PM	Salty	D
GS	0.54	1.9	13.46	11.56	1.5	OC	12.28	M	Sweet	D
CW	1.50	5.80	14.10	8.30	3.55	OC	12.28	M	Obj. col.	No use
AG	0.41	8.98	16.81	7.83	5.48	OC	3.74/3.74	PM	Sweet	D
SU	0.30	4.33	7.34	3.01	1.26	OS	7.30/7.30	PM	Sweet	D
KW	0.76	1.39	3.80	2.41	1.24	OS	28.6/28.6	M	Obj. col	D
SG	0.69	15.00	28.00	13.00		OS	6.1/6.1	PM	Obj. col	D
MG	0.64	3.89	22.51	18.62	2.05	OS	6.2	M	Obj. col	D
VT (m)	0.53	3.83	14.32	10.49	3.00	OC	6.1	M	Obj. col/O	No use
VT (s)	0.00	2.00	12.84	10.84	1.30	OC	2.42	M	Sweet	D
SW	0.40	4.33	7.42	3.89	1.35	OC	2.45	M	Sweet	D
Kot (m)	0.50	4.87	8.24	3.37	2.30	OC	9.75	M	Dirty	Other
Kot	0.80	6.18	6.30	0.12	1.25	OC	1.17	PM	Sweeet	D

PMSWL - Pre-monsoon static water level, Post-monsoon SWL, MP-measuring point above ground level, DWT - Depth to water table, TD-Total depth, DWC - Depth to water column, WTY- Well type, WC - Construction of the well,, WQ- Water quality, D- Domestic, I- Irrigation

Abbreviations of locations

1. Kottikere tank (Kot) main and small
2. Math Galli (MG)
3. Virbhadra temple(VT) main and small
4. Congress well (CW)
5. Goodshed (GS)
6. Konwal Galli(KG)
7. Shivaji Udyan (SU)
8. Alwan Galli (AG)
9. Kapileshwara temple (KW)

(i) One bottle of 500 ml for direct measurement of pH, electrical conductivity, temperature and total dissolved solids at the spot in the field while collecting the samples.

(ii) One bottle of 250 ml for chemical analysis of nitrate. These samples were preserved by adding 2 ml of conc. Sulphuric acid (A. R. grade) per litre.

(iii) One bottle of 1000 ml for the chemical analysis of acidity/alkalinity, hardness, chloride, fluoride, sulphate, sodium, potassium, calcium and magnesium.

5.2 Methods of Analysis

Physico chemical analysis is conducted following standard methods as described in UM -26. The physical parameters such as temperature, pH and electrical conductivity are determined in the field at the time of sample collection using portable thermometer, portable pH meter and portable water testing kit. Total dissolved solids (TDS) was also determined using portable kit.

The total hardness and calcium hardness is determined by EDTA titrimetric method and magnesium hardness is determined by deducting calcium hardness from total hardness. Calcium is calculated by multiplying calcium hardness with 0.401 and magnesium by multiplying magnesium hardness with 0.243.

Sodium and potassium parameters are determined by flame emission method using Flame photometer. Chloride concentration is determined by argentometric method in the form of silver chloride. Acidity/alkalinity is determined by titrimetric method using phenolphthalein and methyl orange indicator. Sulphate, nitrate and fluoride concentrations are determined using UV-VIS spectrometer.

6.0 Results and Discussion

6.1 Dissolved Constituents in Ground water

1. pH value

The pH value of water is a measure of hydrogen ion concentration of that water sample. It may be noted that the pH of natural water is 7, acidic water is less than 7, and alkaline water is more than 7. pH value of analysed sample are in the range of 6 - 8.2.

2. Specific Electrical conductance

Water that has high specific conductance induces corrosion of iron and steel. The range of EC for CCB groundwater is 0.157- 4.410 micromhos/cm and the conductivity measured for open wells is 0.16 - 0.86 micromhos/cm.

3. Total Dissolved Solids

The bulk of the total dissolved solids include bicarbonates, sulphates and chlorides of calcium, magnesium, sodium and silica. The total dissolved solids content of ground water may range from 20 ppm in areas of high rainfall to over 100,000 ppm in some desert brines. The range of TDS for CCB ground water is 100-4200 mg/l.

4. Total Hardness (TH)

Hardness is an important criterion for determining the usability of water for domestic, drinking and many industrial supplies.

Hardness has no known adverse effects on health, however, some evidence has been given to indicate its role in heart disease. The hard water is also not suitable for domestic use in washing, cleaning and laundering. The highest desirable value for drinking water standard is 100 mg/l. The range of TH for CCB ground water is 38 - 1588 mg/l.

5. Calcium (Ca)

Calcium occurs in calcareous rocks, such as lime stone, dolomite, gypsum and basic igneous rocks. Because of its widespread occurrence in rocks and soils and its ready solubility, calcium is present in nearly all waters.The desirable limit of calcium for drinking water is 75 mg/l. The range of Ca in bore wells of CCB is 15.14 - 582.85 mg/l and 20 mg/l to 44 mg/l for open wells.

Calcium as such has no hazardous effects on human health. Concentrations upto 1800 mg/l have been found not to impair any physiological reaction in man. The importance of Calcium concentration lies in the fact that its disadvantages in household and industrial uses. High concentration of calcium are not desirable in washing, laundering and bathing owing to its suppression of formation of lather with soap.

6. **Magnesium (Mg)**

In ground water, the calcium content generally exceeds the magnesium content, in accordance with their relative abundance in rocks but contrary to the relative solubilities of their salts. As in the case of calcium carbonate, magnesium carbonate is more soluble in water containing sodium salts.

The recommended desirable limit of magnesium for drinking water standard is 30 mg/l. Magnesium concentration ranges between 17 mg/l and 49 mg/l.

Magnesium is supposed to be non-toxic at the concentrations generally met within natural waters. High concentration may be cathartic and diuretic for the initial user but tolerance is developed after sometime. High concentration combined with sulphate acts as laxative to human beings. Concentration as high as 500 mg/l impart an unpleasant taste to the water, thus rendering it unpalatable. Magnesium adds to hardness of water.

7. **Sodium (Na)**

Sodium content in groundwater ranges from about 1 ppm in humid and snow-fed regions to over 100,000 ppm in brines. In general, there is a concomitant increase in sodium and chloride, the concentration of both increasing with total dissolved solids content. Groundwater in well-drained areas with good amounts of rainfall usually has less than 10 to 15 ppm of sodium.

The range of sodium in CCB groundwater (borewell) is 7.0 - 480 mg/l and in open wells it ranges between 163 and 426 mg/l.

At lower concentration there are no adverse effects on the health. The high concentration of sodium can be related to cardiovascular diseases and in women toxemia associated with pregnancy. Sodium may be of concern in the person having abnormal sodium metabolism. Besides high concentration of sodium associated with chlorides and sulphates to make the water salty and renders it unpalatable.

8. Potassium (K)

Although potassium is nearly as abundant as sodium in igneous and metamorphic rocks, its concentration in groundwater is one-tenth or even one-hundredth that of sodium. Parity in concentration of sodium and potassium is found only in waters with low mineral contents. Two factors are responsible for the scarcity of potassium in groundwater, one being the resistance of potassium minerals to decomposition by weathering (Golditch, 1938) and the other the fixation of potassium in clay minerals formed due to weatehring. The concentration of potassium ranges from 1 ppm or less to about 10 to 15 ppm in potable waters, and from 100 ppm to over several thousand ppm in some brines. Potassium salts, being more soluble than sodium salts, are the last to crystallise during evaporation.

The concentration of potassium is 0-6 mg/l for borewell waters and 0.2 to 102.5 mg/l in open well waters. This high value of Potassium (K) is observed near the dump site.

9. Chloride (Cl)

Chloride is the main constituent of the earth's crust, but a major dissolved constituent of most natural waters. Usually water high in chloride is also high in sodium. Chloride content varies between 0.1 ppm in arctic snow and 1,50,000 ppm in brines. Shallow groundwater in regions of heavy precipitation generally contains less than 300 ppm of chloride. Concentration of 1,000 ppm or more are common in ground water.

The chloride concentration is harmless upto 1500 mg/l but produces a salty taste at 250 mg/l to 500 mg/l. The range of chloride in ground waters of the CCB varies between 30 and 276 mg/l for bore wells and in open wells it varies from 248 mg/l to 567 mg/l.

10. Fluoride (F)

Fluoride derived from fluorite and the minerals apatite and mica, is generally present in only low concentration in ground water. Volcanic and fumeralic gases can contain fluoride, and in some areas may be the source of fluoride in groundwater.

The concentration of fluoride in groundwater doesnot exceed 10 mg/l. But water for drinking purposes containing 1 mg/l to 0.5 mg/l may cause mottled tooth enamel in children and in adults. If fluoride is less than 0.5 mg/l then also similar effects result. Hence fluoride content should be around 0.9 mg/l to 1 mg/l. The range of fluoride varies from 0.13 mg/l to 0.75 mg/l in bore wells and 0.1 mg/l to 1.08 mg/l.

11. **Sulphate (SO_4)**

The sulphate content of atmospheric precipitation is only about 2 ppm, but a wide range in sulphate content in groundwater is made possible through reduction by precipitation, solution and concentration, as the water traverses through rocks. It is reported that in arid and semi-arid regions , it is found in particularly higher concentration due to the accumulation of soluble salts in soil and shallow aquifer. Rain water has quite high concentration of sulphate particularly in the areas of high atmospheric pollution.

Concentration of Sulphate in bore wells ranges between 8.5 and 129 mg/l. The concentration in open wells varies from 14.9 mg/l to 57.7 mg/l.

12. **Nitrates (NO_3)**

Nitrate represent the highest oxidised form of nitrogen. The most nitrates in natural water come from organic sources or from industrial and agricultural fertilisers. Nitric oxides produced in atmosphere by lightning discharges are added in the form of nitrate to water. Normal water contains only 0.1 to 10 ppm of nitrate. Nitrate compounds are highly soluble and encourages the growth of primitive plants.

Groundwater, when not polluted, contains less than 5 ppm of nitrates, but polluted waters contain up to 100 ppm; or even more. Some brines attain very high nitrate concentrations. Groundwater contamination in CCB is 0.38-120 mg/l.

In cattle, the high concentration of nitrates is reported to cause more mortality in pigs and calves and abortion in some animals. In waste treatment systems, high amount of nitrate denote the aerobic conditions and stability of the waste.

13. **Carbonate and Bicarbonate (CO_3, HCO_3)**

The primary source of carbonate and bicarbonate ions in ground water is the dissolved carbon dioxide in rain (and snow) which, as it enters the soil, dissolves more carbon dioxide.

An increase in temperature or decrease in pressure causes reduction in the solubility of carbon dioxide in water. Decay of organic matter may also release carbon dioxide for dissolution.

The pH of the water indicates the form in which carbon dioxide is present. Presence of carbonic acid is indicated when pH is less than 4.5, of bicarbonate is pH between 4.5 and 8.2, and of carbonate in pH over 8.2.

Water charged with carbon dioxide dissolves carbonate minerals, as it passes through soil and rocks, to give bicarbonates. Carbonate dissolution from rocks and precipitation from water is a two way process dependant on the partial pressure of carbon dioxide. Under normal conditions in hard rock areas the bicarbonate concentration in ground water ranges from 100 to 800 ppm. The bicarbonate content is fairly constant because of only small variations in the partial pressure of carbon dioxide in the interstitial pores of the rocks in the aeration zone. It is observed that the carbonate content varies widely between 0 and 30 mg/l. Bicarbonate content varies between 244 mg/l to 366 mg/l.

The results obtained from the analyses of water samples are used for evaluation of water quality and suitability for drinking and irrigation. The graphical analysis also can be carried out to find out the water quality.

The Ground water analysis of the Belgaum City area show concentrations of various constituents within the permissible limits. However, higher values of sodium and potassium are reported in many of the samples which is attributed to sewage water pollution and fertiliser used in the area. Almost all the samples show high to very high values of total hardness. In few localities nitrate concentration is also seen. Most of the wells which are showing higher concentration of contaminants is mainly in the unused wells. Renovation and utilisation of the ground water will improve the quality of the water. The analyses of the samples from INDAL area shows (table.2) that the water quality is not affected by the bauxite processing plant situated within the INDAL campus. All the chemical parameters observed in and around the Indal campus are well within the permissible limit. However, in some of the wells the concentration of sodium is higher than the values reported from other parts of the city.

Water samples were also collected from the solid waste disposal silter at Khasbhag and wells besides the Bellary nala drain show increasing concentrations of Ca, Mg and Na away from the drain and potassium decreases away from the drain (fig. 4 & 5). The increasing could be due to use of sewage water for the agricultural purpose. It is observed that

Table.2: Water Chemistry of the samples collected from wells in and around INDAL campus

Chemical Const.	St 1	St 2	St 3	St 4	St 5	St 6	St 7
Ph	7.2	7.2	7.40	7.80	7.60	7.6	8.10
EC	0.421	0.37	0.35	0.81	0.16	0.30	0.68
CO3	-	1.00	1.00	1.00	-	-	-
HCO3	6.0	5.00	6.00	5.00	6.00	7.00	5.00
Ca	1.8	1.60	1.80	1.20	2.20	2.80	1.20
Mg	2.4	3.00	2.80	3.00	2.60	2.20	4.00
Na	7.09	21.00	18.00	13.36	13.09	11.43	17.16
Cl	7.00	17.00	14.00	13.00	11.00	10.00	18.00
SO4	0.35	0.63	0.85	0.37	0.43	0.71	0.50
SAR	10.12	13.09	12.50	11.72	8.45	7.77	10.06

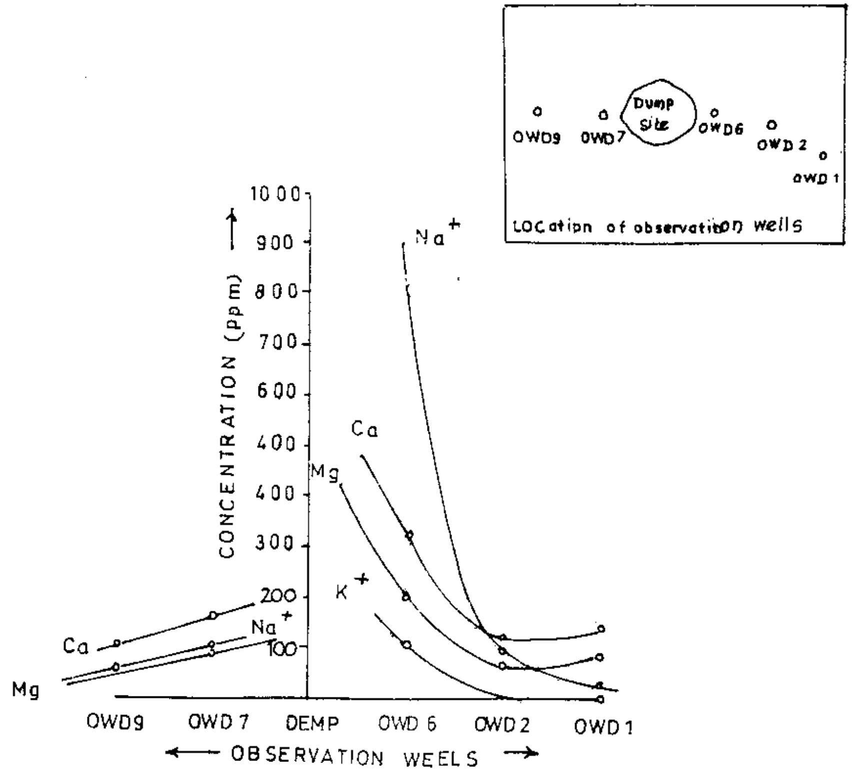


Fig 4 :- Concentrations of Na^+, Ca, Mg, and K^+ in observation wells around waste dump site
(After Suresh'96)

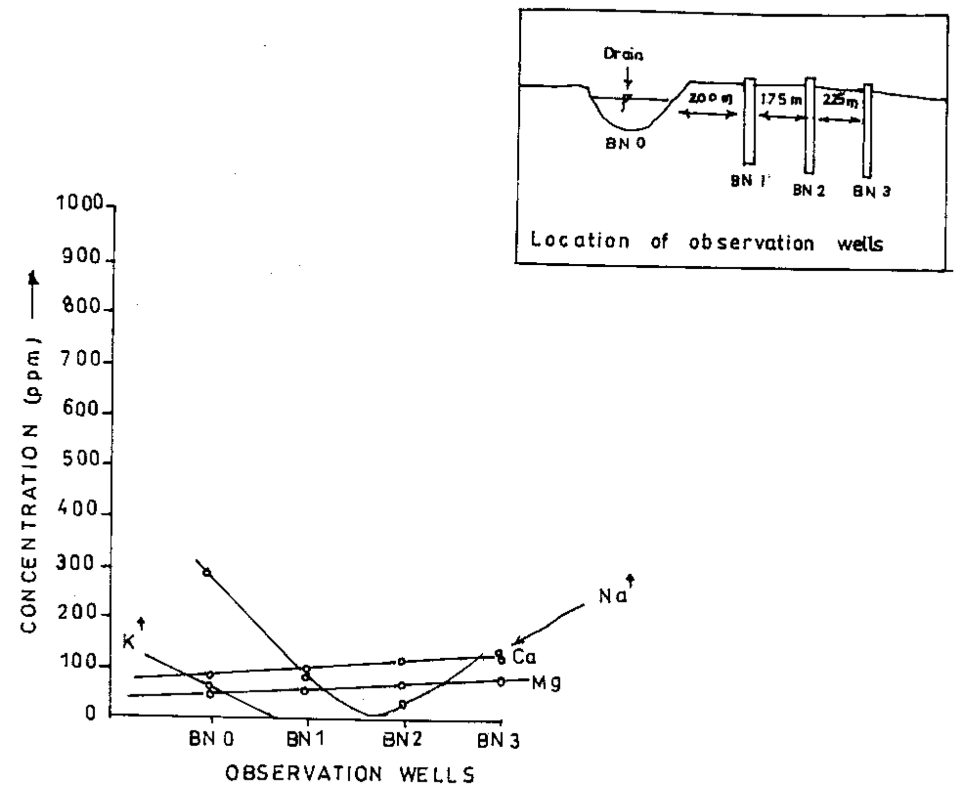


Fig: 5 - Concentration of Na, K, Ca and Mg across Bellory Nala samage drain (After Suresh'96) these constituents are not added to the groundwater from the drain seepage. Instead, it is expected that the constituents are being added to the groundwater region through sewage and fertilisers used for agricultural purposes.The bore well data collected from the GIT, Belgaum show that the Nitrate content varies widely between 0.3 mg/l and 120 mg/l. This clearly indicate that most of the ground water are contaminated with surface sewage waters. Calcium content also showed an increase especially in bore well waters above the permissible limits. The specific locations are Gandhinagar, Shetty galli, Bapat galli, Hudco colony. In bore well waters the TDS content is relatively low and it causes health problems related to digestive system. However, in majority of the open wells it is well within the limits.As reported by Swapneel Bhadale et al (1996), the groundwater from the borewells possess carbonate hardness which exceeds 50%, i.e., chemical properties are dominated by alkaline earth and weak acids from the facies of Back (1966). The ground waters are non-corrosive and belongs to rock dominance class of Gibbs (1970). Some of the samples are highly polluted/contaminated. These areas are Khasbhag, Vadagaon, Shahapur, Main market areas (Bogarves. Khadebazar, Maruti galli, Old Belgaum).

6.2 Diagrammatic Representation of Geochemical 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 characteristics 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.

The dominant ions, Ca, Mg, Na + K, HCO3 + CO3 , SO4 and Cl in a water sample can be represented by in several ways. For these representations , the epm values are most commonly used. Progressive changes in the geochemical characters of a large number of samples can best be studied by plotting selected constituents on bilinear and trilinear diagrams. Such diagrams can show the relation between concentrations of various constituents or groups of constituents. Thus, on a two coordinate field, the relation between the concentrations of calcium, magnesium, sodium, bicarbonate, sulphate, chloride, etc. and total dissolved solids can be studied . Among the various trilinear methods of plotting (Palmer, 1911; Hill, 1940; Piper, 1953), Piper's diagram (fig 6) has been extensively used to understand problems about the geochemical evolution of groundwater. The diagram consists of three 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 earths) and Na (alkali), and anions, HCO3 (weak acid) and SO4 and Cl (strong acid). The

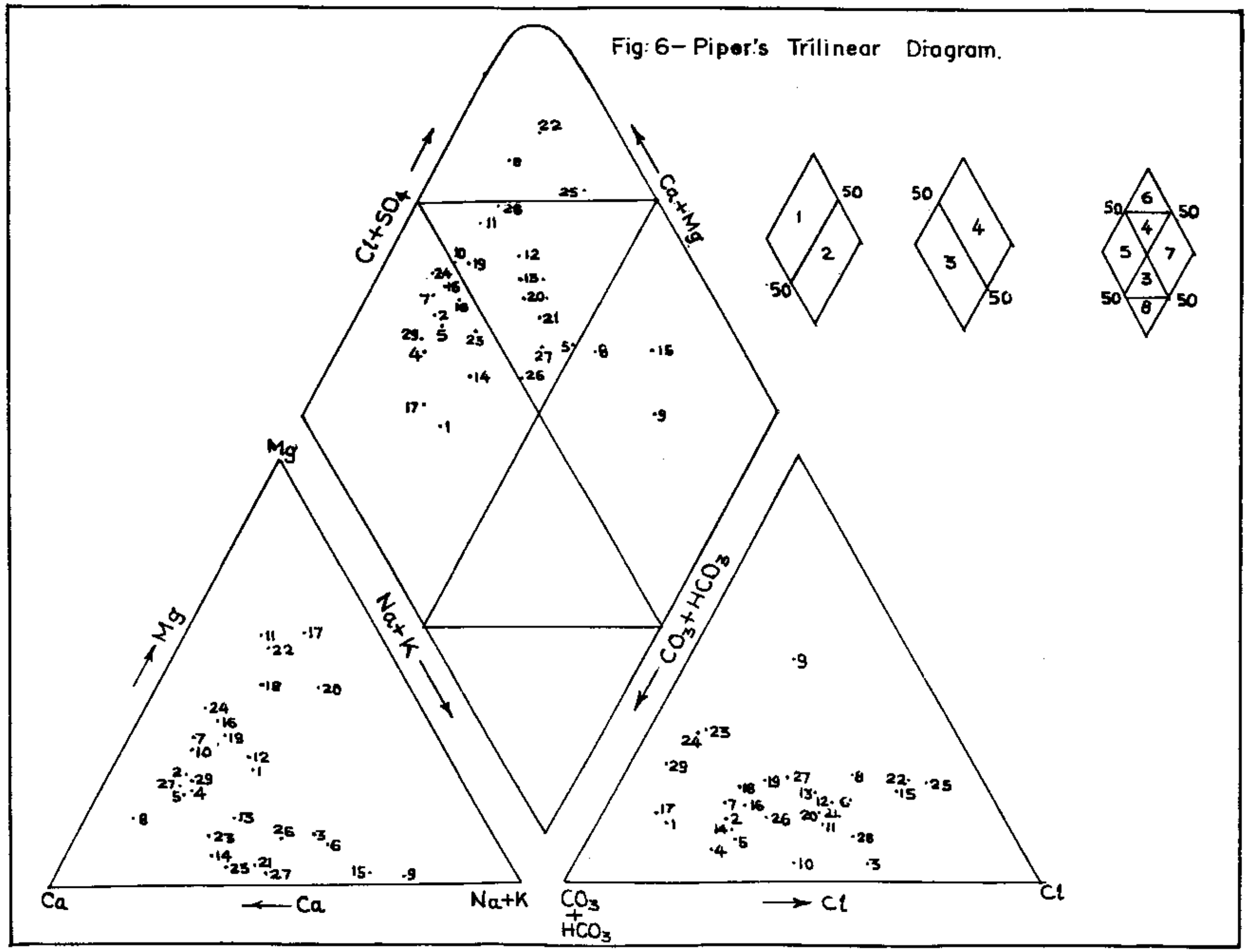


Fig: 6 – Piper's Trilinear Diagram.

overall characteristic 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 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%,i.e. chemical properties of the water are dominated by alkaline earths and weak acids.
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 subarea
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%.

Progressive changes in the geochemical characteristics of a large number of water samples can best be studied by plotting selected constituents on bilinear and trilinear diagrams. The chemical relationship of the samples of groundwater in Piper trilinear diagram shows that the cations and anions are evenly distributed in the triangular fields. In the diamond shaped fields the chemical ions are grouped in four areas, viz.,

(i) Strong acids exceeds weak acids
(ii) Carbonate hardness exceeds 50%, i.e., chemical properties of the water are dominated by alkaline earths and weak acids.
(iii) Non-carbonate hardness exceeds 50%.
(iv) Non-carbonate alkali exceeds 50%.

The ionic distribution in the Piper's diagram indicate the different geochemical environment present in the study area.

6.3 Gibb's Diagram

The mechanism controlling world water chemistry has been described by Gibbs (1970). The Gibbs diagram is being used to understand the factors controlling groundwateer chemistry also. Many workers like Vishwanathaiah et al (1978)*, Puranik et al (1981)*, Balasubramanian and Shastri (1987)*, Renuka Prasad (1989)* and many others have used it for this purpose.

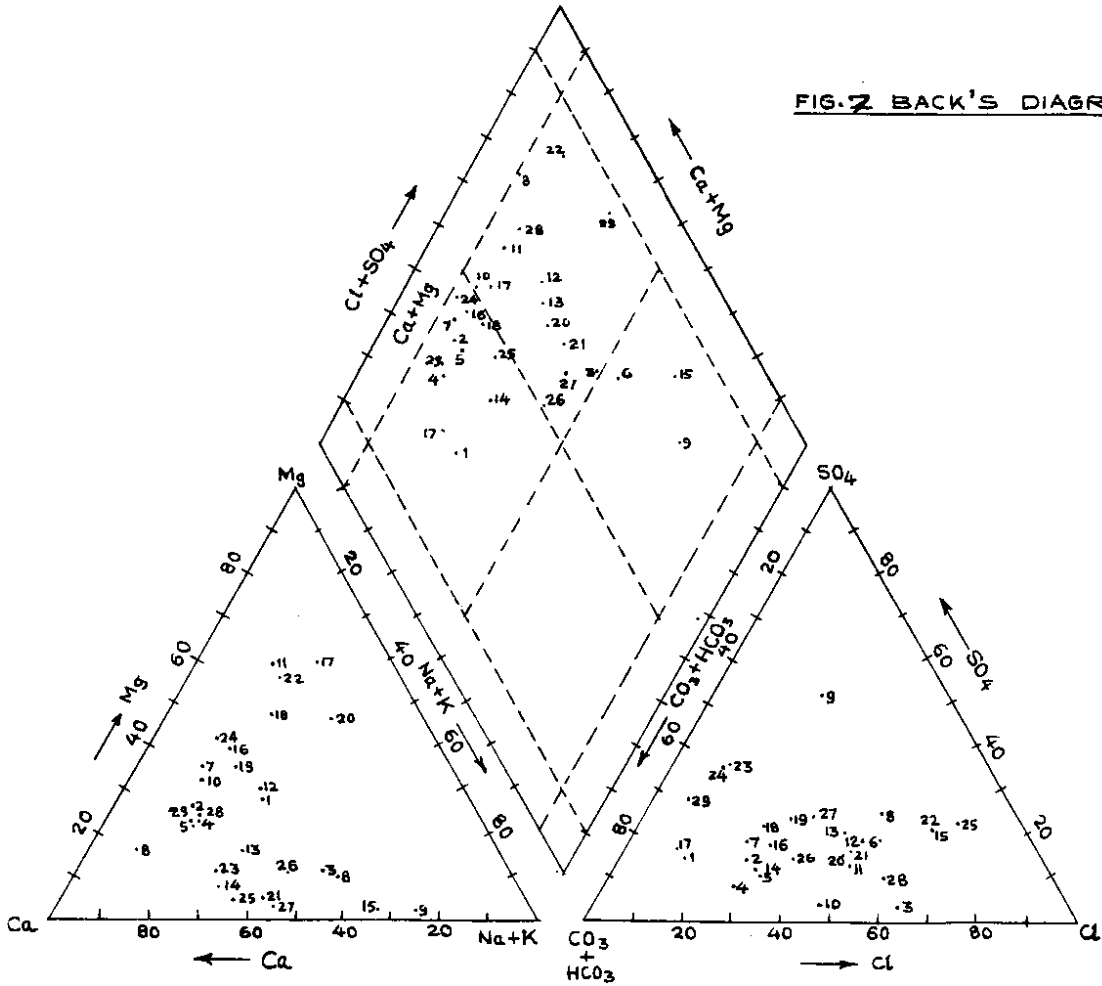
6.4 Back's Hydrochemical Analysis

The concept of hydrochemical facies was introduced by Back (1966). He has distinguished various hydrochemical facies as given below. In this method, chemical classification of analytical data expressed in percentage of epm and plotted in trilinear diagram.

Back (1966) has identified two facies. Further division have been made into chemical type based on the dominant anion in the particular type of facies. The overall character of water is indicated by both the cation and anion facies. Back opines that the origin of particular hydrochemical facies is mainly controlled by geology while hydrogeology controls the spatial distribution of facies. The plots of groundwater under study has been plotted in the diagram and are classified into three hydrochemical facies using classification (table 3) given by Back (1966) are described below, (fig. 7).

Thus, it is clear that among cation Ca+Mg - Na + K dominate over Ca + Mg and other facies. Among anion facies HCO_3+Cl+SO_4 facies dominate over all other facies, but one sample makes its presence in HCO_3 facies. Fig. 8 shows the Gibb's diagram drawn for groundwater samples of CCB area which lies in the rock dominance field. The study reveals that the quality of groundwater is affected by the parent rock/aquifer. Here the plots are made against the ratio of (Na/Na + Ca) and (Cl/Cl + HCO3) to know the mechanism controlling the chemistry of groundwater . The plots fall in the Central field indicating the chemistry of ground water is due to interaction between lithological units and infiltering precipitated water into subsurface.

FIG. 7 BACK'S DIAGRAM



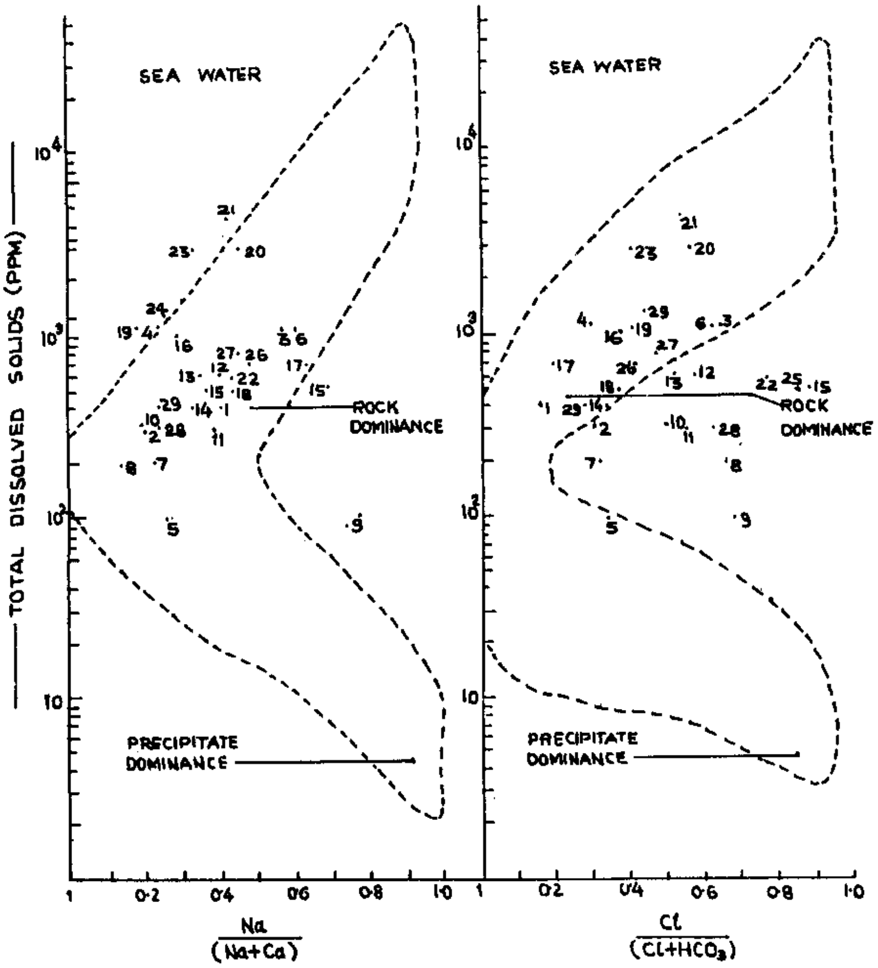


FIG. 8 GIBB'S DIAGRAM SHOWING THE MECHANISM CONTROLLING GROUNDWATER CHEMISTRY

Table 3 : Hydrochemical classification by Back (1966)

Facies	Ca + Mg	Na + K	HCO3 + CO3	Cl + SO4
1. Cation				
Ca-Mg	90 - 100	0 - 100	--------	--------
Ca-Na	50 - 90	10 - 50	--------	---------
Na-Ca	10 - 50	50 - 90	--------	---------
Na-K	0 - 10	90 - 100	--------	----------
2. Anion				
HCO3	------	------	90 - 100	0 - 10
HCO_3-Cl-SO_4	------	------	50 - 90	10 - 50
Cl-SO_4-HCO_3	------	------	10 - 50	50 - 90
Cl-SO_4	-------	-------	0 - 10	90 -100

Water suitability classification is given in table 4.

Table 4 : Suitability classification

Parameters	WHO International Standards (1971)		Indian Standards Institution (1983)		ICMR		Study Area	
	Highest desirable	Max. permissible	High. desir.	Max.permissible	Max. Perm.	Min. Allow.	Min	Max
pH	7.5-8.5	6.5-9.2	6.5-8.5	8.5-9.2	7.0-8.5	6.5-9.2	5.89	9.06
TDS	500	1500	500	1500	-	-	40	920
TH	100	500	300	600	-	-	74	680
Ca	75	200	75	200	77	200	18.4	201.9
Mg	30	150	30	100	50	150	3.5	157.1
Cl	200	600	250	1000	250	1000	5.4	183.1
SO4	200	400	150	400	200	400	1.3	44.7
Fe	0.05	1.5	0.3	1.0	-	-	0.063	3.68

All values are in mg/l except pH

6.5 Irrigation Use

The classification of irrigation water with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil.

Low Sodium water(Class S1) can be used for irrigation on almost all soils with little danger of the devlopment of harmful levels are exchangeable sodium.

Medium Sodium water (Class S2) will present an appreciable sodium hazard in fine textured soils of high cation exchange capacity. This water may be used on coarse-textured or organic soils that have good permeability.

High sodium water (Class S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management and good drainage.

Very high sodium water (Class S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity. The solution of calcium from the soil or use of gypsum or other constituents may improve the quality of the water (S4) for irrigation.

Generally, C1-S1 and C2-S1 is said to be of good quality, C1-S2, C2-S2, C3-S2 and C2-S1 tolerable quality and the rest are of bad quality.

Water samples analysed for the present study shows (table 5) that most of the samples lie within the S1 and S2 category and salinity zone lies in C1 to C3 zone.

7.0 Conclusions

Groundwater pollution studies in our country is mainly limited to know the distribution of various chemical constituents both in time and space. However, hydrological and hydrogeological aspects are still not taken up in an extensive manner. Groundwater pollution is essentially a product of contaminating solutes and formation water. Study of the phenomenon requires evaluation of source nature and strength of pollutants on one hand and magnitude of changes caused by them on the invaded soils, aquifer material and groundwater on the other. To understand the actual chemical behaviour in groundwater, it is essential to know the source or the strata from which it is derived.

Stratigraphically the area is covered mostly by weathered rocks except in certain patches (fig .9). It is expected that lessweathered zones is capable of releasing good quantity of major cations such as Na, K, Ca, Mg, and SiO_2 and on weathering rarely sulphates. As it is evident from the available data, the distribution pattern of chemical elements indicate its origin from various geochemical environment. Hence, we have to look for a different origin of HCO_3, Cl and NO_3 and in most cases, also SO_4. As to bicarbonates the source is carbon dioxide released by plant roots and the decomposing organic matter in soils. The weathering action of carbondioxide on primary minerals can be described as a break down of the silicate with release of the cations which will appear as bicarbonates. As the bicarbonates concentration increases, the breakdown of primary minerals decreases despite the high carbon dioxide pressure. The reason for this is the increasing pH following the increase in bicarbonates. The weathering is very slow at pH value between 7 - 8, judging from the chemistry of groundwater in crystalline rock areas. This is true in the present case as in most of the observations, the ph value falls between 7 and 8. Chemical weathering is mostly completed before the water reaches the groundwater table.

Table 5 : EC and SAR Values of selected water samples collected from Belgaum city

Sl no	Station no	EC mmhos/cm	SAR
1	P_6	0.34	12.53
2	P_7	0.52	10.00
3	P_{10}	0.54	8.77
4	P_{11}	0.21	6.79
5	P_{12}	0.61	8.13
6	P_{13}	0.56	12.01
7	P_{14}	0.26	3.61
8	P_{15}	0.10	8.65
9	P_{16}	0.37	9.62
10	P_{17}	0.41	11.5
11	P_{18}	0.23	13.0
12	P_{19}	0.25	12.01
13	P_{20}	0.32	7.98
14	P_{21}	0.39	11.05
15	P_{22}	0.13	11.20
16	S_3	0.41	10.00
17	S_2	0.86	11.67

An analysis of the data collected, followed by field investigations and discussion held with various scientists working in this area indicated that ground water is getting contaminated, especially, due to waste disposals without any precautions. Suresh (1996) reported that the constituents from the waste sites are being added to the groundwater region. However, away from the dump site the concentration diminished to an acceptable level. This observation it is necessary to go for sewage treatment plants so that the pollution due to use of these water by farmers and mixing of sewage with groundwater can be minimised.

8.0 Recommendations

In view of reported ground water pollution in several parts, 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 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 disposal and hydrogeological conditions prevalent in different areas. For planning water supply schemes in pollution prone areas where ground water is the only or major source of supply, it may be necessary to carry out monitoring on top priority basis to delineate affected areas. As amelioration of aquifer which has already been affected by pollution is very difficult, delineation of pollution prone areas will help in taking steps to stop further pollution.

For pollution monitoring and control programs to be effective, multi -disciplinary approach and greater cordination between different agencies, is required. Ground water pollution monitoring is highly specialised work for which not only system is required for collection, processing and dissemination of environmental information but also specialised instruments are required for analytical work. Some of the important factors to be considered in controlling pollution problems are the following.

The wastage of water which amounts to about 20% delivered should be brought under control by replacing the pipelines which are old and damaged. These would also reduce the often noticed intermixing of sewage with drinking supplies. The city drainage should be diverted through lined gutters or pipes to the treatment plants to protect local health and hygiene besides shallow groundwater.

There is a need to recognise the rapid rate at which ground water pollution is taking place at present. Groundwater pollution is a serious threat to the society and if we allow further decay of environment, it will not be possible to sustain long term growth,

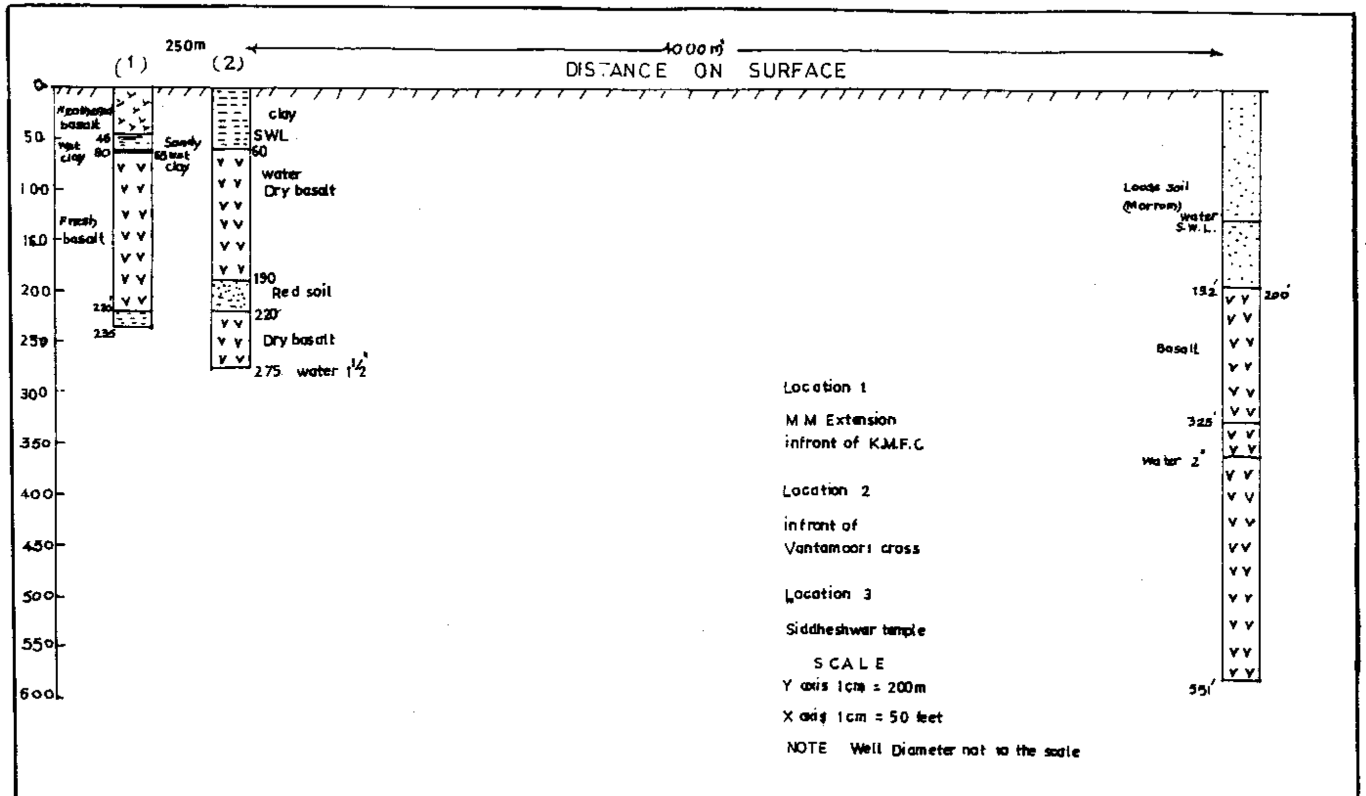


Fig: 9 – Litho logs Belgaum area

development and prevent hazards to public health unless immediate steps are taken. It has become vital important that various agencies connected with ground water pollution should take cognisance of the situation and there is fortification of efforts for safe guarding ground water resources and for implementation of pollution prevention and control programs.

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* Cross references (are not listed)

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