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GROUND WATER QUALITY MAPPING AND SURVEILLANCE FOR SAFE WATER SUPPLY IN DISTRICT HARDWAR, UTTARAKHAND

Bahadrabad Block

आपो हिष्टा मयोभुवः

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PREFACE

Ground water forms the major source of water supply for drinking purposes in most part of the country. For proper utilization of water for various purposes, understanding of geo-chemical controls and study of the extent of ground water contamination are of prime importance. The quality of ground water is particularly important to humans when the water is used for drinking water supply. The quality of ground water varies from place to place along with the depth of water table. It also varies with seasonal changes and is primarily governed by the extent and composition of dissolved solids present in it.

The creation of new state of Uttarakhand has posed many challenges for the planners and policy makers. For sustainable development of a society it is essential that the natural resources are made use of, in judicious manner for the benefit of not only existing population but also to meet the needs and aspiration of future generations. Drinking water is one such precious commodity for which a planned strategy is needed not only for immediate demands but for sustainability for the future needs also. There are wide number of activities that are associated with man's introduction of foreign chemical and biological materials in the subsurface environment. Bacteriological parameters are of great importance from human point of view.

In context of the above scenario, Environmental Hydrology Division of the Institute has taken up a study on Ground Water Quality Mapping and Surveillance for Safe Water Supply in District Hardwar, Uttarakhand. In this report analysis results of Bahadrabad Block have been discussed. The report has been prepared by Dr. C. K. Jain, Sc. 'F' and Head of the Environmental Hydrology Division under the work programme for the year 2013-14. Other Scientists and Staff involved in the study include Dr. Rama Mehta, Sc. 'D', Dr. S. K. Sharma, Sc. 'B', Sri. Yatveer Singh, PRA and Smt. Babita Sharma, RA. I hope that the report will be of immense use to the planners, scientists and engineers concerned with the management and protection of ground water quality in Bahadrabad Block of District Hardwar (Uttarakhand).

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ABSTRACT

The ground water quality of Bahadrabad Block in District Hardwar has been assessed to see the suitability of ground water for domestic and irrigation applications. Fifty two ground water samples from various abstraction sources were collected and analysed for various water quality constituents. The hydro-chemical and bacteriological data was analyzed with reference to BIS and WHO standards, ionic relationships were studied, hydrochemical facies were determined and water types identified. The concentration of total dissolved solids exceeds the acceptable limit of 500 mg/L in 42.3% of the samples analyzed but the values are well within the permissible limit of 2000 mg/L. The alkalinity values exceed the acceptable limit of 200 mg/L in 76.9% of the samples but these are also within the permissible limit of 600 mg/L. From the hardness point of view, more than 80% of the samples exceed the acceptable limit of 200 mg/L but these are also within permissible limits. Two samples of the study area exceed the acceptable limit of 45 mg/L for nitrate. Higher concentration of nitrate at these locations may be attributed due to improper sanitation and unhygienic conditions around the structures. Other constituents like chloride, sulphate and fluoride are within the acceptable limits.

The bacteriological analysis of the ground water samples indicates bacterial contamination at few locations. Inadequate maintenance of hand pumps, improper sanitation and unhygienic conditions around the structure may be responsible for bacterial contamination in ground water of the region and is a cause of concern. It is recommended that the water drawn from such sources should be properly disinfected before being used for drinking and other domestic purposes.

The presence of heavy metals in ground water has been recorded at many locations. The water quality standards have been violated for iron, manganese and nickel at many locations. The concentration of iron varies from 3002 to 19771 μg/L as against the acceptable limit of 300 μg/L. The concentration of manganese varies from 5.5 to 2712 μg/L as against the permissible limit of 300 μg/L and concentration of nickel varies from 63 to 527 μg/L as against the permissible limit of 20 μg/L. The concentration of copper, chromium, lead, cadmium and zinc were found well within the permissible limits at most of the locations.

An attempt has also been made to classify the ground water on the basis of different classification schemes, viz., Piper trilinear, Chadha's diagram and U.S. Salinity Laboratory classifications. The grouping of samples according to their hydrochemical facies indicates that all the samples of the study area fall under Ca-Mg-HCO_3 hydrochemical facies. The suitability of ground water for irrigation purpose has been evaluated based on salinity, Sodium Adsorption Ration (SAR), Residual Sodium Carbonate (RSC) and boron content. In general the ground water of Bahadrabad Block is safe for irrigation purpose. According to U.S. Salinity Laboratory classification of irrigation water, about 50% of the samples fall under water type C2-S1 and about 50% under water type C3-S1 type.

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1.0 INTRODUCTION

Water is an essential and vital component for our life support system. In tropical regions ground water plays an important role with context to fluctuating and increasing contamination of water resources. Ground water has unique features, which render it particularly suitable for public water supply. It has excellent natural quality, usually free from pathogens, colour and turbidity and can be consumed directly without treatment. Ground water is widely distributed and can be frequently developed incrementally at points near the water demand, thus avoiding the need for large-scale storage, treatment and distribution system. It is particularly important as it accounts for about 88% safe drinking water in rural areas, where population is widely dispersed and the infrastructure needed for treatment and transportation of surface water does not exist. Ground water plays an important role in agriculture, for both watering of crops and for irrigation of dry season crops. It is estimated that about 45% of irrigation water requirement is met from ground water sources. Industrial demands for ground water are also high, as many of the qualities which make ground water a preferred source of potable water (low TDS, low turbidity, absence of pathogens) are also important in use of ground water in various industries.

Unfortunately, the availability of ground water is not unlimited nor it is protected from deterioration. In most of the instances, the extraction of excessive quantities of ground water has resulted in drying up of wells, damaged ecosystems, land subsidence, salt-water intrusion and depletion of the resource. Ground water quality is being increasingly threatened by agricultural, urban and industrial wastes. It has been estimated that once pollution enter the subsurface environment, it may remain concealed for many years, becoming dispersed over wide areas of ground water aquifer and rendering ground water supplies unsuitable for consumption and other uses. The rate of depletion of ground water levels and deterioration of ground water quality is of immediate concern in major cities and towns of the country.

The intensive use of natural resources and the large production of wastes in modern society often pose a threat to ground water quality and have already resulted in many incidents of ground water contamination. Pollutants are being added to the ground water system through human activities and natural processes. Solid waste from industrial units is being dumped near the factories, which is subjected to reaction with percolating rain water and reaches the ground water level. The percolating water picks up a large amount of dissolved constituents and reaches the aquifer system and contaminates the ground water.

The newly created state of Uttarakhand has been in utter neglect in the past in the area of infrastructure development. The hill region has remarkable heterogeneity in all its cultural and natural environments. The terrain is evidenced by a variety of land formations viz. snow covered peaks, gorgeous mountains, steep escarpments, deep gorges, hanging valleys, fascinating glaciers and bewitching lakes, gushing streams, swiftly falling and foaming rivers, lush green meadows and vast forest lands.

A vast stretch of land (62.5%) in the state of Uttarakhand is covered by forests and the land available for the cultivation, on an average, stands at 14.23%. The population composition of Uttarakhand is heavily rural based. The share of rural population stands at about 77% while rest of the 23% is concentrated in the urban areas. It is noteworthy that the three most populated districts of Nainital, Dehradun and Haridwar contribute about 43% of the total rural population of Uttarakhand whereas their share in the total urban population is about 83%. In all, these three districts share about 52% of the population and 23% of the land area.

The creation of new state has posed many challenges for the planners and policy makers. The problems such as drinking water, transportation, power sector, housing and construction and safety against natural hazards are very serious and require immediate attention. For sustainable development of a society it is essential that the natural resources are made use of, in judicious manner for the benefit of not only existing population but also to meet the needs and aspiration of future generations. Drinking water is one such precious commodity for which a planned strategy is needed not only for immediate demands but for sustainability for the future needs also. A large part of the state of Uttarakhand lies in the hills, where distribution of drinking water supply and its quality is a major problem needing immediate attention. About 90% of the rural population of this region depend upon the natural springs for their daily water demand. However, due to population pressure, unplanned construction, garbage disposal and change in land use patterns, the water of these springs is becoming contaminated besides declining the discharge of these springs.

There are wide number of activities that are associated with man's introduction of foreign chemical and biological materials in the subsurface environment. In the long run the most potentially hazardous of these may be the use of chemical pesticides in agriculture. But it is possible that tremendous use of chemical fertilizers as plant nutrients may be a more significant problem, causing an increasing build up of nutrients in some ground waters. Bacteriological parameters are of great importance from human point of view. It is highly essential to examine the presence of toxic substances and pathogenic organisms in distribution water for potable purposes. Experience has established the significance of coliform group density as a criteria of the degree of pollution and thus of sanitary quality. The significance of the various tests and the interpretation of results are well authenticated and have been used as a basis for standards of chemical and bacteriological quality of water supplies.

In context of the above scenario, it is essential to monitor and evaluate drinking water quality and its suitability before it is used for drinking purpose. It is therefore proposed to examine suitability of ground water in the state of Uttarakhand through comprehensive monitoring of various water quality constituents including natural contaminants. This will provide a proper basis for the judicial management of the drinking water supplies schemes in the state.

In this report, ground water quality of Bahadrabad Block in District Hardwar has been studied with the objective to examine the suitability of ground water for drinking and irrigation applications. In order to achieve the objectives of the study, ground water samples from Bahadrabad Block in District Hardwar were collected representing various geo-hydrological and land use conditions during pre-monsoon seasons in 2013 and analysed for various water quality constituents. The data has been analysed with reference to BIS and WHO standards, ionic relationships were studied, hydrochemical facies were determined and water types identified. An attempt has also been made to classify the ground water on the basis of different classification schemes, viz., Piper trilinear diagram, Chadha's diagram and U.S. Salinity Laboratory classification.

2.0 BAHADRABAD BLOCK, DISTRICT HARDWAR

District Hardwar is a part of the Indo-Gangetic plains and lies between latitude 29°30' to 30°20' N and longitude 77°40' to 78°25' E in the State of Uttarakhand (Fig. 2.1). The scenic and beautiful State of Uttarakhand formerly known as Uttaranchal was carved out of the State of Uttar Pradesh in 2000 and became the 27th State in India. The Population of Uttarakhand according to the 2011 census stands at about 10 million, making it the 20th most populated State in India. The State of Uttarakhand experiences beautiful climate throughout the year and the location close to the Himalayas has prompted an increase in the population in recent times. The State is spread over an area of about 53000 km^2 and thus it is one of the smaller states in the country. The density of population per km^2 is about 189 and fairly below the national average. The State has a growth rate of about 19% which slightly exceeds the national growth rate of about 17%. The population of the State is rising considerably due to rapid efforts towards development and progress. The literacy rate in the state is about 80% a figure that has improved tremendously in the last few years due to the consistent efforts of the government. The sex ratio in Uttarakhand exceeds the national average by 20 points. The statistics in the Uttarakhand Census 2011 reveal facts that can be instrumental in planning for a better development plan for the State. The ISOCODE assigned by International Organization for Standardization for Uttarakhand State is UK.

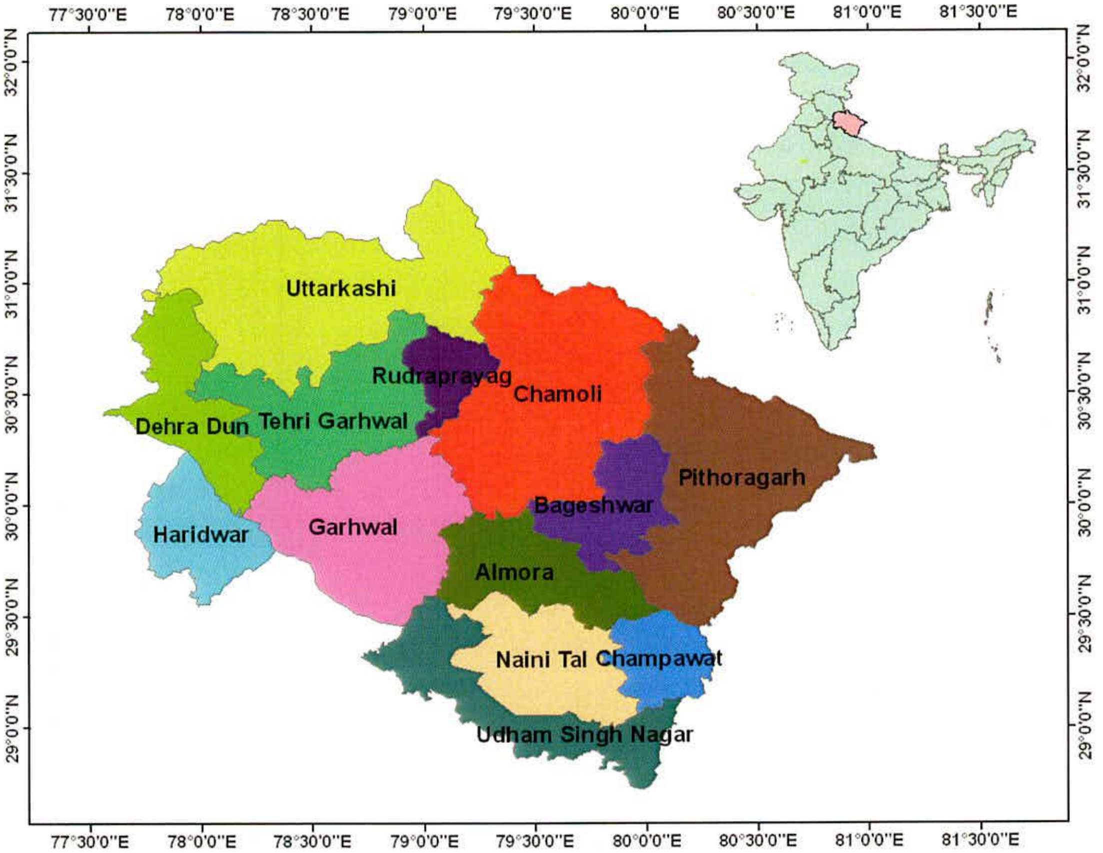

Fig. 2.1 Location of Different Districts in Uttrakhand State

As per details from Census 2011, Uttarakhand State has population of 1.01 Crores, an increase from figure of 84.89 Lakh in 2001 census. Total population of Uttarakhand as per 2011 census is 1,00,86,292 of which male and female are 51,37,773 and 49,48,519 respectively. In 2001, total population was 84,89,349 in which males were 43,25,924 while females were 41,63,425.

Literacy rate in Uttarakhand State has seen upward trend and is 78.82 percent as per 2011 population census. Of that, male literacy stands at 87.40 percent while female literacy is at 67.06 percent. In 2001, literacy rate in Uttarakhand stood at 71.62 percent of which male and female were 81.02 percent and 63.36 percent literate respectively.

Total area of Uttarakhand State is 53,483 km^2. Density of Uttarakhand is 189 per km^2 which is lower than national average 382 per km^2. In 2001, density of Uttarakhand was 159 per km^2, while nation average in 2001 was 324 per km^2.

The Uttarakhand State comprises of 13 districts. The district wise area and population of Uttarakhand State is presented in Table 2.1. The District Hardwar occupies an area of about 2,360 km^2. It is the largest district of Uttarakhand (population wise) and 10^{th} (area wise). As per the 2011 census, the population of the District Hardwar is 18,90,422 with 10,05,295 males and 8,85,127 females. The population density in the district is 801 per km^2. Location of different blocks in District Hardwar is shown in Fig. 2.2 and Block wise area and population is presented in Table 2.2.

Table 2.1 District Wise Area and Population of Uttarakhand State

District	Headquarters	Area (km^2)	Population		
			Male	Female	Total
Hardwar	Hardwar	2,360	10,05,295	8,85,127	18,90,422
Dehradun	Dehradun	3,088	8,92,199	8,04,495	16,96,694
Almora	Almora	3,144	2,91,081	3,31,425	6,22,506
Bageshwar	Bageshwar	2,241	1,24,326	1,35,572	2,59,898
Chamoli	Chamoli Gopeshwar	8,030	1,93,991	1,97,614	3,91,605
Champawat	Champawat	1,766	1,31,125	1,28,523	2,59,648
Nainital	Nainital	4,251	4,93,666	4,60,939	9,54,605
Pauri Garhwal	Pauri	5,329	3,26,829	3,60,442	6,87,271
Pithoragarh	Pithoragarh	7,090	2,39,306	2,44,133	4,83,439
Rudra Prayag	Rudraprayag	1,984	1,14,589	1,27,696	2,42,285
Tehri Garhwal	New Tehri	3,642	2,97,986	3,20,945	6,18,931
Udham Singh Nagar	Rudrapur	2,542	8,58,783	7,90,119	16,48,902
Uttarkashi	Uttarkashi	8,016	1,68,597	1,61,489	3,30,086
Total		53,483	51,37,773	49,48,519	1,00,86,292

Source: Census of India (2011)

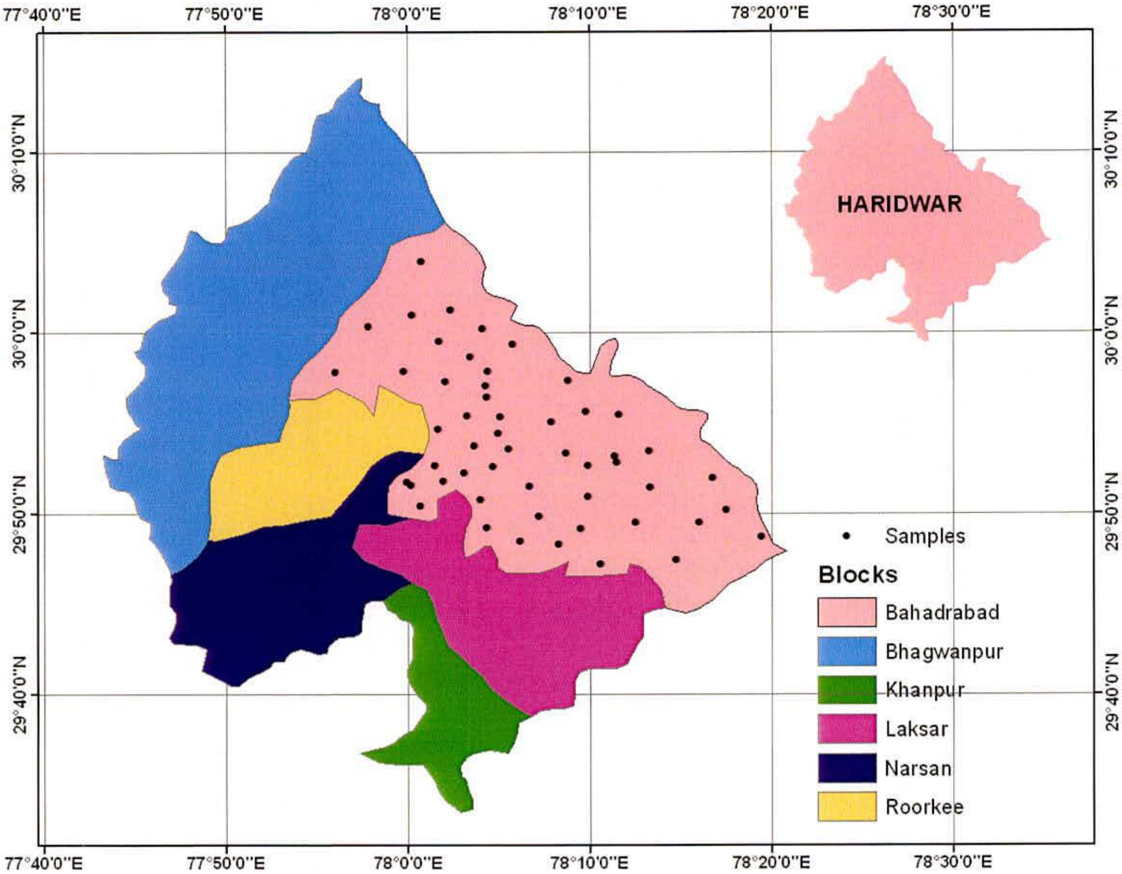

Fig. 2.2 Location of Different Blocks in Haridwar District

Table 2.2 Block Wise Area of District Hardwar

Block	Area (km^2)
Bahadrabad	478.6
Bhagwanpur	319.3
Khanpur	140.3
Laksar	283.6
Narsan	231.9
Roorkee	223.0
Total	1676.7

2.1 Physiography and Drainage

Physiographically the area is generally flat except for the Siwalik hills in the north and north east. The area is devoid of relief features of any prominence except for deep gorges cut by nalas and rivers flowing through the area. The area is bounded by river Yamuna in the west and river Ganga in the east.

Most rivers in the region flow from west to east. However, water from ground water storage flow round the year. The most important rivers in the region are Ganga, Solani and Ratmau. These rivers are ephemeral in nature, i.e., ground water is discharged into the rivers. The rivers carry base flow from ground water storage during the non-monsoon season. Apart from these rivers, the Upper Ganga Canal also drains the area.

2.2 Cimate

The climate of the area is as that of the greater part of subcontinent and is characterized by moderate type of subtropical monsoonic climate. The average annual rainfall in the region is about 1000 mm, major part of which is received during the monsoon period. The major land use is agriculture and there is no effective forest cover. The soils of the area are loam to silty loam and are free from carbonates.

2.3 Geology

The area under study is a part of Indo-Gangetic plains, which is mainly composed of pleistocene and subrecent alluvial sediments transported and deposited by river action from the Himalayan region. Lithologically, sediments consist of clay, silt and fine to coarse sand. The deposits of sandy horizons of varying thickness are the main source of ground water in the area. The soils are very fertile for growing wheat, sugar cane and vegetables. However, along the sandy river course, fruit orchards are also common.

2.4 Potential of Ground Water

The ground water conditions in the region are influenced by the varying lithology of the subsurface formation. It has been observed that the strata exhibit great variation both laterally and vertically due to the general fluviatile nature of the deposit of Indogangetic plains. The most common ground water structures in the area are shallow and deep tube wells. Dug wells are also used as source for drinking water, but to a lower extent. The ground water body is contained in fine to coarse-grained sands recharged by rainfall. Other sources of ground water replenishment are infiltration from rivers, canals and return flow from irrigation and inflow from the neighboring areas.

The most common ground water utilization is achieved by hand pumps and tube wells. Based on the lithological logs and water table fluctuation data, two types of aquifers have been delineated in the area. The upper one is the shallow unconfined aquifer which generally extends to depths around 25 m. The deeper one is confined to semi confined in nature and located at depth about 25 to 150 m, below ground level separated by three to four aquifers at average depths of 25 to 55, 65 to 90 and 120 to 150 m. Water table contours in the area indicate the southward trend of ground water flow both in unconfined and confined aquifers.

2.5 Land Use and Irrigation Patterns

The important crops are sugar cane, wheat, rice, barley, gram, maize, mustard etc. The crops are grown normally in Rabi and Kharif seasons. The land is used for agriculture in the plains and the ploughing is done either by oxen or tractors. The method of irrigation is purely by tube well. The canal and river irrigation is rarely used. The tube wells are driven either by diesel engine or electricity.

2.6 Flora and Fauna

A variety of herbs and serbs are found in the district. Among the trees, Sesam, Sagaun, Babul, Aam (mango) are the most common. The animals found in the district include fox, jackal and squirrels. The wolf, hyena and wild cats are also found. The most common birds are black Partridge, Jack Shipe, Duch, Goose etc. The poisonous variety of snakes including Cobra and Kraites are also found.

2.7 Mineral Resources and Industries

The foundry sand is found in the rivers of the district. It is a high grade silica sand left behind the change in the course of the rivers. It is used for the construction of buildings, dams, bridges etc. Some of the Shiwalik ranges are used as the source of calcium carbonate. The calcium carbonate is used again as the building material and also used in the Sugar Mill for the production of sugar.

The District Hardwar is not the main center/district for industrial point of view. However, Iqbalpur Sugar Mill and Bharat Heavy Electrical Limited are the famous industrial units in the District. The city Hardwar has an abundance of Ayurvedic small scale industries. Besides these, the other small scale industries such as kraisher, steel, agro and food processing units are also found in the region.

3.0 EXPERIMENTAL METHODOLOGY

3.1 Sampling and Preservation

Total 52 ground water samples from Bahadrabad Block in District Hardwar were collected during June 2013 from various abstraction sources at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good areal and vertical representation (Fig. 3.1). All the collected samples were preserved by adding an appropriate reagent (Jain and Bhatia, 1988; APHA, 1992). The hand pumps and tube wells were continuously pumped prior to the sampling, to ensure that ground water to be sampled was representative of ground water aquifer. The water samples for trace element analysis were collected in acid leached polyethylene bottles and preserved by adding ultra pure nitric acid (5 mL/lit.) while samples for bacteriological analysis were collected in sterilized high density polypropylene bottles covered with aluminium foils. All the samples were stored in sampling kits maintained at 4°C and brought to the laboratory for detailed chemical and bacteriological analysis. The details of sampling locations and source and depth wise distribution are given in Table 3.1 and 3.2 respectively.

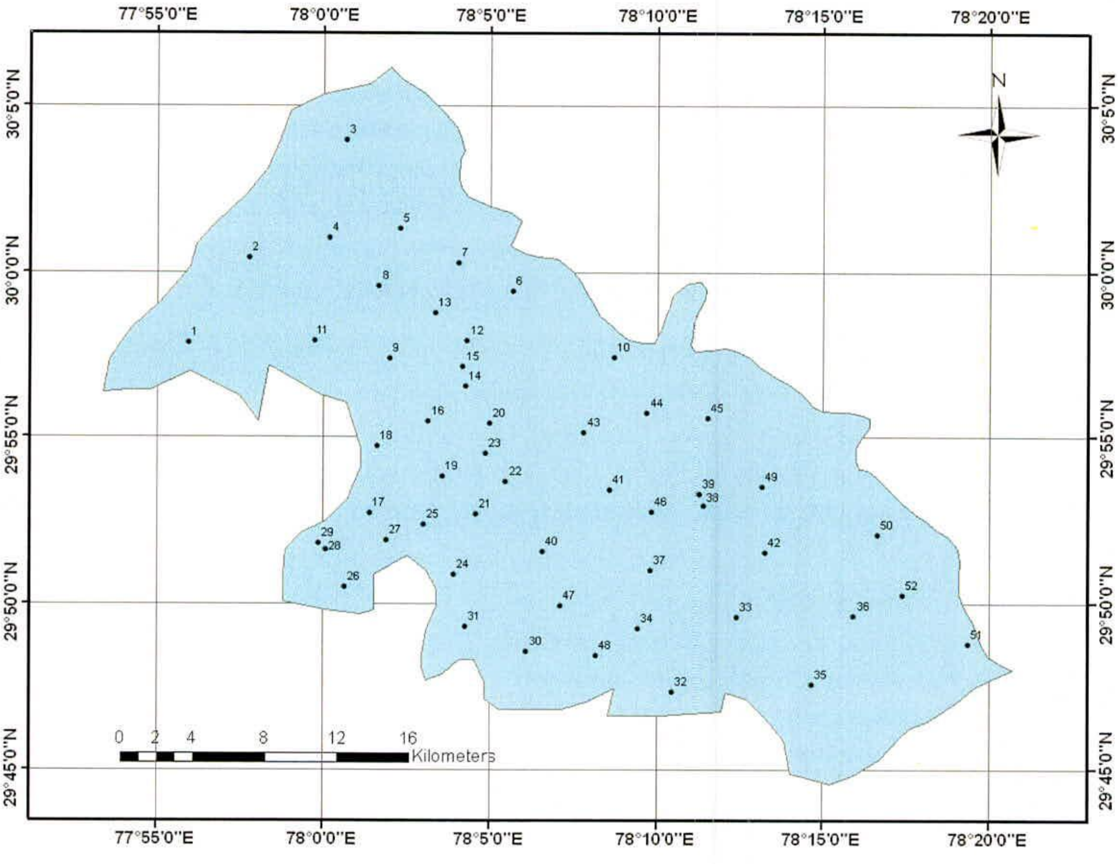

Fig. 3.1 Location of Sampling Points in Bhadrabad Block

Table 3.1 Description of Ground Water Sampling Locations in Bahadrabad Block

S.No.	Location	Identification	Source	Depth (m)	Water Use	Land Use
1	Sohalpur Sikrodha	Near Big Gate on Road	IM - II	49	Domestic	Agriculture
2	Kotta Muradnagar	House of Mr.Mulakiraj, near Ravidas Mandir	IM - II	40	Domestic	Agriculture
3	Hazara Grant	House of Mr. Ved Singh	IM - II	11	Domestic	Agriculture
4	Aurangabad	Govt. Tanki	TW	92	Domestic	Agriculture
5	Aurangabad	Mother Child Govt. Hospital	IM - II	21	Domestic	Agriculture
6	Aneki Hetmapur	House of Mr. Chander Pal Yadav Pradhan	HP	19	Domestic	Agriculture
7	Aneki Hetmapur	Prachin Shiv Mandir Chok	IM - II	24	Domestic	Agriculture
8	Puranpur Sahlapur	Ravidas Mandir parisar	IM - II	47	Domestic	Agriculture
9	Rajpur	Near Mr. Mahamud home, on Chok	IM - II	43	Domestic	Agriculture
10	Meerpur Muwaqzarpur	House of Mr. Mange Ram Sharma	IM - II	61	Domestic	Agriculture
11	Garh	Ambedakar Chok	IM - II	37	Domestic	Agriculture
12	Shivdaspur Urf Teliwala	House of Mr. Sudhir s/o Sh. Jagram	HP	17	Domestic	Agriculture
13	Dadupur Govindpur	Near Samir Provision Store	IM - II	31	Domestic	Agriculture
14	Salempur Mahamoodpur	Near Mr. Arjun Home	IM - II	58	Domestic	Agriculture
15	Rawali Mahadood	Ambedakar Chok	IM - II	37	Domestic	Agriculture
16	Bahadrabad	Parisar Govt. Pra. Vi. Bahadrabad	IM - II	20	Domestic	Agriculture
17	Atamalpur Baungla	Parisar Govt. Pra. Vi. Baungla	IM - II	18	Domestic	Agriculture
18	Ruhalki Kisanpur	Mother & Child Govt. Hospital	IM - II	18	Domestic	Agriculture
19	Alipur Ibrahimpur	Panchayat Ghar	IM - II	11	Domestic	Agriculture
20	Subhashnagar Sitapur	Svajal tank Subhash nagar	TW-Sawjal	92	Domestic	Agriculture
21	Acar kalan Bhagatanpur Aabidpur	Stand/Adda Acar kalan	IM - II	18	Domestic	Agriculture
22	Acar Khurd Bhagatanpur Aabidpur	Sh. Majeed ki Baithak	IM - II	14	Domestic	Agriculture
23	Ibrahimpur Bhagatanpur Aabidpur	Sh. Abdul malik ki Baithak, Nr. Masjid	IM - II	14	Domestic	Agriculture
24	Pathari Gadh	Dr. Anuj Sharma Clinic, Nr. Pathri Rly. St.	IM - II	12	Domestic	Agriculture
25	Peetpur	Parisar Govt. Pra. Vi. Peetpur	IM - II	12	Domestic	Agriculture
26	Ransura	Masjid Parisae Ransura	IM - II	21	Domestic	Agriculture
27	Kasampur	On road Nr. Mandarasa	IM - II	21	Domestic	Agriculture
28	Boddaheri Mohadinpur	Sh. Fakira Purv pradhan ki Baithak	IM - II	18	Domestic	Agriculture
29	Boddaheri Mohadinpur	Sh. Fakira Purv pradhan ke Ghar	HP	41	Domestic	Agriculture
30	Naseerpur uraf Nasratpur Alavalpur	Parisar Govt. Pra. Vi. Naseerpur uraf Nasratpur	IM - II	11	Domestic	Agriculture
31	Moham. Pur Kunhari	Nr. Sh. Nafish Home	IM - II	12	Domestic	Agriculture
32	Badshapur	Badshapur Bus Stand	IM - II	34	Domestic	Agriculture
33	Dhariwala	On main Lakshar road	TW-Sawjal	58	Domestic	Agriculture
34	Nasirpur Kanla	Masjid Parisae	IM - II	11	Domestic	Agriculture
35	Shahpur Shitala Khera	Nr. Govt. Pra. Vi., Bus stand	IM - II	18	Domestic	Agriculture
36	Hardevpur Shadevpur urf Rani Majara	Nr. Mastar Yeshpal Home	IM - II	12	Domestic	Agriculture
37	Padartha urf Dhanpura	Masjid Parisae	IM - II	31	Domestic	Agriculture
38	Dhanpura	Aaganwadi Kendra	IM - II	12	Domestic	Agriculture
39	Dogiwala	Nr.Dabal Singh Home	IM - II	27	Domestic	Forest
40	Ferupur Ramkhera	Babu Nai ki dukan, Bus stand	IM - II	12	Domestic	Forest
41	Katarpur Alipur	Sahkari khad gaudam	IM - II	24	Domestic	Forest
42	Bisanpur Jhara	Nr. Kashiram Home	IM - II	31	Domestic	Forest
43	Jagjeetpur	Mahadev mandir Chok	IM - II	29	Domestic	Forest
44	Gadowali	Nr. Suhel Tant house	IM - II	31	Domestic	Forest
45	Bahadarpur Jat	Nr. Shivam fabricating, Nautiyal Market	IM - II	18	Domestic	Forest
46	Saranya	Nr. Ikram Luhar ki dukan	IM - II	37	Domestic	Forest
47	Jamalpur Kanla	Sahakari mini Bank	IM - II	24	Domestic	Forest
48	Kangari	Nr. Gram Panchayat bhawan	IM - II	15	Domestic	Forest
49	Shyampur Naubad	Nr. Aaganwadi Kendra	IM - II	31	Domestic	Forest
50	Mohalapuri	Nr. Anil Home	IM - II	67	Domestic	Forest
51	Chamariya	Nr. Somendra Bist home	TW-Sawjal	88	Agriculture	Agriculture
52	Chamariya	Savajal Tubewell & Tank	TW-Sawjal	82	Domestic	Agriculture
IM - India Mark (Hand Pump); HP - Han Pump; TW - Tube Well						

Table 3.2 Source and Depth Wise Distribution of Sampling Sites in Bahadrabad Block

Source structure	Depth range			Total number
	< 0-20 m	20-40 m	> 40 m	
Hand Pumps	3,6,12,17,18,19, 21,22,23,24,25, 28,30,31,34,35, 36,38,40,45,48	2,5,7,11,13,15, 16,26,27,32,37, 39,41,42,43,44, 46,47,49	1,8,9,10,14,29, 50	47
Tube Wells	-	-	4,20,33,51,52	5
Open Wells	-	-	-	-
Total	21	19	12	52

3.2 Chemicals and Reagents

All general chemicals used in the study were of analytical reagent grade (Merck/BDH). Standard solutions of metal ions were procured from Merck, Germany. Bacteriological reagents were obtained from HiMedia. De-ionized water was used throughout the study. All glassware and other containers used for trace element analysis were thoroughly cleaned by soaking in detergent followed by soaking in 10% nitric acid for 48 h and finally rinsed with de-ionized water several times prior to use. All glassware and reagents used for bacteriological analysis were thoroughly cleaned and sterilized before use.

3.2 Physico-chemical Analysis

The physico-chemical analysis was performed following standard methods (Jain and Bhatia, 1988; APHA, 1992). The brief details of analytical methods and equipment used in the study are given in Table 3.3. Ionic balance was determined, the error in the ionic balance was within 5%.

3.3 Bacteriological Analysis

Total coliforms and fecal coliforms were determined by membrane filtration technique using M-Endo and M-FC Agar respectively. Colony characteristics of total coliforms and fecal coliforms are given below:

Coliform	**Culture Media**	**Temperature**	**Colony Characteristic**
Total Coliform	M-Endo Agar	37°C for 24 hours	Dark red colour with golden green metallic sheen
Fecal Coliform	M-FC Agar	44.5°C for 24 hours	Blue colonies

3.4 Metal Ion Analysis

Metal ion concentrations were determined using ICP-MS. Operational conditions were adjusted in accordance with the manufacturer's guidelines to yield optimal determination. Quantification of metals was based upon calibration curves of standard solutions of respective metals. These calibration curves were determined several times during the period of analysis.

Table 3.3 Analytical Methods and Equipment Used in the Study

S.No.	Parameter	Method	Equipment
A.	**Physico-chemical**		
1.	pH	Electrometric	pH Meter
2.	Conductivity	Electrometric	Conductivity Meter
3.	TDS	Electrometric	Conductivity/TDS Meter
4.	Alkalinity	Titration by H_2SO_4	-
5.	Hardness	Titration by EDTA	-
6.	Chloride	Titration by $AgNO_3$	-
7.	Sulphate	Turbidimetric	Turbidity Meter
8.	Nitrate	Ultraviolet screening	UV-VIS Spectrophotometer
9.	Fluoride	SPADNS	UV-VIS Spectrophotometer
10.	Sodium	Flame emission	Flame Photometer
11.	Potassium	Flame emission	Flame Photometer
12.	Calcium	Titration by EDTA	-
13.	Magnesium	Titration by EDTA	-
14.	Boron	Carmine method	UV-VIS Spectrophotometer
B	**Bacteriological**		
15.	Total coliform	Membrane Filtration	Bacteriological Incubator
16.	Faecal coliform		
C.	**Heavy Metals**		
17.	Iron	Digestion followed by Atomic spectrometry	ICP-MS
18.	Manganese		
19.	Copper		
20.	Nickel		
21.	Chromium		
22.	Lead		
23.	Cadmium		
24.	Zinc		
25.	Arsenic		
26.	Mercury		

4.0 RESULTS AND DISCUSSION

4.1 Water Quality Evaluation for Drinking Purpose

The Bureau of Indian Standards (BIS) earlier known as Indian Standards Institution (ISI) has laid down the standard specifications for drinking water during 1983, which have been revised and updated from time to time. In order to enable the users, exercise their discretion towards water quality criteria, the maximum permissible limit has been prescribed especially where no alternate source is available. The national water quality standards describe acceptable and permissible limits for various water quality constituents required to be evaluated to assess suitability of water for drinking purpose (BIS, 2012).

The hydro-chemical data for the pre-monsoon samples collected from Bahadrabad Block in District Hardwar are presented in Table 4.1. Distribution of different water quality constituents are given in Table 4.2 to 4.11 and distribution maps are presented in Figs. 4.1 to 4.10.

Table 4.1 Hydro-chemical Data of Ground Water Samples of Bahadrabad Block (June 2013)

Characteristics	Min	Max	Average
pH	6.39	8.35	7.26
Conductivity, μS/cm	279	1592	782
TDS, mg/L	179	1019	501
Alkalinity, mg/L	93	412	263
Hardness, mg/L	152	518	269
Chloride, mg/L	0.17	187	20
Sulphate, mg/L	1.5	123	33
Nitrate, mg/L	0.1	67	10
Fluoride, mg/L	ND	0.54	0.22
Sodium, mg/L	3.4	122	21
Potassium, mg/L	1.3	45	7.2
Calcium, mg/L	23	103	61
Magnesium, mg/L	9	64	28

N = 52

Table 4.2 pH Distribution in Ground Water of Bahadrabad Block

S.No.	pH Range mg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-6.5	< 20	3,6,12	7.7
		20-40	7	
		> 40	-	
2.	6.5-8.5	< 20	17,18,19,21,22,23,24,25,28, 30,31,34,35,36,38,40,45,48	92.3
		20-40	2,5,11,13,15,16,26,27,32,37, 39,41,42,43,44,46,47,49	
		> 40	1,4,8,9,10,14,20,29,33,50,51,52	
3.	> 8.5	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

Table 4.3 TDS Distribution in Ground Water of Bahadrabad Block

S.No.	TDS Range mg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-500	< 20	19,21,22,24,28,30,36,40,45,48	57.7
		20-40	5,7,11,13,15,27,32,39,41,42,44,49	
		> 40	4,8,9,10,14,20,29, 33	
2.	501-2000	< 20	3,6,12,17,18,23,25,31,34,35,38	42.3
		20-40	2,16,26,37,43,46,47	
		> 40	1,50,51,52	
3.	> 2000	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

Table 4.4 Alkalinity Distribution in Ground Water of Bahadrabad Block

S.No.	Alkalinity Range mg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-200	< 20	22,36,45	23.1
		20-40	7,32,41,42	
		> 40	8,10,14,20,33	
2.	201-600	< 20	3,6,12,17,18,19,21,23,24,25, 28,30,31,34,35,38,40,48	76.9
		20-40	2,5,11,13,15,16,26,27,37, 39,43,44,46,47,49	
		> 40	1,4,9,29,50,51,52	
3.	> 600	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

Table 4.5 Hardness Distribution in Ground Water of Bahadrabad Block

S.No.	Hardness Range mg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-200	< 20	-	15.4
		20-40	5,32,39,42	
		> 40	8,10,14,51	
2.	201-600	< 20	3,6,12,17,18,19,21,22,23,24,25,28, 30,31,34,35,36,38,40,45,48	84.6
		20-40	2,7,11,13,15,16,26,27,37,41, 43,44,46,47,49	
		> 40	1,4, 9, 20,29,33,50, 52	
3.	> 600	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

Table 4.6 Calcium Distribution in Ground Water of Bahadrabad Block

S.No.	Calcium Range mg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-75	< 20	3,19,21,22,24, 28,30, 31,34,35,36,38,40,45,48	80.8
		20-40	2,5,7,11, 15, 26,27, 32,37,39, 41,42,43,44,46, 49	
		> 40	1,4,8,9,10,14,20,29,33, 51,52	
2.	76-200	< 20	6, 12, 17,18, 23, 25,	19.2
		20-40	13, 16, 47,	
		> 40	50	
3.	> 200	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

Table 4.7 Magnesium Distribution in Ground Water of Bahadrabad Block

S.No.	Magnesium Range mg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-30	< 20	19,21,22, 24,25, 30,31, 34, 36,38, 45,48	65.4
		20-40	2,5,7,11,13,15, 27,32, 39,41, 42,43,44,46, 49	
		> 40	4,8, 10,14,20, 33,51	
2.	31-100	< 20	3, 6,12,17,18, 23, 28, 35, 40,	34.6
		20-40	16, 26, 37, 47,	
		> 40	1, 9, 29,50,52	
3.	> 100	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

Table 4.8 Chloride Distribution in Ground Water of Bahadrabad Block

S.No.	Chloride Range mg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-250	< 20	3,6,12,17,18,19,21,22,23,24,25,28, 30,31,34,35,36,38,40,45,48	100
		20-40	2,5,7,11,13,15,16,26,27,32,37,39, 41,42,43,44,46,47,49	
		> 40	1,4,8,9,10,14,20,29,33,50,51,52	
2.	251-1000	< 20	-	-
		20-40	-	
		> 40	-	
3.	> 75	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

Table 4.9 Sulphate Distribution in Ground Water of Bahadrabad Block

S.No.	Sulphate Range mg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-200	< 20	3,6,12,17,18,19,21,22,23,24,25,28, 30,31,34,35,36,38,40,45,48	100
		20-40	2,5,7,11,13,15,16,26,27,32,37,39, 41,42,43,44,46,47,49	
		> 40	1,4,8,9,10,14,20,29,33,50,51,52	
2.	201-400	< 20	-	-
		20-40	-	
		> 40	-	
3.	> 400	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

Table 4.10 Nitrate Distribution in Ground Water of Bahadrabad Block

S.No.	Nitrate Range mg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-45	< 20	3,6, 17,18,19,21,22,23,24,25, 28,30,31,34,35,36,38, 40,45,48	96.2
		20-40	2,5,7,11,13,15,16, 26,27,32,37,39, 41,42,43,44,46,47,49	
		> 40	1,4,8,9,14,20,29,33,50,51,52	
2.	> 45	< 20	12	3.8
		20-40	-	
		> 40	10	
Total number of samples			52	100

Table 4.11 Fluoride Distribution in Ground Water of Bahadrabad Block

S.No.	Fluoride Range mg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-1.0	< 20	3,6,12,17,18,19,21,22,23,24,25,28, 30,31,34,35,36,38,40,45,48	100
		20-40	2,5,7,11,13,15,16,26,27,32,37,39, 41,42,43,44,46,47,49	
		> 40	1,4,8,9,10,14,20,29,33,50,51,52	
2.	1.1-1.5	< 20	-	-
		20-40	-	
		> 40	-	
3.	> 1.5	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

4.1.1General Characteristics

The pH values in the ground water of Bahadrabad Block are mostly confined within the range 6.39 to 8.35. The pH values of almost all the samples are well within the limits prescribed by BIS (2012) and WHO (1996) for various uses of water including drinking and other domestic supplies. The pH distribution map is shown in Fig. 4.1.

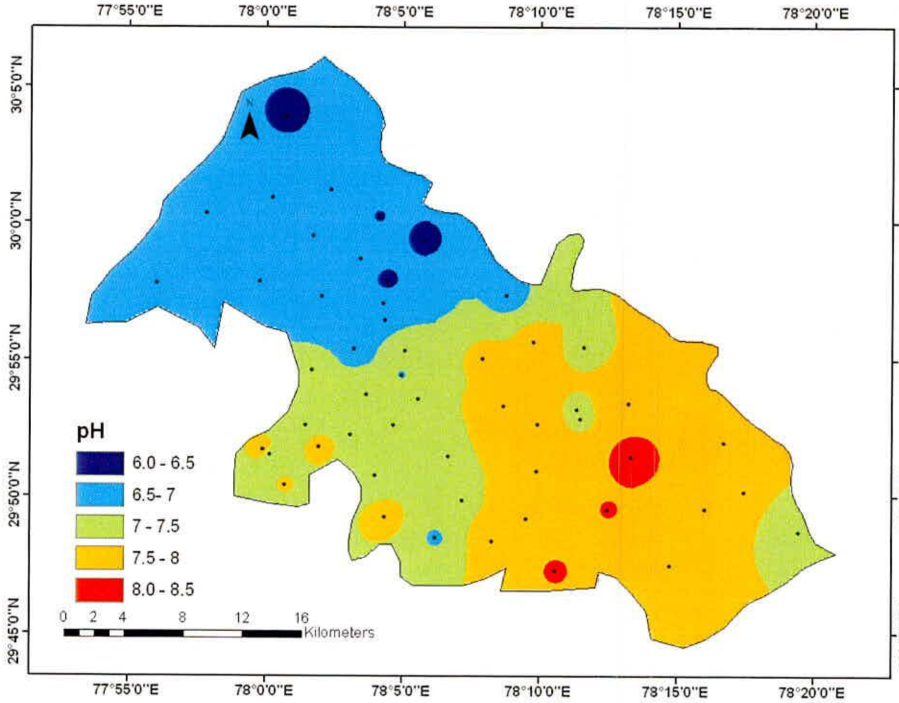

Fig. 4.1 pH Distribution in Ground Water of Bahadrabad Block

The measurement of electrical conductivity is directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. The conductivity values in the ground water samples of Bahadrabad Block vary from 279 to 1592 μS/cm during pre-monsoon season with about 20% samples having conductivity value above 1000 μS/cm. The maximum conductivity value of 1592 μS/cm was observed at Village Shivdaspur (Hand Pump, 17 m depth).

In natural waters, dissolved solids consists mainly of inorganic salts such as carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, sodium, potassium, iron etc. and small amount of organic matter and dissolved gases. In the present study the values of total dissolved solids (TDS) in the ground water varies from 179 to 1019 mg/L indicating low mineralization in the area. More than 50% of the samples analysed were found within the acceptable limit of 500 mg/L and about 50% samples were found above the acceptable limit but are within the permissible limit of 2000 mg/L. The TDS content at deeper levels (>40 m depth) is comparatively low and lies well within desirable limit of 500 mg/L. The TDS distribution map is shown in Fig. 4.2. Water containing more than 500 mg/L of TDS is not considered desirable for drinking water supplies, though more highly mineralized water is also used where better water is not available. For this reason, 500 mg/L as the acceptable limit and

2000 mg/L as the permissible limit has been suggested for drinking water (BIS, 2012). Water containing TDS more than 500 mg/L causes gastrointestinal irritation (BIS, 2012). No sample of Bahadrabad Block crosses the permissible limit of 2000 mg/L.

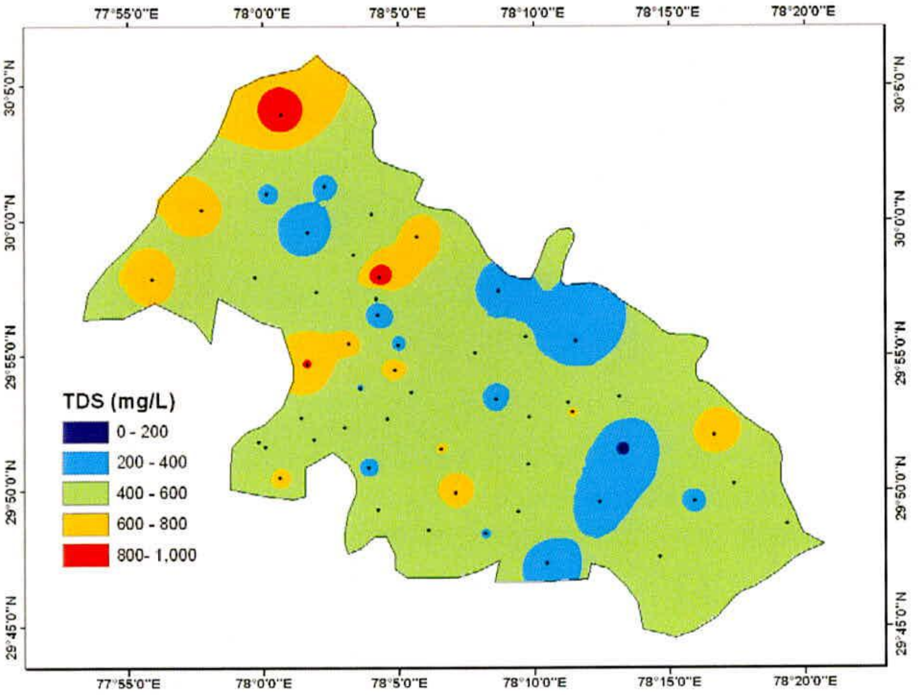

Fig. 4.2 TDS Distribution in Ground Water of Bahadrabad Block

The presence of carbonates, bicarbonates and hydroxides are the main cause of alkalinity in natural waters. Bicarbonates represent the major form since they are formed in considerable amount from the action of carbonates upon the basic materials in the soil. The alkalinity value in the ground water varies from 93 to 412 mg/L. About 23% of the samples of the study area fall within the acceptable limit of 200 mg/L and remaining about 77% of the samples crosses the acceptable limit but are within the permissible limit of 600 mg/L. No sample of the study area crosses the permissible limit of 600 mg/L. The alkalinity distribution map is shown in Fig. 4.3. The high alkalinity may be due to the action of carbonates upon the basic materials in the soil.

Calcium and magnesium along with their carbonates, sulphates and chlorides make the water hard. A limit of 200 mg/L has been recommended as acceptable limit for potable water (BIS, 2012). The total hardness values in the study area range from 152 to 518 mg/L. About 15% of the samples of the study area fall within the acceptable limit of 200 mg/L and remaining about 85% of the samples exceed the acceptable limit but are well within the permissible limit of 600 mg/L. The hardness distribution map is shown in Fig. 4.4. From the hardness point of view all the samples of Bahadrabad Block are found within the permissible limit of 600 mg/L.

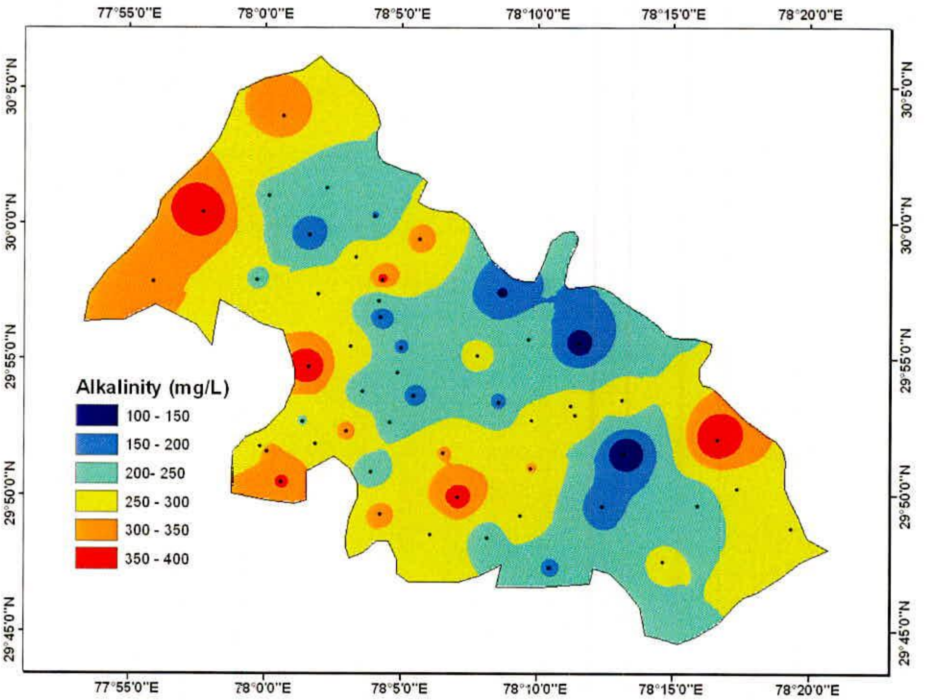

Fig. 4.3 Alkalanity Distribution in Ground Water of Bahadrabad Block

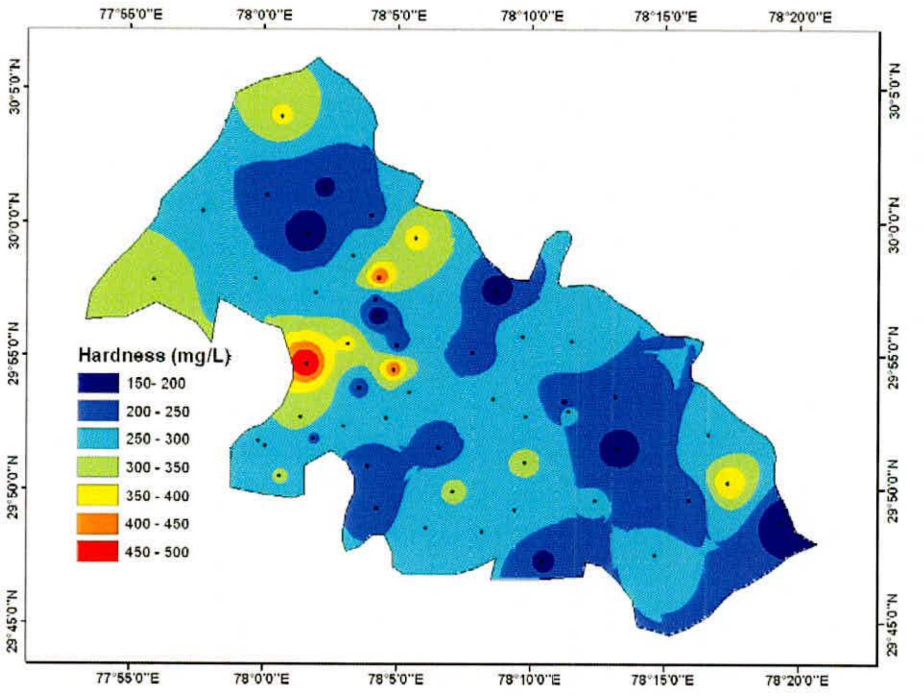

Fig. 4.4 Hardness Distribution in Ground Water of Bahadrabad Block

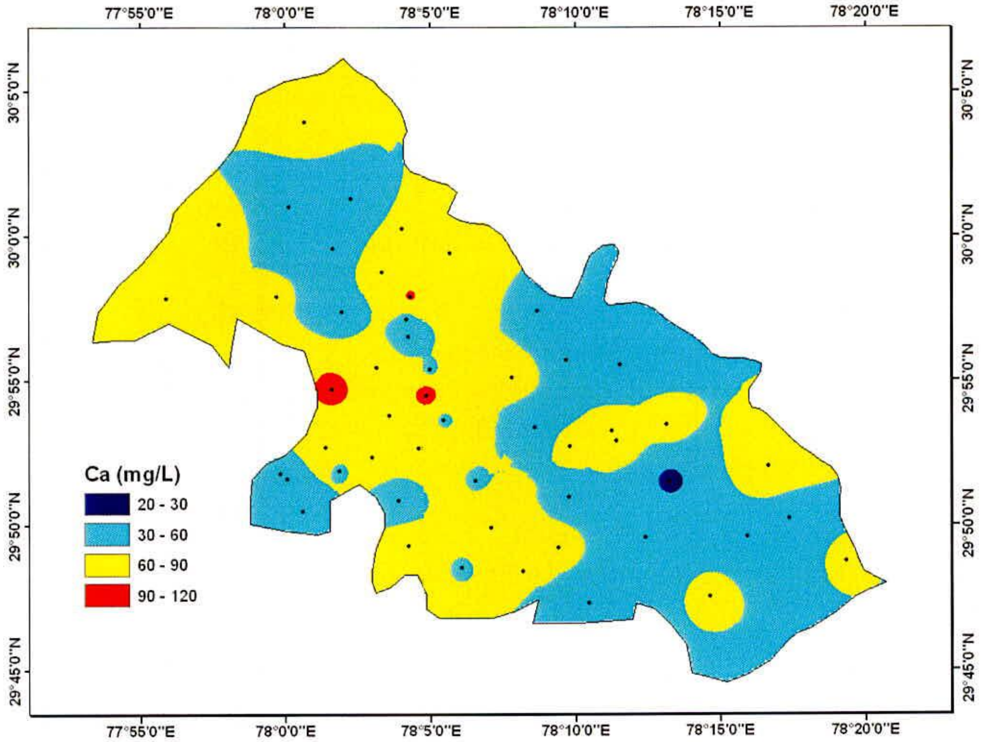

Fig. 4.5 Calcium Distribution in Ground Water of Bahadrabad Block

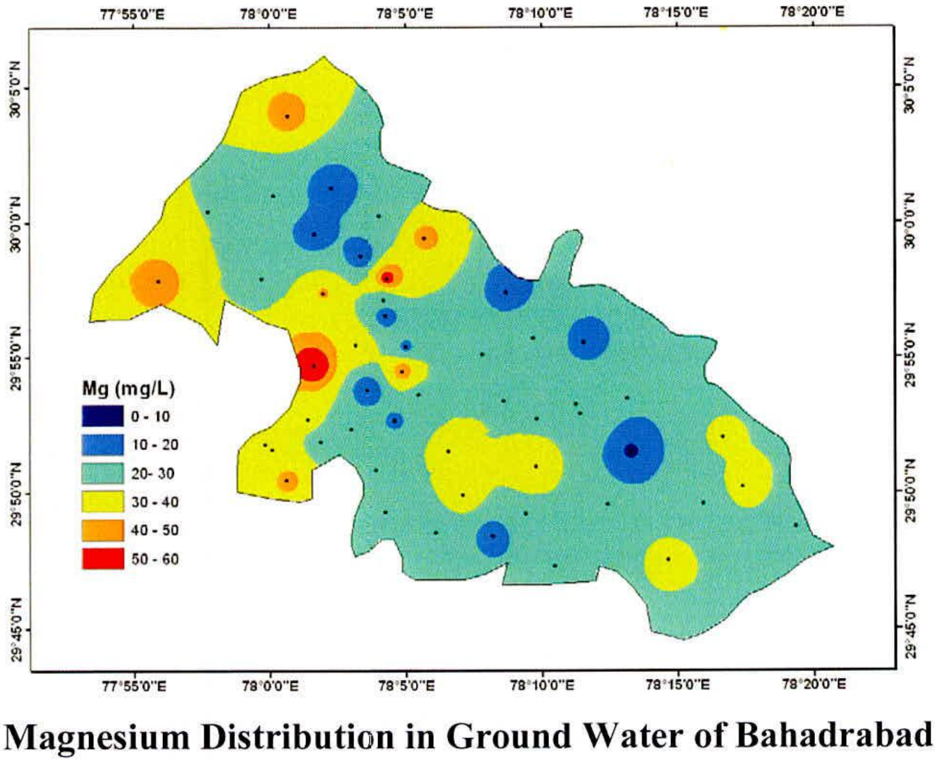

Fig. 4.6 Magnesium Distribution in Ground Water of Bahadrabad Block

The acceptable limit for calcium and magnesium for drinking water are 75 and 30 mg/L respectively (BIS, 2012). In ground water of the study area, the values of calcium and magnesium varies from 23 to 103 mg/L and 9.0 to 64 mg/L respectively. In ground water, the calcium content generally exceeds the magnesium content in accordance with their relative abundance in rocks. The increase of magnesium is quite proportionate with calcium. The calcium and magnesium distribution maps are shown in Fig. 4.5 and 4.6 respectively. More than 80% of the samples of the study area fall within the acceptable limit for calcium while more than 65% of the samples fall within the acceptable limit for magnesium.

The concentration of sodium in the study area varies from 3.4 to 122 mg/L. The violation of BIS limits could not be ascertained for sodium as no permissible limit of sodium has been prescribed in BIS drinking water specifications. Ground water with high sodium is not suitable for irrigation due to sodium sensitivity of crops/plants.

The concentration of potassium in ground water of Bahadrabad Block varies from 1.3 to 45 mg/L. Potassium is an essential element for humans, plants and animals and derived in food chain mainly from vegetation and soil. The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation. It is more abundant in sedimentary rocks and commonly present in feldspar, mica and other clay minerals. The Bureau of Indian Standards has not included potassium in drinking water standards. However, the European Economic Community (EEC, 1980) has prescribed guideline level of potassium at 10 mg/L in drinking water. As per EEC criteria, about 10-15% of the samples of the study area exceed the guideline level of 10 mg/L. Though potassium is extensively found in some of igneous and sedimentary rocks, its concentration in natural waters is usually quite low. This is due to the fact that potassium minerals offer resistance to weathering and dissolution. Higher potassium content in ground water is indicative of ground water pollution.

The concentration of chloride in the study area varies from 0.17 to 187 mg/L. The chloride distribution map is shown in Fig. 4.7. The limits of chloride have been laid down primarily from taste considerations. A limit of 250 mg/L chloride has been recommended as desirable limit for drinking water supplies (BIS, 2012; WHO, 1996). However, no adverse health effects on humans have been reported from intake of waters containing even higher content of chloride. No sample in the study area crosses the desirable limit of 250 mg/L.

The sulphate content in ground water generally occurs as soluble salts of calcium, magnesium and sodium. The sulphate content changes significantly with time during infiltration of rainfall and ground water recharge, which mostly takes place from stagnant water pools and surface runoff water collected in low lying areas. The concentration of sulphate in the study area varies from 1.5 to 123 mg/L. The sulphate distribution map is shown in Fig. 4.8. It is clearly evident from the distribution maps that all the samples of Bahadrabad Block fall within the acceptable limit of 200 mg/L prescribed for drinking water supplies.

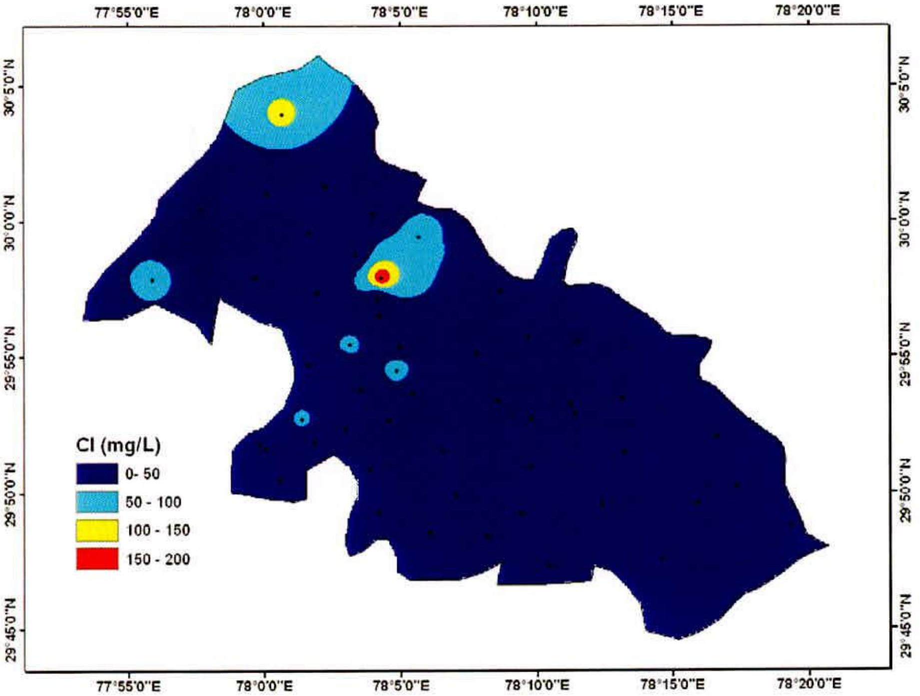

Fig. 4.7 Chloride Distribution in Ground Water of Bahadrabad Block

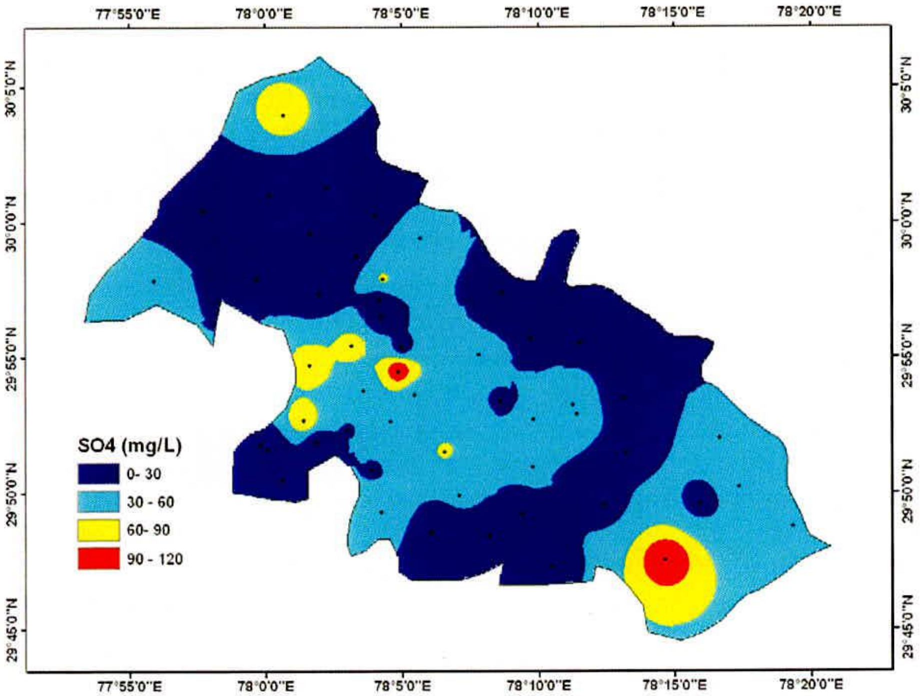

Fig. 4.8 Sulphate Distribution in Ground Water of Bahadrabad Block

The nitrate content in Bahadrabad Block varies from 0.1 to 67 mg/L. Excess nitrate content in drinking water is considered dangerous for its adverse health effects. The occurrence of high levels of nitrate in ground water is a prominent problem in many parts of the country. About 95% of the samples in Bahadrabad Block shows nitrate content within the acceptable limit of 45 mg/L. Only two sample of the study area exceeds the acceptable limit of 45 mg/L. The nitrate distribution map is shown in Fig. 4.9. The higher level of nitrate at the two locations may be attributed to the improper sanitation and unhygienic conditions around the structure.

Nitrate is effective plant nutrient and moderately toxic. A limit of 45 mg/L has been prescribed by WHO (1996) and BIS (2012) for drinking water supplies. Its concentration above 45 mg/L may prove detriment to human health. In higher concentrations, nitrate may produce a disease known as methaemoglobinaemia (blue babies) which generally affects bottle-fed infants. Repeated heavy doses of nitrates on ingestion may also cause carcinogenic diseases.

The fluoride content in the ground water of Bahadrabad Block varies from ND to 0.54 mg/L and lies well within the acceptable limit of 1.0 mg/L in all the samples. The fluoride distribution map is shown in Fig. 4.10. The presence of fluoride in ground water may be attributed to the localized effects of natural sources. The fluoride is present in soil strata due to the presence of geological formations like fluorspar, fluorapatite, ampheboles such as hornblinde, trimolite and mica. Weathering of alkali, silicate, igneous and sedimentary rocks specially shales contribute a major portion of fluorides to ground waters. In addition to natural sources, considerable amount of fluorides may be contributed due to man's activities. Fluoride salts are commonly used in steel, aluminium, bricks and tile-industries. The fluoride containing insecticides and herbicides may be contributed through agricultural runoff. Phosphatic fertilizers, which are extensively used, often contain fluorides as impurity and these may increase levels of fluoride in soil. The accumulation of fluoride in soil eventually results in its leaching due to percolating water, thus increase fluoride concentration in ground water.

The study has clearly indicated that the concentration of total dissolved solids exceeds the acceptable limit of 500 mg/L in about 40% of the samples analyzed but the values are well within the permissible limit of 2000 mg/L in all the samples. The alkalinity values exceeds the acceptable limit of 200 mg/L in about 75% of the samples but the values are well within the permissible limit of 600 mg/L. The total hardness values exceed the acceptable limit of 200 mg/L in about 80% of the samples. The nitrate content exceeds the acceptable limit of 45 mg/L in two samples. The fluoride content is well within the acceptable limit in all the samples analyzed. The violation of BIS limit could not be ascertained for sodium and potassium as no permissible limit of sodium and potassium has been prescribed in BIS drinking water specifications.

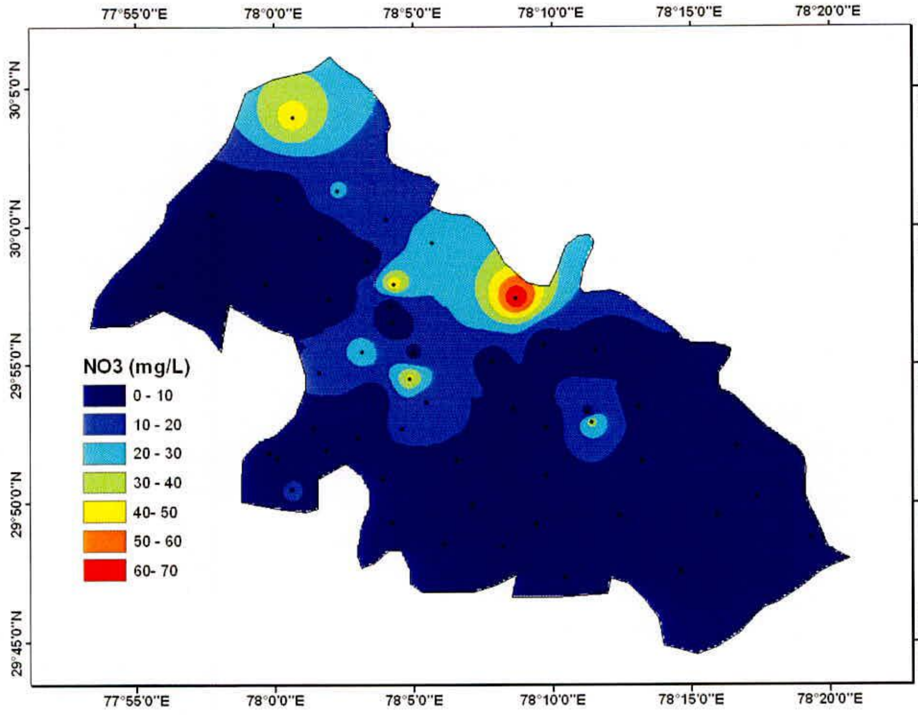

Fig. 4.10 Nitrate Distribution in Ground Water of Bahadrabad Block

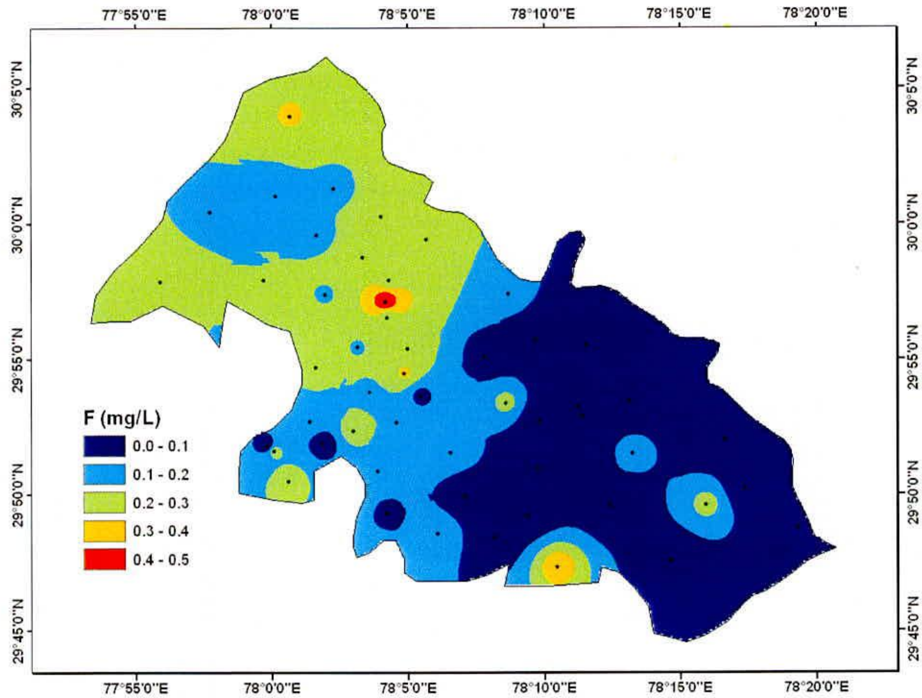

Fig. 4.10 Fluoride Distribution in Ground Water of Bahadrabad Block

4.1.2Bacteriological Parameters

The coliform group of bacteria is the principal indicator of suitability of water for domestic, industrial or other uses. The density of coliform group is the criteria for the degree of contamination and has been the basis for bacteriological water quality standard. In ideal situation all the samples taken from the distribution system should be free from coliform organisms and the following standards have been recommended for bacteriological quality of drinking water (BIS, 2012):

S.No.	Organisms	Requirement
i)	All water intended for drinking: a) E.coli or thermotolerant coliform bacteria	Shall not be detectable in any 100 ml sample
ii)	Treated water entering the distribution system: a) E.coli or thermotolerant coliform bacteria b) Total coliform bacteria	Shall not be detectable in any 100 ml sample Shall not be detectable in any 100 ml sample
iii)	Treated water in the distribution system: a) E.coli or thermotolerant coliform bacteria b) Total coliform bacteria	Shall not be detectable in any 100 ml sample Shall not be detectable in any 100 ml sample

From bacteriological considerations, the objectives should be to ensure the absence of faecal coliform. The presence of coliforms in water is an indicator of contamination by human or from animal excrement. The presence of faecal colifirms in ground water indicates a potential public health problem, because faecal matter is a source of pathogenic bacteria and viruses. The ground water contamination from faecal coliform bacteria is generally caused by percolation from contamination sources (domestic sewage and septic tank) into the aquifers and also because of poor sanitation. Shallow wells are particularly susceptible for such contamination. The indiscriminate land disposal of domestic waste on surface, improper disposal of solid waste, leaching of waste water from landfill areas, further aggravate the chances of bacterial contamination in ground water. The results of bacteriological analysis of ground water samples of Bahadrabad Block are given in Table 4.12.

Table 4.12 Bacteriological Contamination in Ground Water of Bahadrabad Block

Range Total Coliform per 100 ml	No. of samples	%
Nil	37	71.2
< 10	3	5.8
10-20	8	15.4
21-30	2	3.8
31-40	1	1.9
41-50	-	-
51-100	-	-
> 100	1	1.9

The bacteriological analysis of the ground water samples collected from Bahadrabad Block indicates bacterial contamination at few locations. Inadequate maintenance of hand pumps, improper sanitation and unhygienic conditions around the structure may be responsible for bacterial contamination in the ground water of the region and is a cause of concern. The water from such sources should be properly disinfected before being used for drinking and other domestic purposes.

4.1.3Heavy Metals

The contamination of ground water by heavy metals has received great significance during recent years due to their toxicity and accumulative behaviour. These elements, contrary to most pollutants, are not biodegradable and undergo a global eco-biological cycle in which natural waters are the main pathways. The major sources of heavy metals in ground water include weathering of rock minerals, discharge of sewage and other waste effluents on land and runoff water. The water used for drinking purpose should be free from any toxic elements, living and nonliving organism and excessive amount of minerals that may be hazardous to health. Some of the heavy metals are extremely essential to humans, for example, cobalt, copper, etc., but large quantities of them may cause physiological disorders. The arsenic, cadmium, chromium, lead and mercury are highly toxic to humans even in low concentrations. The trace element data of ground water samples collected from the study area are given in Tables 4.13. The distribution of different metals with depth and season are presented in Tables 4.14 to 4.23 and graphically shown in Fig. 4.11 to 4.20. The toxic effects of these elements and extent of their contamination in ground water is discussed in the following sections.

Table 4.13 Trace Element Data of Ground Water Samples of Bahadrabad Block

Metal	Min	Max	Average
Iron, µg/L	3002	19771	8501
Manganese, µg/L	5.5	2712	501
Copper, µg/L	2.1	81	18
Nickel, µg/L	63	527	226
Chromium, µg/L	7.5	301	20
Lead, µg/L	2.3	74	13
Cadmium, µg/L	0.5	10	1.9
Zinc, µg/L	24	13227	1299
Arsenic, µg/L	0.8	90	8
Mercury, µg/L	0.3	254	9

N = 52

Table 4.14 Iron Distribution in Ground Water of Bahadrabad Block

S.No.	Fe Range µg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-300	< 20	-	-
		20-40	-	
		> 40	-	
2.	>300	< 20	3,6,12,17,18,19,21,22,23,24,25, 28,30,31,34,35,36,38,40,45,48	100
		20-40	2,5,7,11,13,15,16,26,27,32,37,39,41, 42,43,44,46,47,49	
		> 40	1,4,8,9,10,14,20,29,33,50,51,52	
Total number of samples			52	100

Table 4.15 Manganese Distribution in Ground Water of Bahadrabad Block

S.No.	Mn Range µg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-100	< 20	19,21,22,23,31,34,35,36,45	36.5
		20-40	32,42,43,44,46,49	
		> 40	20,33,50,51	
2.	101-300	< 20	6,30,48	23.1
		20-40	2,11,15,26,37,47	
		> 40	10,29,52	
3.	> 300	< 20	3,12,17,18,24,25,28,38,40	40.4
		20-40	5,7,13,16,27,39,41	
		> 40	1,4,8,9,14	
Total number of samples			52	100

Table 4.16 Copper Distribution in Ground Water of Bahadrabad Block

S.No.	Cu Range µg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-50	< 20	3,6,12,17,18,19,21,22,23,24,25, 28,30,31,34,35,36,38,40, 48	94.2
		20-40	2,5,7,11,13,15,16,26,27,32, 39,41,42,44,46,47,49	
		> 40	1,4,8,9,10,14,20,29,33,50,51,52	
2.	51-1500	< 20	45	5.8
		20-40	37, 43	
		> 40	-	
3.	> 1500	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

Table 4.17 Nickel Distribution in Ground Water of Bahadrabad Block

S.No.	Ni Range µg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-20	< 20	-	-
		20-40	-	
		> 40	-	
2.	> 20	< 20	3,6,12,17,18,19,21,22,23,24,25, 28,30,31,34,35,36,38,40,45,48	100
		20-40	2,5,7,11,13,15,16,26,27,32,37,39, 41,42,43,44,46,47,49	
		> 40	1,4,8,9,10,14,20,29,33,50,51,52	
Total number of samples			52	100

Table 4.18 Chromium Distribution in Ground Water of Bahadrabad Block

S.No.	Cr Range µg/L	Depth Range m	Sample numbers	Areal distribution, %
1.	0-50	< 20	3,6,12,17,18,19,21,22,23,24,25, 28,30,31,34,35,36,40,45,48	94.2
		20-40	2,5,7,11,13,15,16,26,27,32, 39,41,43,44,46,47,49	
		> 40	1,4,8,9,10,14,20,29,33,50,51,52	
2.	>50	< 20	38	5.8
		20-40	37,42	
		> 40	-	
Total number of samples			52	100

Table 4.19 Lead Distribution in Ground Water of Bahadrabad Block

S.No.	Pb Range µg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-10	< 20	3,6,12,19,21,22,23, 28,30, 35, 36, 38, 45,48	63.5
		20-40	2,5,7,11,13,16, 27,49	
		> 40	1,4,8,9,10,14,20,29,33, 51,52	
2.	>10	< 20	17,18, 24,25,31, 34, 40	36.5
		20-40	15, 26, 32, 37, 39,41,42,43,44, 46,47	
		> 40	50	
Total number of samples			52	100

Table 4.20 Cadmium Distribution in Ground Water of Bahadrabad Block

S.No.	Cd Range µg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-3	< 20	3,6,12,18,19,21,22,23,24,25,28, 30, 34,35,36, 38,40,45,48	92.3
		20-40	2,5,7,13,15,16,26,27,32,37,39, 41,42,43,44,46,47,49	
		> 40	4,8,9,10,14,20,29,33,50,51,52	
2.	>3	< 20	17, 31	7.7
		20-40	11	
		> 40	1	
Total number of samples			52	100

Table 4.21 Zinc Distribution in Ground Water of Bahadrabad Block

S.No.	Zn Range µg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-5000	< 20	3,6,12,19,21,22,23,24,25,28, 30,31,34,35,36, 38,40,45,48	94.2
		20-40	2,5,7,11,13,15,16,26,27, 32,37,39,41,42,43,44,46, 49	
		> 40	1,4,8,9,10,14,20,29,33,50,51,52	
2.	5001-15000	< 20	17,18	5.8
		20-40	47	
		> 40	-	
3.	> 15000	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

Table 4.22 Arsenic Distribution in Ground Water of Bahadrabad Block

S.No.	As Range µg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-10	< 20	6,16,17,18,19,21,22,23,24,25, 31,34,35,36,40,45,48	80.8
		20-40	2,5,7,10,11,13,15,32,37,39, 41,42,43,44,46,47,49	
		> 40	4,8,9,20,29,50,51,52	
2.	11-50	< 20	3,12,28,30,38	19.2
		20-40	26,27	
		> 40	1,14,33	
3.	> 50	< 20	-	-
		20-40	-	
		> 40	-	
Total number of samples			52	100

Table 4.23 Mercury Distribution in Ground Water of Bahadrabad Block

S.No.	Hg Range µg/L	Depth Range m	Sample Numbers	Areal Distribution %
1.	0-1	< 20	16,17,18,19,21,22,23,24,25,28, 30,31,34,35,36,38,40,45,48	71.2
		20-40	26,27,32,37,39,41, 42,43,44,46,47,49	
		> 40	20,29,33,50,51,52	
2.	> 1	< 20	3,6,12,	28.8
		20-40	2,5,10,11,13,15	
		> 40	1,4,8,9,14	
Total number of samples			52	100

Iron (Fe)

The concentration of iron in the ground water of Bahadrabad Block ranges from 3002 to 19771 µg/L. The distribution of iron at different sites is shown in Fig. 4.11. The Bureau of Indian Standards has recommended 300 µg/L as the acceptable limit for drinking water (BIS, 2012). It is evident from the results that all the samples of the study area exceed the acceptable limit of 300 µg/L. High concentrations of iron generally cause inky flavour, bitter and astringent taste. It can also discolour clothes, plumbing fixtures and cause scaling which encrusts pipes. Excessive concentration may promote bacterial activities in pipe and service mains, causing objectionable odours and red-rod disease in water. Well water containing soluble iron remain clear while pumped out, but exposure to air causes precipitation of iron due to oxidation, with a consequence of rusty colour and turbidity.

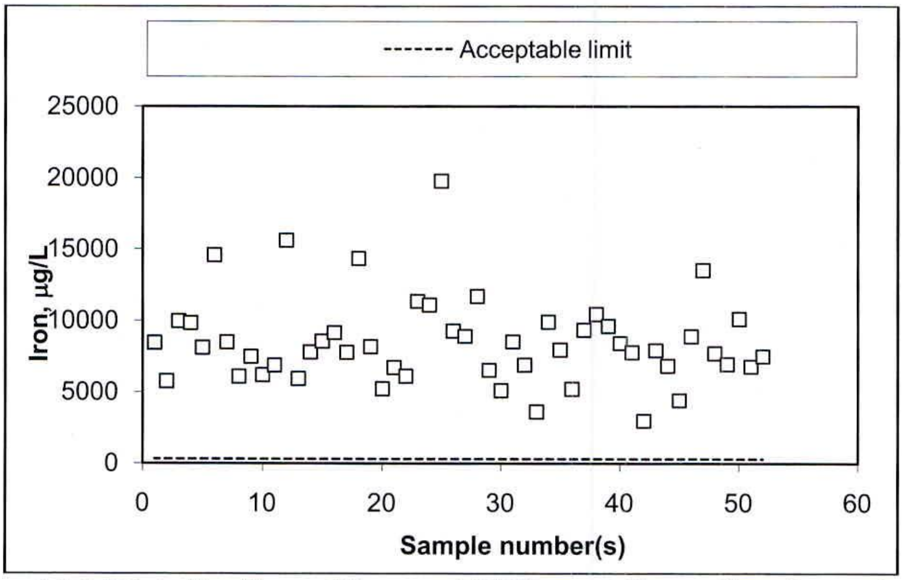

Fig. 4.11 Distribution of Iron at Different Sampling Locations

The high concentrations of iron may be attributed due to mixing phenomena of recharge water, which is having more oxygen to react with iron ore, which may be available in clay lenses in the aquifer. Limits of iron in water supplies for potable use have not been laid down from health consideration but due to the fact that iron in water supplies may cause discoloration of clothes, plumbing fixtures and porcelain wares. The "red rot" disease of water caused by bacterial precipitation of hydrated oxides of ferric iron with consequent unaesthetic appearance to water, clogging of pipes, pitting of pipes and occurrence of foul smells, is due to the presence of relatively high iron in water. The concentration of iron in natural water is controlled by both physico-chemical and microbiological factors. The weathering of rock and discharge of waste effluents on land are generally considered the main source of iron in ground water. Iron migrates as adsorbed to suspended matter, insoluble hydrated iron compounds, complexed to inorganic and organic ligands and also as hydrated ions. Dissolved carbon dioxide, pH and Eh of water affect the nature of aqueous iron species present in the water. In ground water iron generally occurs in two oxidation states, i.e., Ferrous (Fe^{2+}) and Ferric (Fe^{3+}) forms.

Manganese (Mn)

The concentration of manganese recorded a maximum level of 2712 µg/L. The distribution of manganese at different sites is shown in Fig. 4.12. Manganese is an essential element, which does not occur naturally as a metal but is found in various salts and minerals frequently in association with iron compounds. In general concentration of manganese in ground water is low due to geo-chemical control. A concentration of 100 µg/L has been recommended as a acceptable limit and 300 µg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 500 µg/L as the provisional guideline value for drinking water (WHO, 1996). The presence of manganese above permissible limit of drinking water often imparts alien taste to water. It also has adverse effects on domestic uses and water supply structures.

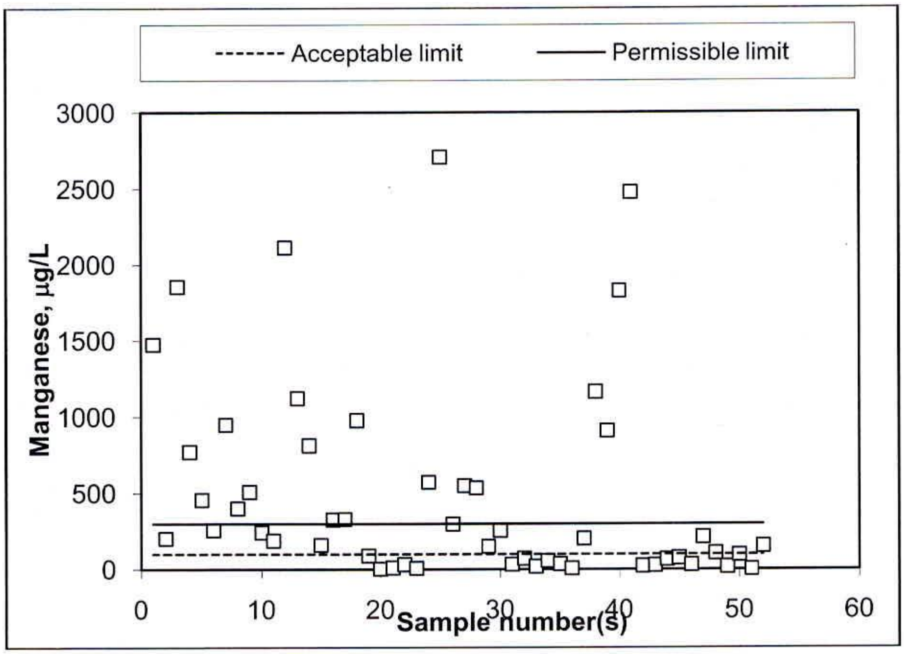

Fig. 4.12 Distribution of Manganese at Different Sampling Locations

It is evident from the results that about 35% of the samples of Bahadrabad Block fall within the acceptable limit of 100 µg/L, 23% of the samples exceeds the acceptable limit but are within the permissible limits and about 40% samples exceeds the permissible limit of 300 µg/L. High concentration of manganese may be attributed to the reducing conditions of the water and dissolution of manganese bearing minerals from the soil strata. Manganese may gain entry into the body by inhalation, consumption of food and through drinking water.

Copper (Cu)

The concentration of copper recorded a maximum level of 81 µg/L. The distribution of copper at different sites during is shown in Fig. 4.13. The Bureau of Indian Standards has recommended 50 µg/L as the desirable limit and 1500 µg/L as the permissible limit in the absence of alternate source (BIS, 2012). Beyond 50 µg/L the water imparts astringent taste and cause discoloration and corrosion of pipes, fittings and utensils. World Health Organization has recommended 2000 µg/L as the provisional guideline value for drinking purpose (WHO, 1996).

In Bahadrabad Block, about 94% of the samples fall within the acceptable limit of 50 µg/L and as such the ground water of Bahadrabad Block can be safely used as a source of drinking water supplies. In general the principal sources of copper in water supplies are corrosion of brass and copper pipe and addition of copper salts during water treatment for algae control. The toxicity of copper to aquatic life is dependent on the alkalinity of the water. At lower alkalinity, copper is generally more toxic to aquatic life. Copper if present in excess amount in public water supplies enhances corrosion of aluminium and zinc utensils and fittings. High intake of copper may results in damage to liver. The industrial sources of copper that enhance the concentration in ground water include industrial effluents from electroplating units, textiles, paints and pesticides.

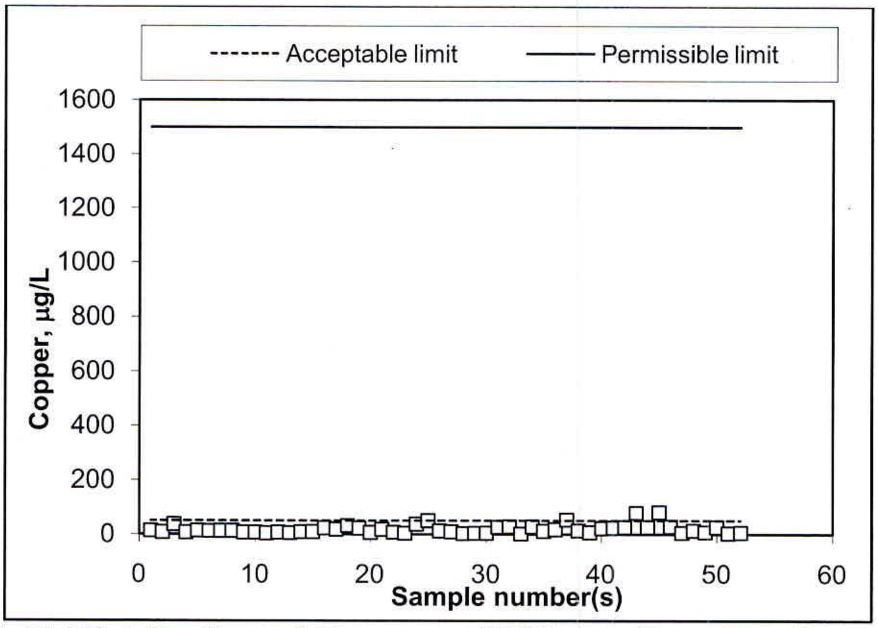

Fig. 4.13 Distribution of Copper at Different Sampling Locations

Nickel (Ni)

The concentration of nickel in the study area recorded a maximum level of 527 µg/L. The distribution of nickel at different sites is shown in Fig. 4.14. The Bureau of Indian Standards has prescribed 20 µg/L nickel as the acceptable limit for drinking water (BIS, 2012). World Health Organization has also recommended 20 µg/L as the guideline value for drinking water (WHO, 1996). In Bahadrabad Block, all the samples exceed the BIS and WHO limit of 20 µg/L. Nickel at trace level is essential to human nutrition and no systemic poisoning from nickel is known in this range. The level of nickel usually found in food and water is not considered a serious health hazard. Some of the important nickel minerals include Garnierite, nickeliferous limonite and pentiandite. Certain nickel compounds have carcinogenic effects on animals, however, soluble compounds are not currently regarded as human or animal carcinogens.

Chromium (Cr)

The concentration of chromium in the study area recorded a maximum level of 301 µg/L. The distribution of chromium at different sites is shown in Fig. 4.15. A concentration of 50 µg/L has been recommended as a acceptable limit for drinking water (BIS, 2012). WHO has also prescribed 50 µg/L as the guideline value for drinking water (WHO, 1996). In the study area, about 94% of the samples fall within the acceptable limit for drinking water and 6% of the samples exceed the acceptable limit of 50 µg/L.

The two important oxidation states of chromium in natural waters are +3 and +6. In well oxygenated waters, Cr(+6) is the thermodynamically stable species. However, Cr(3+), being kinetically stable, could persist bound to naturally occurring solids. Inter-conversions of Cr(+3) and Cr(+6) occur in conditions similar to natural waters. Municipal wastewater release considerable amount of chromium into the environment. Chromium is not acutely toxic to humans. This is due to the high stability of natural chromium complexes in abiotic matrices. In addition, the hard acid nature of chromium imparts strong affinity for oxygen donors rather than sulfur donors present in biomolecules. However, Cr(+6) is more toxic than Cr(+3) because of its high rate of adsorption through intestinal tracts. In the natural environment, Cr(+6) is likely to be reduced to Cr(+3), thereby reducing the toxic impact of chromium discharges.

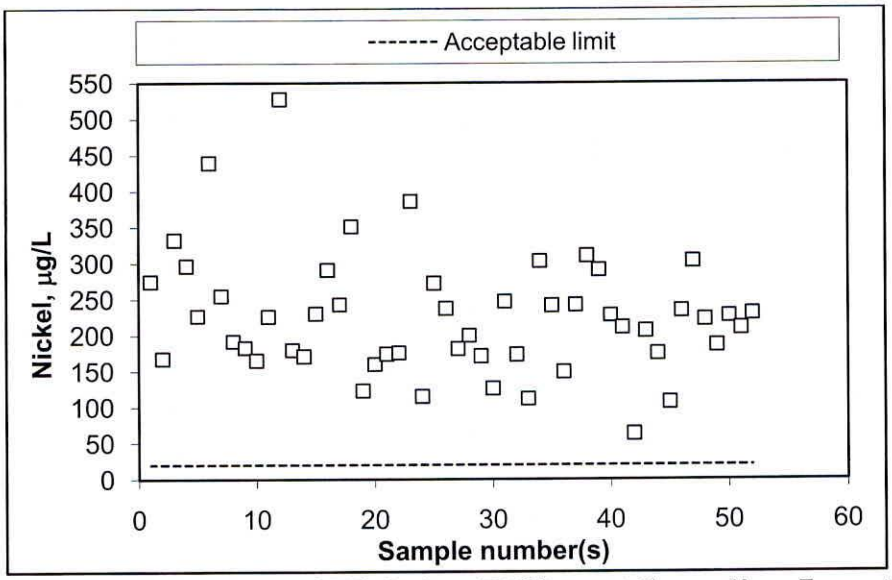

Fig. 4.14 Distribution of Nickel at Different Sampling Locations

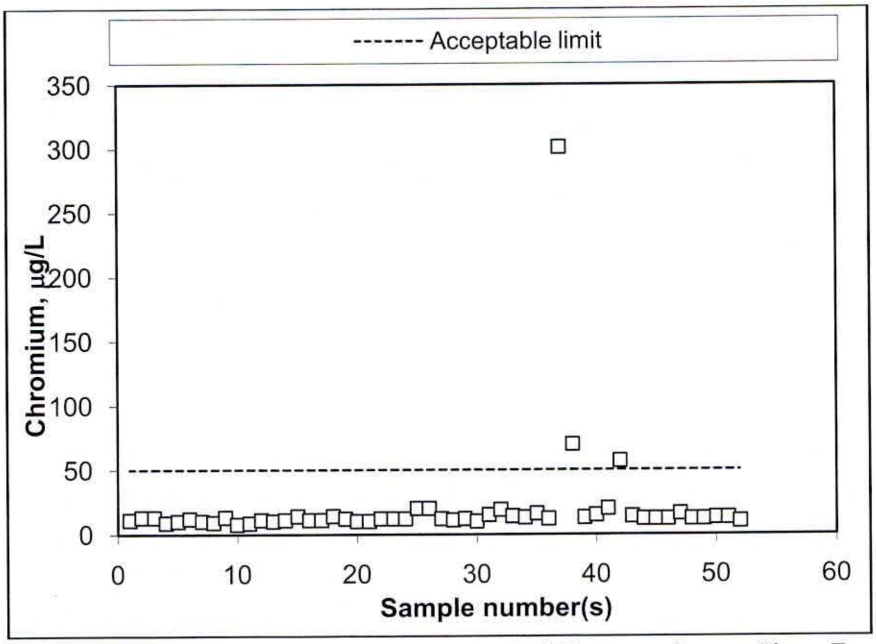

Fig. 4.15 Distribution of Chromium at Different Sampling Locations

Lead (Pb)

The concentration of lead in the study area recorded a maximum level of 74 μg/L. The distribution of lead at different sites is shown in Fig. 4.16. The Bureau of Indian Standards has prescribed 10 μg/L lead as the acceptable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic.

In Bahadrabad Block, 63.5% of the samples fall within the acceptable limit of 10 μg/L for drinking water while 36.5% samples exceed the acceptable limit for drinking water and therefore the ground water of the study area is not safe a source of drinking water supplies. The major source of lead contamination is the combustion of fossil fuel. Lead is removed from the atmosphere by rain and falls back on the earth surface and seeps into the ground. Lead passes from the soil to water and to the plants and finally into the food chain. In drinking water it occurs primarily due to corrosion of lead pipes and solders, especially in areas of soft water. Since dissolution of lead requires an extended contact time, lead is most likely to be present in tap water after being in the service connection piping and plumbing overnight.

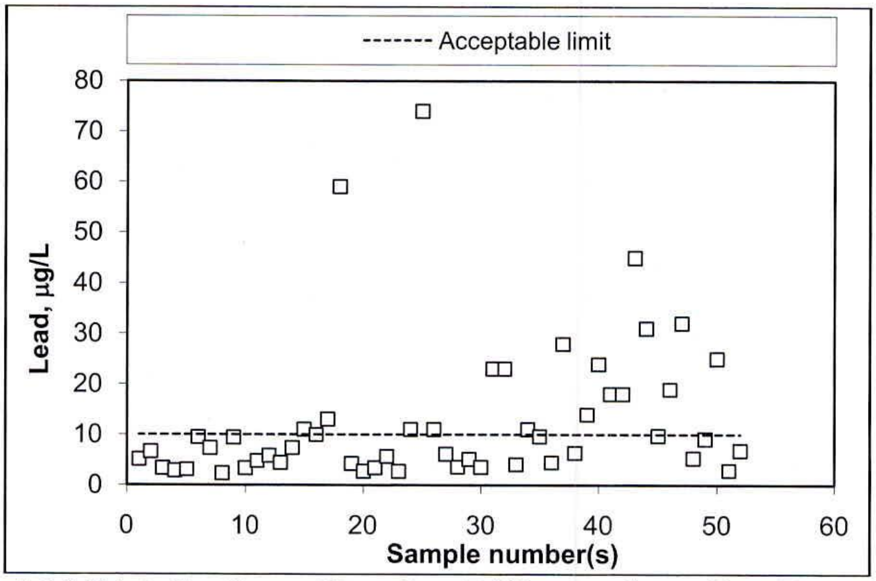

Fig. 4.16 Distribution of Lead at Different Sampling Locations

Cadmium (Cd)

Cadmium is a nonessential non-beneficial element known to have a high toxic potential. The cadmium content in the study area varies from 0.5 to 10 μg/L. The distribution of cadmium at different sites is shown in Fig. 4.17. The Bureau of Indian Standards has prescribed 3 μg/L cadmium as the acceptable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. WHO has also prescribed 3 μg/L cadmium as the guideline value for drinking water (WHO, 1996).

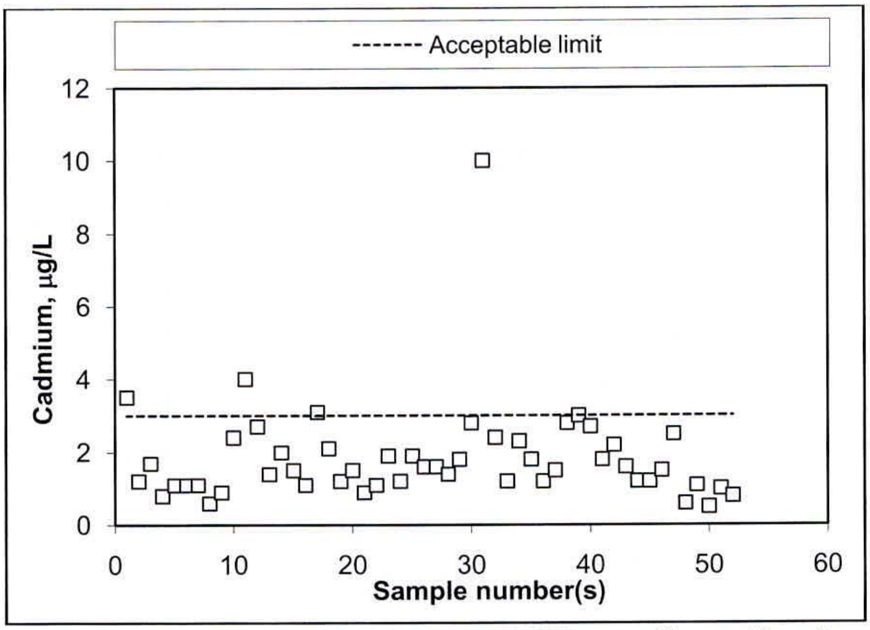

Fig. 4.17 Distribution of Cadmium at Different Sampling Locations

In Bahadrabad Block, 92.3% of the samples falls within the acceptable limit of 3 µg/L prescribed by BIS for drinking water supplies. It is obvious, therefore, that the ground water of Bahadrabad Block does not present any cadmium hazards to humans at most of the places. The levels of cadmium in public water supplies are normally very low since generally only small amounts exist in raw water and many conventional water treatment processes remove much of the cadmium. The drinking water having more than 10 µg/L of cadmium can cause bronchitis, emphysema, anaemia and renal stone formation in animals. Cadmium can also enter the environment from a variety of industrial applications, including mining and smelting, electroplating, and pigment and plasticizer production. Drinking water is generally contaminated with galvanized iron pipe and plated plumbing fittings of the water distribution system. USEPA has classified cadmium as a probable human carcinogen based on positive carcinogenicity testing. However, no such health hazard is expected in ground water of Bahadrabad Block.

Zinc (Zn)

The concentration of zinc in the study area varies from 24 to 13227 µg/L. The distribution of zinc at different sites is shown in Fig. 4.18. The Bureau of Indian Standards has prescribed 5000 µg/L zinc as the acceptable limit and 15000 µg/L as the permissible limit for drinking water (BIS, 2012). WHO has prescribed 3000 µg/L as the guideline value for drinking water (WHO, 1996). In the study area, all the samples analysed are found within the permissible limit prescribed by BIS (2012).

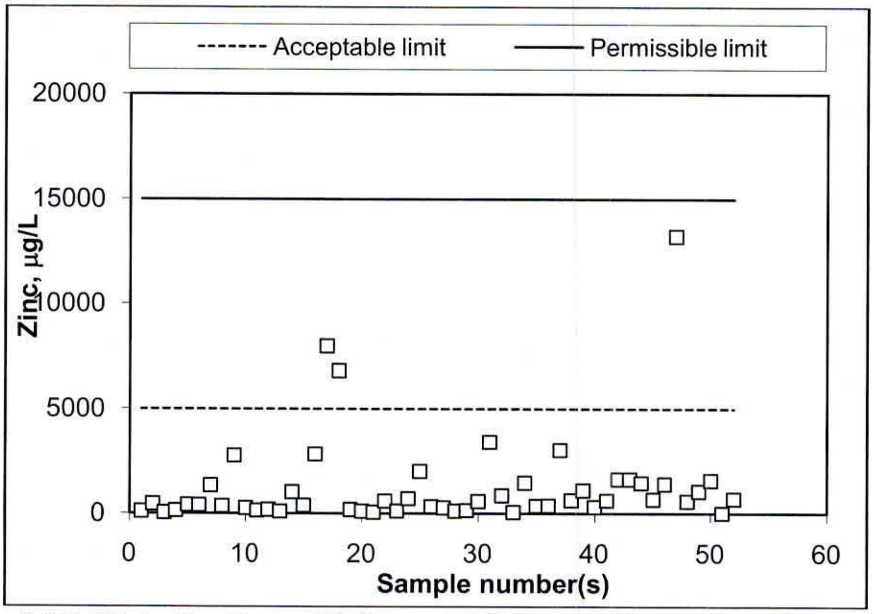

Fig. 4.18 Distribution of Zinc at Different Sampling Locations

Arsenic (As)

Arsenic is a semi-metallic element and it occurs naturally in rocks, soils and waters that come in contact with these rocks and soils. Arsenic can combine with other elements to form inorganic and organic arsenicals. In general, inorganic derivatives are regarded as more toxic than the organic forms. While food can contain both inorganic and organic arsenicals, primarily inorganic forms are present in water. Exposure to arsenic at high levels poses potential serious health effects as it is a known human carcinogen or cancer-causing agent. It also has been reported to affect the vascular system in humans and has been associated with the development of diabetes. Arsenic enters the human body principally through the mouth and inhaled arsenic is absorbed through the lungs into the bloodstream. Small amounts of arsenic may enter the body through the skin but this is not of much important consideration.

The concentration of arsenic in the study area varies from 0.8 to 90 µg/L. The distribution of arsenic at different sites is shown in Fig. 4.19. The Bureau of Indian Standards has prescribed 10 µg/L arsenic as the acceptable limit and 50 µg/L as the permissible limit for drinking water (BIS, 2012). Arsenic adversely affects the health of human being when their concentration exceeds the limit of 10 µg/L. Ingestion of inorganic arsenic can result in both cancer and non-cancer health effects. Arsenic interferes with a number of essential physiological activities, including the actions of enzymes, essential cations and transcriptional events in cells. The USEPA has classified arsenic as a Class 'A' human carcinogen. Chronic exposure to low arsenic levels has been linked to health complications, including cancer of the skin, kidney, lung and bladder, as well as other diseases of the skin, neurological and cardiovascular system.

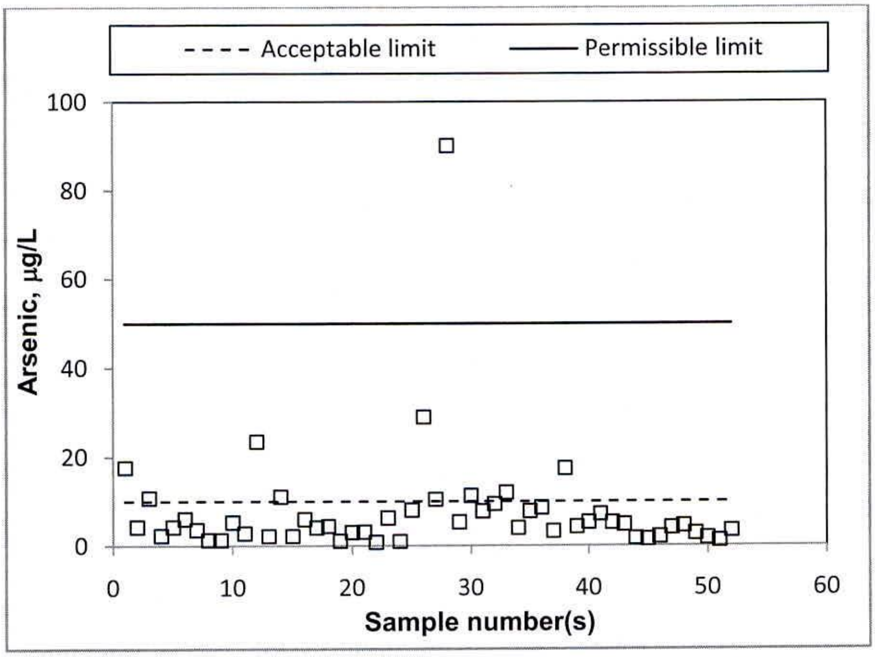

Fig. 4.19 Distribution of Arsenic at Different Sampling Locations

Mercury (Hg)

The concentration of mercury in the study area varies from 0.3 to 25 µg/L. The distribution of arsenic at different sites is shown in Fig. 4.20. The Bureau of Indian Standards has prescribed 1 µg/L mercury as the acceptable limit for drinking water (BIS, 2012). The major sources of mercury in drinking water are erosion of natural deposits, discharge from refineries and factories, runoff from landfills and runoff from croplands. Elemental mercury is typically released from industrial processes, agricultural processes, household, commercial and medical products containing mercury, sewage discharge and sediment. Elemental mercury vapor may cause nervous system damage when exposed at high concentrations.

Mercury may cause health problems if present in public or private water supplies in amounts greater than the drinking water standard. Some people who drink water containing mercury well in excess of the prescribed limit for many years could experience kidney damage. Inorganic mercury is found in batteries and is used in the chemical industry and it is produced from elemental mercury through the process of oxidation. Inorganic mercury is the most common form that is present in drinking water but is not considered to be very harmful to human health, in terms of the levels found in drinking water. However, kidney damage may result from exposure to inorganic mercury through other sources.

Organic mercury (primarily methyl mercury) is produced by specific bacterial organisms in surface waters that convert inorganic mercury into organic mercury, which is the form of mercury that poses a significant threat to human health. Methyl mercury is ingested typically by fish and bioaccumulates both in the tissues of fish and the humans that eat these fish. Large predatory fish can contain as much as 100,000 times more methyl mercury than the surrounding water medium. This form is rarely present in drinking water but is a very common contaminant in the tissues of fish and causes damage to the nervous system as well as teratogenesis. Both inorganic and organic mercury are considered to have a more detrimental effect on children due to the fact that both forms are more easily absorbed into their system.

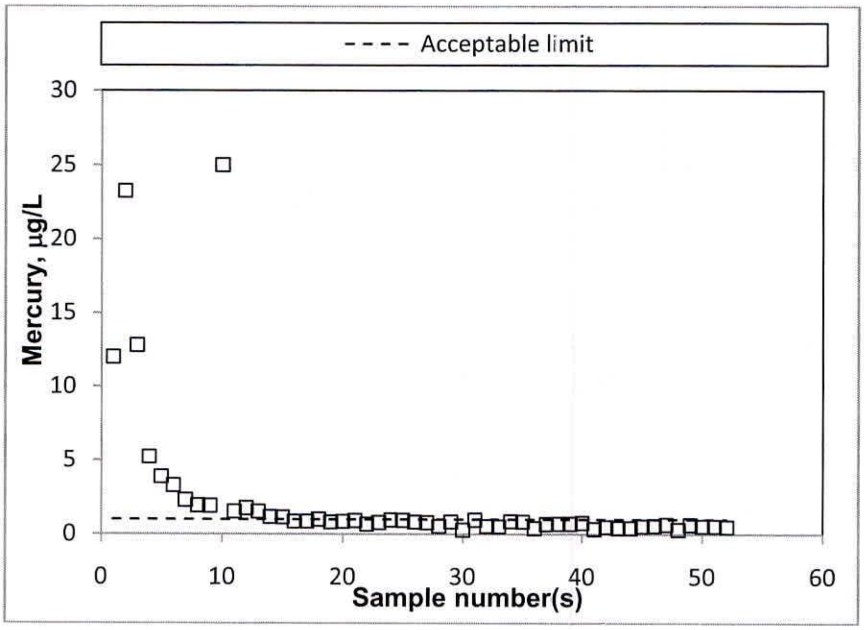

Fig. 4.20 Distribution of Mercury at Different Sampling Locations

The presence of heavy metals in ground water has been recorded at many locations. The water quality standards have been violated for iron, manganese and nickel at many locations. The concentration of iron varies from 3002 to 19771 µg/L as against the acceptable limit of 300 µg/L. The concentration of manganese varies from 5.5 to 2712 µg/L as against the permissible limit of 300 µg/L and concentration of nickel varies from 63 to 527 µg/L as against the prescribed limit of 20 µg/L. The concentration of copper, chromium, lead, cadmium and zinc were found well within the permissible limits at most of the locations.

4.2 Water Quality Evaluation for Irrigation Purpose

Irrigation water quality refers to its suitability for agricultural use. The concentration and composition of dissolved constituents in water determine its quality for irrigation use. Quality of water is an important consideration in any appraisal of salinity or alkali conditions in an irrigated area. Good quality water has the potential to cause maximum yield under good soil and water management practices. The most important characteristics of water which determine suitability of ground water for irrigation purpose are as follows:

1) Salinity
2) Relative Proportion of Sodium to other Cations (SAR)
3) Residual Sodium Carbonate (RSC)
4) Boron

The safe limits of electrical conductivity for crops of different degrees of salt tolerances under varying soil textures and drainage conditions are given in Table 4.24. The quality of water is commonly expressed by classes of relative suitability for irrigation with reference to salinity levels. The recommended classification with respect to electrical conductivity, sodium content, Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are given in Table 4.25. The values of sodium percentage (Na%), SAR and RSC in ground water of Bahadrabad Block are given in Table 4.26.

Table 4.24 Safe Limits of Electrical Conductivity for Irrigation Water

S.No.	Nature of soil	Crop growth	Upper permissible safe limit of EC in water, µS/cm
1.	Deep black soil and alluvial soils having clay content more than 30% soils that are fairly to moderately well drained	Semi-tolerant	1500
		Tolerant	2000
2.	Having textured soils having clay contents of 20-30% soils that are well drained internally and have good surface drainage system	Semi-tolerant	2000
		Tolerant	4000
3.	Medium textured soils having clay 10-20% internally very well drained and having good surface drainage system	Semi-tolerant	4000
		Tolerant	6000
4.	Light textured soils having clay less than 10% soil that have excellent internally and surface drainage system	Semi-tolerant	6000
		Tolerant	8000

Source: CGWB and CPCB (2000).

Table 4.25 Guidelines for Evaluation of Irrigation Water Quality

Water class	Sodium (Na) %	Electrical Conductivity, µS/cm	SAR	RSC meq/l
Excellent	< 20	< 250	< 10	< 1.25
Good	20-40	250-750	10-18	1.25-2.0
Medium	40-60	750-2250	18-26	2.0-2.5
Bad	60-80	2250-4000	> 26	2.5-3.0
Very bad	> 80	> 4000	> 26	> 3.0

Source: CGWB and CPCB (2000).

Table 4.26 SAR, Na% and RSC Values in Ground Water of Bahadrabad Block

S.No.	Location	Source	Depth (m)	SAR	Na (%)	RSC
1	Sohalpur Sikrodha	IM - II	49	0.61	14.9	-0.66
2	Kotta Muradnagar	IM - II	40	1.67	33.5	2.30
3	Hazara Grant	IM - II	11	2.80	46.1	-0.60
4	Aurangabad	TW	92	0.33	11.4	0.73
5	Aurangabad	IM - II	21	0.47	15.4	0.37
6	Aneki Hetmapur	HP	19	0.72	17.6	-1.02
7	Aneki Hetmapur	IM - II	24	0.29	9.2	-0.68
8	Puranpur Sahlapur	IM - II	47	0.39	14.6	0.17
9	Rajpur	IM - II	43	0.22	7.4	0.72
10	Meerpur Muwaqzarpur	IM - II	61	0.24	9.2	-0.58
11	Garh	IM - II	37	0.27	8.6	-0.22
12	Shivdaspur Urf Teliwala	HP	17	1.65	33.8	-1.88
13	Dadupur Govindpur	IM - II	31	0.30	9.8	0.17
14	Salempur Mahamoodpur	IM - II	58	0.19	9.8	0.21
15	Rawali Mahadood	IM - II	37	0.21	7.2	-0.36
16	Bahadrabad	IM - II	20	0.34	8.7	-1.27
17	Atamalpur Baungla	IM - II	18	0.47	11.9	-1.95
18	Ruhalki Kisanpur	IM - II	18	0.25	5.7	-2.19
19	Alipur Ibrahimpur	IM - II	11	0.11	4.7	-0.06
20	Subhashnagar Sitapur	TW-Sawjal	92	0.48	14.6	-0.46
21	Acar kalan Bhagatanpur Aabidpur	IM - II	18	0.59	16.0	-0.37
22	Acar Khurd Bhagatanpur Aabidpur	IM - II	14	0.33	10.7	-1.55
23	Ibrahimpur Bhagatanpur Aabidpur	IM - II	14	0.74	15.3	-4.04
24	Pathari Gadh	IM - II	12	0.14	5.4	0.15
25	Peetpur	IM - II	12	0.80	21.2	0.56
26	Ransura	IM - II	21	0.47	21.6	1.07
27	Kasampur	IM - II	21	0.39	12.7	0.94
28	Boddaheri Mohadinpur	IM - II	18	0.59	16.9	1.29
29	Boddaheri Mohadinpur	HP	41	0.35	11.5	0.01
30	Naseerpur uraf Nasratpur Alavalpur	IM - II	11	0.44	13.9	0.05
31	Moham. Pur Kunhari	IM - II	12	0.75	21.04	0.17
32	Badshapur	IM - II	34	0.11	5.72	-0.05
33	Dhariwala	TW-Sawjal	58	0.35	15.70	-0.16
34	Nasirpur Kanla	IM - II	11	0.56	17.31	-0.02
35	Shahpur Shitala Khera	IM - II	18	0.57	18.24	-0.95
36	Hardevpur Shadevpur urf Rani Majara	IM - II	12	0.30	18.38	-0.09
37	Padartha urf Dhanpura	IM - II	31	0.52	15.53	0.41
38	Dhanpura	IM - II	12	0.64	24.83	-0.25
39	Dogiwala	IM - II	27	0.59	16.72	-0.22
40	Ferupur Ramkhera	IM - II	12	0.97	24.32	0.21
41	Katarpur Alipur	IM - II	24	0.34	15.07	-0.03
42	Bisanpur Jhara	IM - II	31	0.18	12.63	0.00
43	Jagjeetpur	IM - II	29	0.30	11.03	-0.67
44	Gadowali	IM - II	31	0.19	8.28	-0.40
45	Bahadarpur Jat	IM - II	18	0.25	12.26	-0.64
46	Saranya	IM - II	37	0.67	17.95	-0.46
47	Jamalpur Kanla	IM - II	24	0.43	12.32	0.27
48	Kangari	IM - II	15	0.25	11.71	0.19
49	Shyampur Naubad	IM - II	31	0.15	6.41	0.43
50	Mohalapuri	IM - II	67	0.71	16.86	1.42
51	Chamariya	TW-Sawjal	88	0.85	21.60	0.51
52	Chamariya	TW-Sawjal	82	0.93	23.06	0.41

IM - India Mark (Hand Pump); HP - Hand Pump; TW - Tube Well

4.2.1Salinity

Salinity is broadly related to total dissolved solids (TDS) and electrical conductivity (EC). High concentration of TDS and electrical conductivity in irrigation water may increase the soil salinity, which affect the salt intake of the plant. The salts present in the water, besides affecting the growth of the plants directly, also affect the soil structure, permeability and aeration, which indirectly affect the plant growth. Soil water passes into the plant through the root zone due to osmotic pressure. As the dissolved solid content of the soil water in the root zone increases, it is difficult for the plant to overcome the osmotic pressure and the plants root membrane are able to assimilate water and nutrients. Thus, the dissolved solids content of the residual water in the root zone also has to be maintained within limits by proper leaching. These effects are visible in plants by stunted growth, low yield, discoloration and even leaf burns at margin or top. The electrical conductivity values in Bahadrabad Block are well within the prescribed limits of 1500 μS/cm and therefore safe for irrigation purpose.

4.2.2Relative Proportion of Sodium to other Cations

A high salt concentration in water leads to formation of a saline soil and high sodium leads to development of an alkali soil. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of Sodium Adsorption Ratio (SAR). If the proportion of sodium is high, the alkali hazard is high; and conversely, if calcium and magnesium predominate, the hazard is less. There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. If water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles. A simple method of evaluating the danger of high-sodium water is the sodium-adsorption ratio, SAR (Richards, 1954):

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$$

The sodium percentage is calculated as:

$$Na\% = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$$

Where all ionic concentrations are expressed in milliequivalent per liter.

Calculation of SAR for given water provides a useful index of the sodium hazard of that water for soils and crops. A low SAR (2 to 10) indicates little danger from sodium; medium hazards are between 7 and 18, high hazards between 11 and 26, and very high hazards above that. The lower the ionic strength of the solution, the greater the sodium hazards for a given SAR (Richards, 1954).

The values of SAR in the ground water of Bahadrabad Block vary from 0.11 to 2.80. As evident from the SAR values, the ground water of the study area falls under the category of low sodium hazard, which reveals that ground water of the study area is free from any sodium hazard. The sodium percentage in the study area was found to vary from 4.7 to 46.1% indicating that all the samples are well within the permissible limit of irrigation water and does not create any sodium hazard.

4.2.3Residual Sodium Carbonate

In addition to total dissolved solids, the relative abundance of sodium with respect to alkaline earths and boron, and the quantity of bicarbonate and carbonate in excess of alkaline earths also influence the suitability of water for irrigation purposes. This excess is denoted by Residual Sodium Carbonate (RSC) and is determined by the following formula:

$$RSC = (HCO_3^{-} + CO_3^{--}) - (Ca^{++} + Mg^{++})$$

Where all ionic concentrations are expressed in epm. Ground water containing high concentration of carbonate and bicarbonate ions tends to precipitate calcium and magnesium as carbonate. As a result, the relative proportion of sodium increases and gets fixed in the soil thereby decreasing the soil permeability. If the RSC exceeds 2.5 epm, the water is generally unsuitable for irrigation. Excessive RSC causes the soil structure to deteriorate, as it restricts the water and air movement through soil. If the value is between 1.25 and 2.5, the water is of marginal quality, while values less than 1.25 epm indicate that the water is safe for irrigation. During the present study, the RSC values clearly indicate that the majority of ground water of Bahadrabad Block is not having any residual sodium carbonate hazard.

4.2.4Boron

Boron is essential to the normal growth of all plants, but the concentration required is very small and if exceeded may cause injury. Plant species vary both in boron requirement and in tolerance to excess boron, so that concentrations necessary for the growth of plants having high boron requirement may be toxic for plants sensitive to boron. Though boron is an essential nutrient for plant growth, generally it becomes toxic beyond 2 mg/L in irrigation water for most of the field crops. It does not affect the physical and chemical properties of the soil, but at high concentrations it affects the metabolic activities of the plant. During the present study, the boron content in the ground water clearly indicates that the ground water is safe for irrigation purpose.

4.3 Classification of Ground Water

Different accepted and widely used graphical methods such as Piper trilinear diagram, Chadha's diagram and U.S. Salinity Laboratory classification have been used in the present study to classify the ground water of the study area. Piper trilinear (Piper, 1944) and Chadha's diagram (Chadha, 1999) are used to express similarity and dissimilarity in the chemistry of water based on major cations and anions. U.S. Salinity Laboratory classification (Wilcox, 1955) is used to study the suitability of ground water for irrigation purposes. In classification of irrigation waters, it is assumed that the water will be used under average conditions with respect to soil texture, infiltration rate, drainage, quantity of water used, climate and salt tolerance of crop. The results of all the aforesaid classifications are discussed in the following pages and compiled in Table 4.27.

Table 4.27 Summarized Results of Water Classification for Bahadrabad Block

Classification/Type	Sample Numbers
Piper Trilinear Classification	
Ca-Mg-HCO_3 (Group 5)	1-52
Ca-Mg-Cl-SO_4 (Group 6)	-
Na-K-Cl-SO_4 (Group 7)	-
Na-K-HCO_3 (Group 8)	-
Chadha's Diagram	
Ca-Mg-HCO_3 (Group 5)	1-52
Ca-Mg-Cl-SO_4 (Group 6)	-
Na-K-Cl-SO_4 (Group 7)	-
Na-K-HCO_3 (Group 8)	-
U.S. Salinity Laboratory Classification	
C1-S1	-
C2-S1	4,5,7,8,9,10,11,13,14,15,19,20,21,22,24, 27,29,30,32,33,36,41,42,44,45,48,49
C3-S1	1,2,3,6,12,16,17,18,23,25,26,28,31,34, 35,37,38,39,40,43,46,47,50,51,52
C4-S1	-

4.3.1Piper Trilinear Classification

Piper (1944) has developed a form of trilinear diagram, which is an effective tool in segregating analysis data with respect to sources of the dissolved constituents in ground water, modifications in the character of water as it passes through an area and related geochemical problems. The diagram is useful in presenting graphically a group of analysis on the same plot.

The diagram combine three distinct fields by plotting two triangular fields at the lower left and lower right respectively and an intervening diamond-shaped field. All three fields have scales reading in 100 parts. In the triangular fields at the lower left, the percentage reacting values of the three cation groups (Ca, Mg, Na+K) are plotted as a single point according to conventional trilinear coordinates. The three anion groups (HCO_3, SO_4, Cl) are plotted likewise in the triangular field at the lower right. Thus, two points on the diagram, one in each of the two triangular fields, indicate the relative concentrations of the several dissolved constituents of a ground water. The central diamond-shaped field is used to show the overall chemical character of the ground water by a third single point plotting, which is at the intersection of rays projected from the plotting of cations and anions. The position of this plotting indicates the relative composition of a ground water in terms of cation-anion pairs that correspond to the four vertices of the field. The three areas of plotting show the essential chemical character of ground water according to the relative concentrations of its constituents.

The chemical analysis data of all the samples collected from Bahadrabad Block have been plotted on trilinear diagram (Fig. 4.21) and results have been summarized in Table 4.27. The Piper trilinear diagram combines three areas of plotting, two triangular areas (cations and anions) and an intervening diamond-shaped area (combined field). Using this diagram water can be classified into different hydrochemical facies. It is evident from the results that all the samples of the study area belong to Ca-Mg-HCO_3 hydrochemical facies.

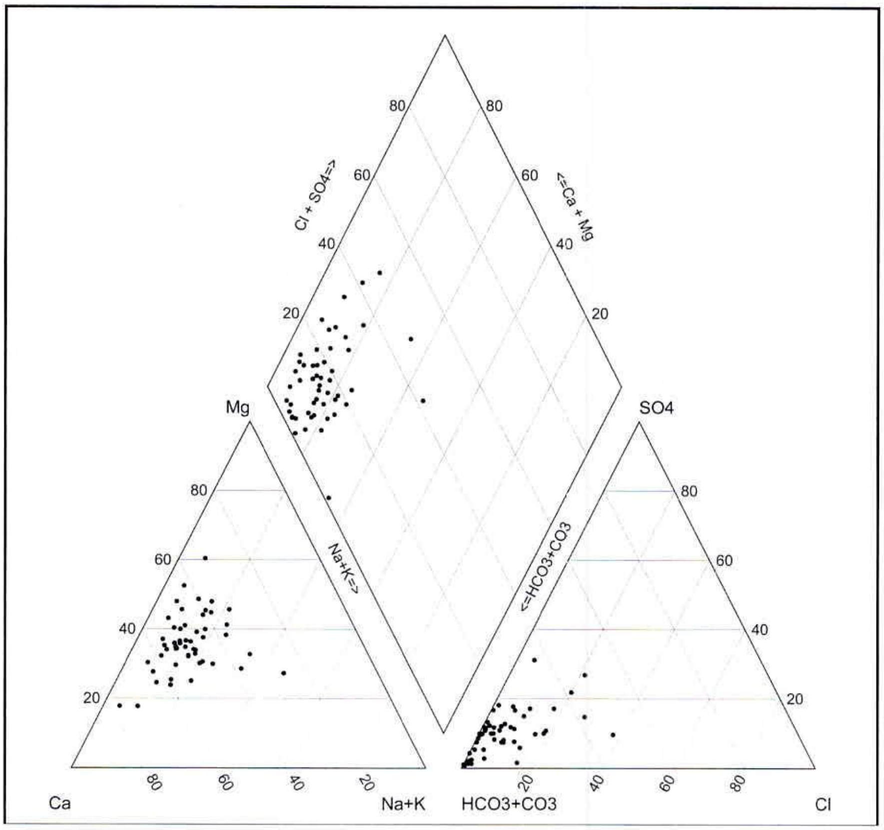

Fig. 4.21 Piper Trilinear Diagram Showing Chemical Character of Ground Water

4.3.2Chadha's Diagram

The diagram is a somewhat modified version of the piper trilinear diagram. In the piper diagram the milliequivalent percentages of the major cations and anions are plotted in two base triangles and the type of water is determined on the basis of position of the data in the respective cationic and anionic triangular fields. The plottings from triangular fields are projected further into the central diamond field, which represents the overall character of the water. Piper diagram allow comparisons to be made among numerous analyses, but this type of diagram has a drawback, as all trilinear diagram do, in that it 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. This method is not very convenient when plotting a large volume of data. Nevertheless, this shortcoming does not lessen the usefulness of the Piper diagram in the representation of some geochemical processes.

In contrast, in 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 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 earth and alkali metals and between weak acidic anions and strong acidic anions would plot in one of the four possible sub-fields of the diagram. The main advantage of this diagram is that it can be made simply on most spreadsheet software packages.

The square or rectangular field describes the overall character of the water. The diagram has all the advantages of the diamond-shaped field of the Piper trilinear 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 earth exceeds alkali metals.
2. Alkali metals exceed alkaline earth.
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 alkali metals and strong acidic anions respectively. Such water has temporary hardness. The position of data points in the 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 position of data points in the diagram represents 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

position of data points in the 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 diagram represent Na^+- HCO_3^--type, Na^+-dominant HCO_3^--type, or HCO_3^--dominant Na^+-type waters.

The chemical analysis data of all the samples collected from Bahadrabad Block have been plotted on Chadha's diagram (Fig. 4.22) and results have been summarized in Table 4.27. It is evident from the results that all the samples of the study area fall in Group 5 (Ca-Mg-HCO_3 type). The Chadha's diagram has all the advantages of the diamond-shaped field of the Piper trilinear diagram and can be conveniently used to study various hydrochemical processes. Another main advantage of this diagram is that it can be made simply on most spreadsheet software packages.

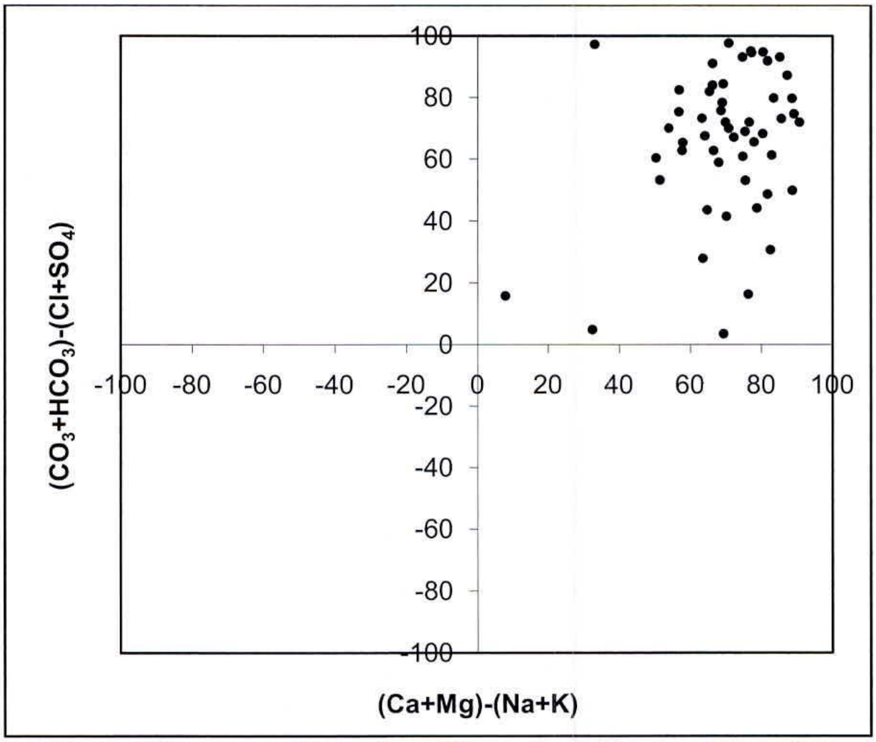

Fig. 4.22 Chadha's Diagram Showing Chemical Character of Ground Water

4.3.3U. 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). A diagram for use in studying the suitability of ground water for irrigation purposes is based on the sodium adsorption ratio (SAR) and electrical conductivity of water expressed in μS/cm. The chemical analysis data of ground water samples of Bahadrabad Block has been processed as per U.S.S.L. classification for the two sets of data (Fig. 4.23) and the results have been summarized in Table 4.27.

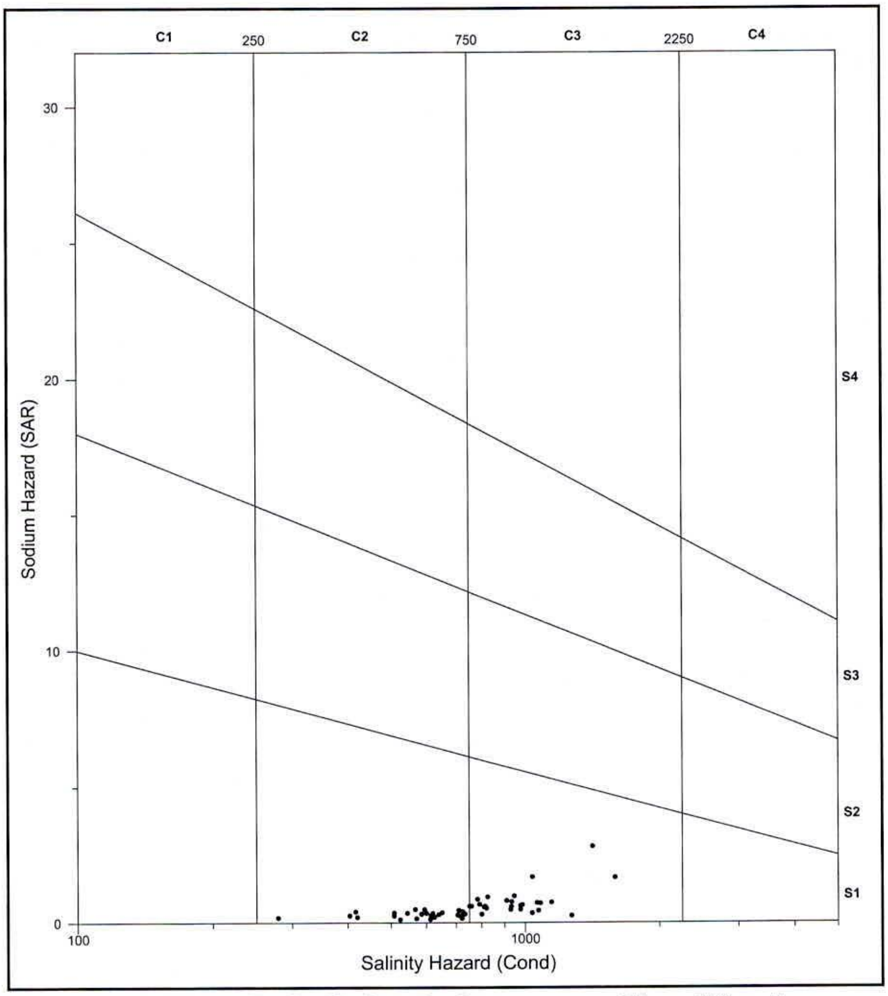

Fig. 4.23 U.S. Salinity Laboratory Classification

It is evident from the results that about 50% of the samples fall under water type C2-S1 (medium salinity and low SAR), such water can be used if a moderate amount of leaching occurs and plants with moderate salt tolerance can be grown in most cases without special practices for salinity control. About 50% samples fall under water type C3-S1 (high salinity and low SAR), such water cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good tolerance should be selected.

5.0 CONCLUSIONS AND RECOMMENDATIONS

1. The ground water quality varies from place to place and with the depth of water table. The water drawn for domestic applications should be tested and analysed to ensure the suitability of ground water for human consumption.
2. The ground water abstraction sources and their surroundings should be properly maintained to ensure hygienic conditions and no sewage or polluted water should be allowed to percolate directly to ground water aquifer.
3. Proper cement platforms should be constructed surrounding the ground water abstraction sources to avoid direct well head pollution and surrounding surface area should be frequently chlorinated by use of bleaching power.
4. The hand pumps and wells, which have been identified as having suspected water quality should be painted red to indicate and warn the public that the water drawn from the source is not fit for human consumption.
5. In the absence of alternate safe source of water, the water with excessive undesirable constituents must be treated with specific treatment process before its use for human consumption.
6. The untreated sewage and sewerage flowing in various open drains are one of the causes of ground water quality deterioration. Proper under ground sewage system must be laid in inhabited areas and the untreated sewage should not be allowed to flow in open drains.
7. A proper system of collection, transportation and disposal of domestic waste should be developed. Land fill site(s) should be identified and it must be scientifically designed. Ground water quality near land fill sites should be regularly monitored.
8. The mass awareness should be generated about quality of water, its effect on human health and responsibilities of public to safeguard water resources.

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