A

Project Report

On

Ground Water Quality Assessment of Roorkee

CARRIED OUT AT

NATIONAL INSTITUTE OF HYDROLOGY (ROORKEE)

Submitted In Partial Fulfillment of the Requirement for the Award of the Degree
of

MASTER OF SCIENCE

IN

CHEMISTRY

(Specialization in Commercial Methods of Chemical Analysis)

SUBMITTED BY

AMIT RATHI

DEPARTMENT OF CHEMISTRY

GURUKULA KANGRI VISHWAVIDYALAYA

HARIDWAR-249404(INDIA)

(2015-2016)

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CANDIDATE'S DECLARATION

I hereby declare that the work being presented in this Project Report entitled "**Ground Water Quality Assessment of Roorkee**" is presented on behalf of partial fulfillment of the requirement for the award of the Degree of Master of Science with specialization in Chemistry (Commercial Methods of Chemical Analysis) and submitted to the Gurukula Kangri Vishwavidyalaya, Haridwar (Uttarakhand). This is an authentic record work carried out under the guidance of **Prof. A. K. Indrayan**, Professor, Gurukula Kangri Vishwavidyalaya, Haridwar and **Dr. Rajesh Singh**, Scientist C, National Institute of Hydrology, Roorkee.

The matter presented in this work has not been submitted by me for the award of any other degree.

Date: 27 April, 2016

Amit Rathi

CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

Prof. A. K. Indrayan
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&

12.05.16

Dr. Rajesh Singh (Scientist C)
National Institute of Hydrology, Roorkee

ACKNOWLEDGEMENT

The Three months project work is a golden opportunity for learning and self-development. I consider myself very lucky and honoured to work at National Institute of Hydrology, Roorkee on project work titled **"Ground Water Quality Assessment of Roorkee".** I thankfully acknowledge all the arrangement and permissions extended by the NIH Roorkee to my endeavour.

It is my glowing feeling to place on record my best regards, deepest sense of gratitude to **Dr. R. D. Kaushik, Professor** and **Head**, Department of Science and my Course Supervision **Prof. A. K. Indrayan** for their approval to letting me work at NIH, Roorkee.

Firstly, I would like to express my indebted gratitude and special thanks to our guide **Dr. Rajesh Singh** Scientist-C, EH Division, National Institute of Hydrology, Roorkee, Uttarakhand, who in spite of being extraordinarily busy with his duties, showed his keen interest, valuable guidance, constant encouragement, enthusiastic involvement and appreciation throughout the internship. I also acknowledge **Er. R. D. Singh**, Director, National Institute of Hydrology, Roorkee, Uttarakhand for giving me chance to work upon this project work & allowing me to use the laboratory for research purposes.

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CONTENTS

CHAPTER 1: INTRODUCTION

India is blessed with a rich and vast diversity of natural resources, water being one of them. Water is nature's most wonderful, abundant and useful compound. There are many essential elements for the existence of living beings; water is rated to be of the greatest importance. Without food, humans can survive for a number of days, but without water one cannot survive for more than a day. Water is not only essential for the lives of animals and plants, but also occupies a unique position in industries. Groundwater is an important source of water supply throughout the world. Groundwater occurs almost everywhere beneath the earth surface not in a single widespread aquifer but in thousands of local aquifer systems and compartments that have similar characters. Knowledge of the occurrence, replenishment, and recovery of groundwater has special significance in arid and semi-arid regions due to discrepancy in monsoonal rainfall, insufficient surface waters and over drafting of groundwater resources.

The ground water quality is still important to the community, therefore it is important to ensure its quality is high at all time so that the consumer health is not compromised. Groundwater resources are affected in principle by three major activities. First of these activities is excessive use of fertilizers and pesticides in agricultural areas. The second one is untreated/partially treated wastewater to the environment. Finally, excessive pumping and improper management of aquifers result. The activity of solid waste disposal in open un-engineered landfill is the one of the factor that cause the ground water pollution due to lack of pollution control interventions such as water proof layer, leachate treatment pond, monitoring wells etc. (Mohamad et al., 2007). Groundwater pollution also occurs due to clandestine disposal of toxic wastes, especially from industrial sites, or undetected leakage from pipes, waste storage containers, or underground tanks. According to WHO organization, about 80% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its restoration to actual condition requires prolonged time and decontamination is not possible by just stopping the ingress of pollutants from the source. Contamination of groundwater by domestic, industrial effluents and agricultural activity is a serious problem faced by developing countries. The industrial waste water, sewage sludge and solid waste materials are currently being discharged into the environment indiscriminately. These materials enter subsurface aquifers resulting in the pollution of irrigation and drinking water (Girija et al., 2007). High rates of mortality and morbidity due to water borne diseases are well known in India. Access to safe drinking water remains an urgent necessity, as 30% of urban and 90% of rural households still depend completely on untreated surface or groundwater (Palanisamy et al., 2007).

The quality of water is defined in terms of its physical, chemical and biological parameters. Its development and management plays a vital role in agriculture production, poverty reduction, environmental sustenance and sustainable economic development. In some areas of the world, people face serious drinking water shortage because of the ground water contamination. Assessing risk involves identifying the hazard associated with a particular occurrence, action, or circumstance and determining the probability of that hazard occurring. Hence, evaluation of groundwater quantity and quality is important for the development of further civilization and to establish database for planning future water resources development strategies. The quality of water may depend on geology of particular area and also vary with depth of water table and seasonal changes and is governed by the extent and composition of the dissolved salts depending upon source of the salt and soil, subsurface environment.

Monitoring of ground water regime is an effort to obtain information on ground water levels and chemical quality through representative sampling. In India, most of the population is dependent on groundwater as the only source of drinking water supply. The groundwater is believed to be comparatively much clean and free from pollution than surface water. But prolonged discharge of industrial effluents, domestic sewage and solid waste dumping results in pollution of groundwater and health problems. Natural phenomena such as volcanoes, algae blooms, storms, and earthquakes also cause major changes in water quality and the ecological status of water. As per the latest estimate of Central Pollution Control Board, about 29,000 million litre/day of wastewater generated from class-I cities and class-II towns out of which about 45% is generated from 35 metro-cities alone (Mangukiya et.al, 2012).

In this study, the groundwater quality study of Roorkee was carried out. Roorkee region is located in Haridwar Uttarakhand state of India. The number of industries in Roorkee, during the last decade, has grown more than ten times and accordingly the problems related to environmental degradation have increased many folds. Most of the wastewater from this area flows to the natural streams without treatment resulting in contamination of surface water as well as groundwater. Groundwater being the sole source of drinking water in this area, the sampling and analysis of groundwater from various locations and sources such as hand pumps and bore wells were carried out. The latitude and longitude (Coordinate) of the sampling location were recorded with the help of GPS meter.

OBJECTIVES

The objectives of this study are-

- Sampling, preservation, and analysis of groundwater samples from Roorkee, District Haridwar, Uttarakhand, India.
- Preparation of sampling location maps on GIS platform
- Processing of data as per BIS and WHO norms

CHAPTER 2: DESCRIPTION OF THE STUDY AREA

Roorkee is a city in Haridwar district, Uttarakhand, which is spread over a flat terrain with the grand spectacle of Himalayas ranges flanking it in the East and the North-east (Figure 1). Roorkee is located at 29.87°N 77.88°E.It has an average elevation of 268 metres (879 feet).

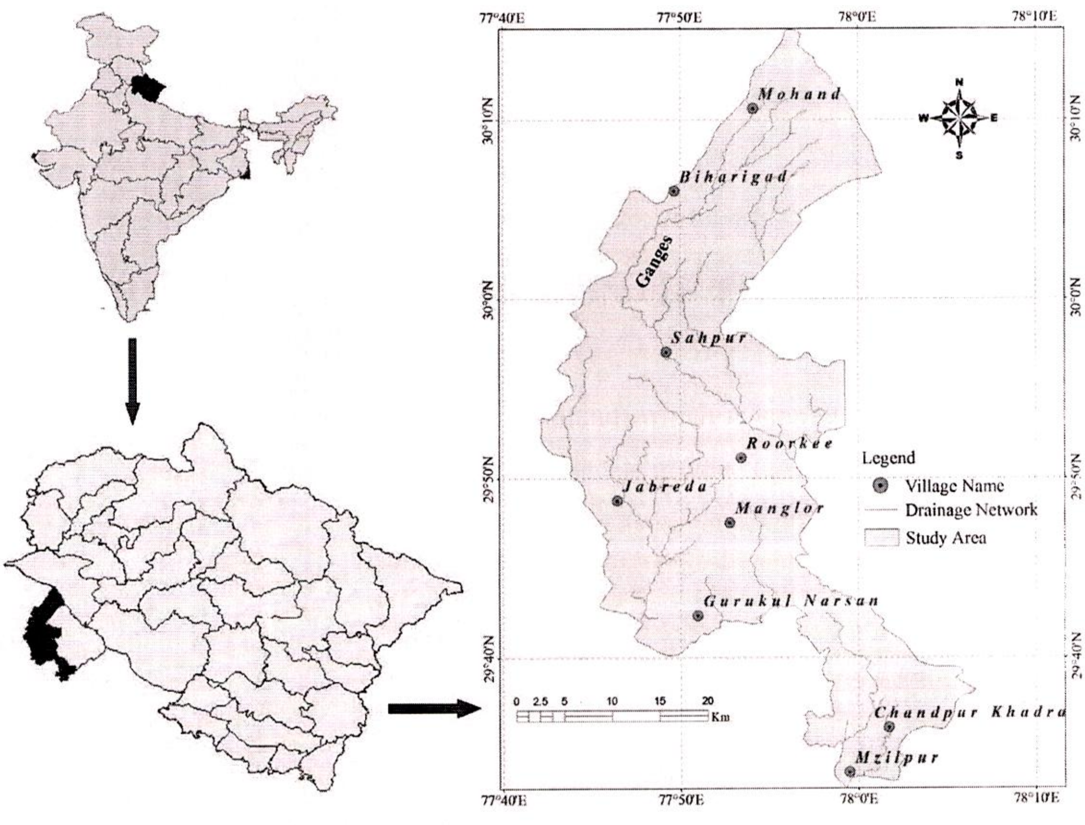

Figure 1. Location Map of Roorkee

POPULATION

The population of Roorkee is 289478 as of the 2011 National population census. The percentage male population is 53, whiles female population is 47. Roorkee has 84.9% literacy rate which is 20.9% higher than the national average literacy in India. The population coupled with several institutions of higher learning, development and businesses make it the fourth largest and busiest city in Uttarakhand.

URBANIZATION

The city is home to numerous commercial and residential dwellers. The commercial nature and other business opportunities could probably be the driving force. Civil line residential area, Ganges enclaves, Colonels enclave, Prem Nagra, Ambedkar Nagra, Indira Vihar colony, Ganeshpur, New Avas Vikas Township (NAVT), Green park colony are but, a few of the several commercial and residential apartments in Roorkee.

INDUSTRIALIZATION

Roorkee is a safe destination for many business and other cottage industries, probably due to the strategic location of the Indian Institute of Technology (IIT) and other several higher institutions of learning. The two major industrial areas are the Ram Nagar and Dev-Bhoomi industrial areas suited at Panchkula NH – 73.

CLIMATIC CONDITION

Roorkee experiences three distinct climatic conditions annually. These conditions and seasons are, summer (hot), monsoon (wet) and winter (cold). The area, witnesses an average temperature of 28^0 C summer, 15^0 C monsoon and 10^0 C in winter. The study area experiences 996.4mm annual rainfall.

SOIL AND LAND USE

Soil is an essential medium for plant growth and thus provides a physical support for the plant to stand firm and upright for the process of photosynthesis to promote the total development of the plant. Good soils with all the essential nutrients are paramount, in a quest to increase crop yield per unit area and volume of water used. Soils in the study area have a combination of sandy loam and clay. These soils are less susceptible to soil erosion and suitable for the cultivation of cereals such as rice, wheat and sugarcane.

CHAPTER 3: SAMPLING & PRECAUTIONS FOR ANALYSIS

3.1 SAMPLING

Sampling is the first of a series of step leading to the generation of water quality data and is an exceedingly important one. Care must always be taken to ensure obtaining a sample that is truly representative. Further, the integrity of the sample must be maintained from the time of collection to the time of analysis. If the sample is not representative of the system sampled, or if the sample has changed in chemical composition between sampling and analysis, all care taken to provide an accurate analysis will be lost. The sampling network also plays an important role in arriving at valid conclusions and hence utmost care is required for designing the sampling network for the study area.

3.3 SAMPLING LOCATIONS

A total number of 47 groundwater samples were collected and analysed. The samples were collected Govt. Hand pump (IM-II) and Submersible pumps with their GPS coordinates during February 2016 and preserved by adding an appropriate reagent (Jain and Bhatia, 1988; APHA, 2012) for Roorkee ~~city~~. Figure 2 presents a view of the various collected samples. The hand pumps were continuously pumped for at least 15 minutes prior to the sampling, to ensure that ground water to be sampled was representative of ground water aquifer. All the ground water samples were collected from the drinking water sources, which are being used extensively. The details of sampling locations along with their GPS coordinates is given in Table 1 and the map showing the sampling locations is given in Figure 3.

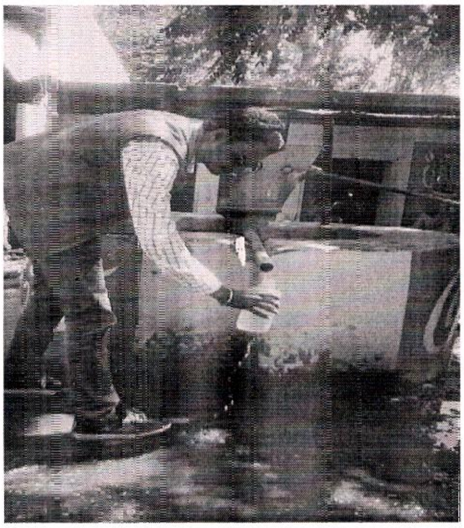 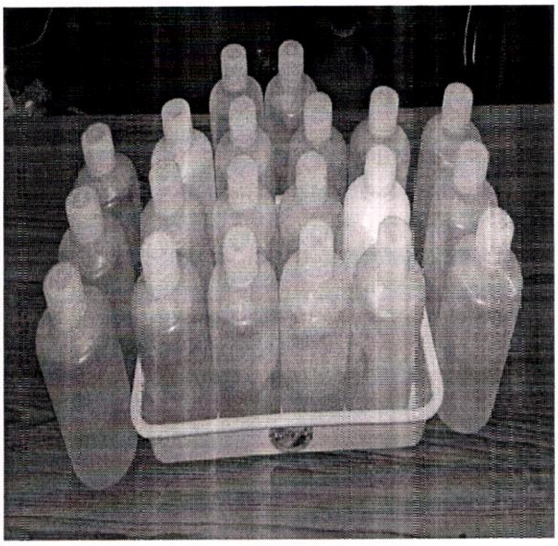

Figure 2. Collection of Groundwater Samples

Table 1. Ground Water Sampling Locations in Roorkee Area

Sr. No.	Sample ID.	Source	Location of sample	Depth (ft.)	Latitude	Longitude
1.	R-1	IM-II HP	Manakpur	150	30°04'45.5"	77°37'36.0"
2.	R-2	IM-II HP	Jhabera	150	29°48'34.5"	77°53'15"
3.	R-3	IM-II HP	Mundalana	150	29°44'23.3"	77°54'55.1"
4.	R-4	IM-II HP	Hajauli jatt	150	29°43'47.7"	77°54'3.72"
5.	R-5	IM-II HP	Ruhalki	150	29°55'4.47"	77°48'15.1"
6.	R-6	IM-II HP	Khanpur	150	29°55'37.6"	77°48'40.8"
7.	R-7	IM-II HP	Sherpur	150	29°30'17.4"	77°41'21.8"
8.	R-8	IM-II HP	Alampur	150	29°39'38.8"	77°59'12.1"
9.	R-9	IM-II HP	Lakshar	150	29°45'13.8"	78°01'17.3"
10.	R-10	IM-II HP	Laundhora	150	29°47'41.0"	77°54'29.4"
11.	R-11	IM-II HP	Kuhedi	150	29°41'44.7"	77°50'39.3"
12.	R-12	IM-II HP	Laknota	150	29°43'47.4"	77°47'52.0"
13.	R-13	IM-II HP	Tikola	150	29°43'13.2"	77°48'21.6"
14.	R-14	IM-II HP	Narsan Kalan	150	29°42'12.4"	77°49'57.3"
15.	R-15	IM-II HP	Gurukul Narsan	150	29°42'08.4"	77°50'58.5"
16.	R-16	IM-II HP	Toda kalyanpur	150	29°50'16.9"	77°55'46.5"
17.	R-17	IM-II HP	Bhangeri	150	29°51'13.1"	77°54'44.9"
18.	R-18	Submersible	Shivaji colony	150	29°50'05.3"	77°54'51.7"
19.	R-19	IM-II HP	Jalalpur	150	29°50'45.8"	77°55'25.9"
20.	R-20	IM-II HP	Khanjarpur	150	29°51'49.7"	77°54'27.0"

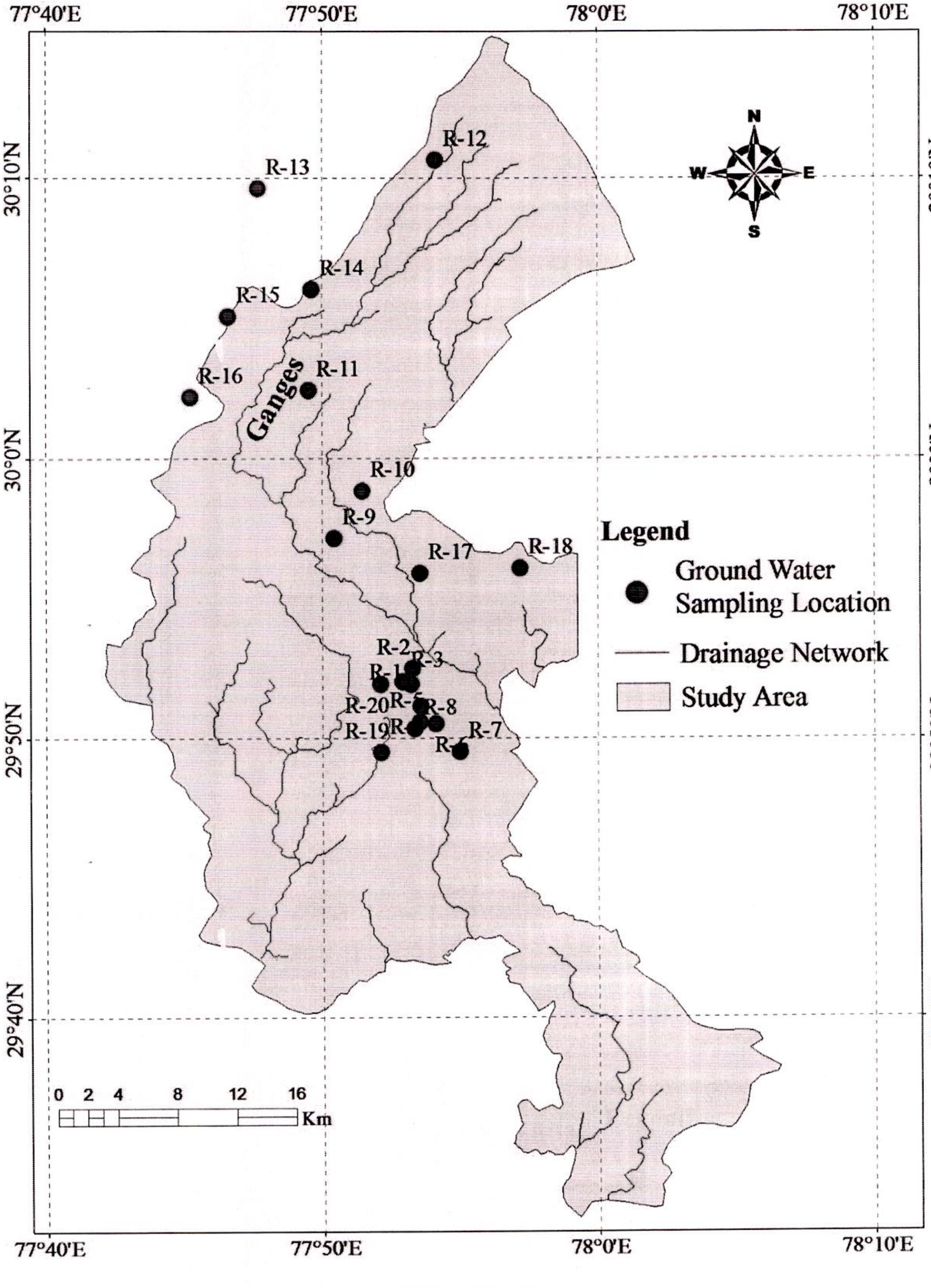

Figure 3. Sampling Locations

CHAPTER 4: MATERIAL AND METHODOLOGY

CHEMICAL AND REAGENTS

All chemicals used for analysis were of analytical reagent grade (Merk/BDH). Bacteriological reagent was obtained from HiMedia. De- ionized water was used throughout the analysis work. All glassware and other containers used for analysis were thoroughly cleaned by soaking in detergent followed by soaking rinsing with de-ionized water several times prior to use. All glassware and reagent used for bacteriological analysis were thoroughly cleaned and sterilized before use.

4.2 PHYSICO-CHEMICAL AND BACTERIOLOGICAL ANALYSIS

The physico-chemical and bacteriological analysis was performed as per standard methods (Jain and Bhatia, 1988; APHA, 2012). The details of analytical method and equipment used in the study are described in Table 2. Ionic balance was calculated, the error in the ionic balance for majority of the samples was within 5%. The total number of parameters analyzed was 23 for evaluation of the suitability of source for drinking water.

Table 2. Details of the analytical method 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	Gravimetric	----
4.	Turbidity	Electrometric	Turbidity Meter
5.	Color	PtCo Method	UV –VIS Spectrophotometer
6.	Hardness	Titration by EDTA	Digital Burette
7.	Calcium	Titration by EDTA	Digital Burette
8.	Magnesium	Titration by EDTA	-
9.	Sodium	Flame emission	Flame photometer
10.	Potassium	Flame emission	Flame photometer
11.	Ammonium	Chromatography	Ion Chromatograph
12.	Alkalinity	Titration by H_2SO_4	Digital Burette
13.	Bicarbonate	Titration by H_2SO_4	-
14.	Sulfate	Turbidimetric	Turbidity Meter
15.	Chloride	Titration by $AgNO_3$	Digital Burette
16.	Fluoride	SPANDS	UV –VIS Spectrophotometer
17.	Nitrite	Chromatography	Ion Chromatograph
18	Nitrate	Chromatography	Ion Chromatograph
19	Phosphate	Chromatography	Ion Chromatograph

20	Silica	Ammonium Molybdate	UV-VIS Spectrometer
21	Iron	1,10-Phenantholine	UV-VIS Spectrometer
B.	**Bacteriological**		
22.	Total Coliform	Maximum probable Number (MPN)	Bacteriological Incubator
23.	Fecal Coliform	MPN method	Bacteriological Incubator

CHAPTER 5: RESULT AND DISCUSSION

Roorkee is an industrial city of Uttarakhand. At present, approximately thirty five large and small scale industries exists in city, and the number is increasing day by day. Most of the wastewater from the city finds its way directly to the natural water bodies such as river, pond, etc. due to the absence of treatment plants. The contaminants also reach the ground water aquifers making it unfit for human consumption. Keeping in view of the emerging problem of groundwater contamination, 20 samples covering the length and breadth of the study area was collected. The samples were analyzed for physical, chemical and bacteriological characteristics as per standard methods. The parameters such as pH, taste, odour, colour, total dissolved solids and total suspended solids indicates the physical characteristics of the groundwater in the study area. The chemical characteristics of the groundwater under the study area were evaluated by the parameters such as total hardness, calcium, magnesium, fluoride, nitrate, chloride, sulfate, alkalinity, potassium, sodium, etc. and bacteriological characteristics were evaluated by total coliform and fecal coliform. The physico-chemical and bacteriological characteristics of groundwater samples collected from the study are is give in Table 3 – 5.

Table 3. Organoleptic characteristics of Groundwater of Roorkee

Sample ID	pH	EC (µS/cm)	TDS (mg/l)	TURBIDITY (NTU)	COLOR (PtCo.)
Acceptable Limit	**6.5 – 8.5**	**----**	**500**	**1**	**5**
Permissible Limit	**NR**	**-----**	**2000**	**5**	**15**
R-1	7.41	474	303	0.40	0
R-2	7.37	578	369	**13.4**	2
R-3	7.16	1134	725	2.94	3
R-4	7.23	748	478	**5.68**	0
R-5	7.43	417	266	**7.74**	0
R-6	7.46	765	489	**9.56**	2
R-7	7.62	228	145	1.25	1
R-8	7.27	706	451	**29.7**	1
R-9	7.28	617	394	**13.8**	1
R-10	7.22	734	469	2.96	0
R-11	7.22	660	422	2.20	0
R-12	7.32	354	226	1.11	3
R-13	7.27	399	255	**17.2**	1
R-14	7.33	1443	923	0.23	0
R-15	7.27	357	228	0.97	1
R-16	7.18	415	265	0.74	0
R-17	7.09	600	384	**6.24**	1
R-18	6.86	1060	678	0.24	0
R-19	7.18	422	270	4.92	0
R-20	7.04	702	449	3.45	2

Table 4. Physico-chemical characteristics of Groundwater of Roorkee

Sample ID	TH (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	NH_4 (mg/l)	TA (mg/l)	SO_4 (mg/l)	Cl (mg/l)	F (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)	Fe (mg/l)	Si (mg/L)
Acceptable Limit	**200**	**75**	**30**	----	----	**0.5**	**200**	**200**	**250**	**1.0**	----	**45**	----	**0.3**	----
Permissible Limit	**600**	**200**	**100**	----	----	**NR**	**600**	**400**	**1000**	**1.5**	----	**NR**	----	**NR**	----
R-1	185	35.2	23.8	27.70	3.8	**0.97**	206	4.8	16	1.06	2.84	0	-	ND	10.9
R-2	**264**	70.4	21.12	16.80	5.00	**1.10**	226	17.5	28	0.26	3.06	0	-	ND	14.20
R-3	**482**	150.4	25.44	36.50	2.40	**2.25**	298	19.3	74	0.37	5.50	**119.6**	-	ND	16.4
R-4	**270**	62.0	27.6	11.30	2.30	**1.33**	206	21.7	14	0.08	3.29	22.26	-	ND	21.4
R-5	194	41.6	21.6	16.60	2.40	**1.20**	192	2.6	8	0.23	2.98	1.28	11.40	ND	12.0
R-6	**202**	48.0	19.68	81.80	5.00	**1.49**	354	2.2	8	0.22	3.34	0	-	ND	10.2
R-7	96	25.6	7.7	5.00	2.30	**1.43**	54	21.2	5	0.56	2.73	0	-	ND	11.0
R-8	**220**	57.6	18.2	18.50	5.30	0.00	165	28.9	36	0.33	5.27	0	-	ND	11.8
R-9	**228**	56.8	20.6	18.00	4.00	0.25	216	6.2	15	0.11	3.03	0	-	ND	12.4
R-10	**228**	60.0	18.7	17.20	3.00	0.34	174	19.1	15	0.18	3.19	24.89	-	ND	18.2
R-11	**282**	76.0	22.1	26.10	1.10	0.31	115	72.8	48	0.11	2.87	**71.09**	-	ND	14.8
R-12	174	42.4	16.3	13.80	3.80	**0.60**	170	2.0	8	0.29	2.76	1.39	-	ND	15.2
R-13	122	41.6	4.3	7.80	3.40	**0.60**	74	25.0	15	0.28	2.96	3.03	-	ND	12.8
R-14	**348**	57.6	49.0	46.50	212	**1.58**	408	81.4	92	0.33	4.60	**78.22**	-	ND	19.4
R-15	170	32.0	21.6	12.60	0.20	**0.65**	114	26.0	10	0.17	2.69	13.81	-	ND	14.6
R-16	200	44.0	21.6	16.30	4.60	**0.75**	192	2.5	16	0.35	2.88	1.57	-	ND	12.8
R-17	**218**	54.4	19.7	20.50	6.30	**0.84**	204	17.5	18	0.13	3.09	0	-	ND	14.0
R-18	**298**	77.6	25.0	46.80	4.30	**1.23**	180	48.7	56	0.02	5.95	**79.26**	-	ND	21.2
R-19	184	48.8	14.9	16.4	3.80	**0.89**	130	10.5	16	0.21	2.81	25.96	-	ND	17.0
R-20	**202**	52.0	17.3	27.70	7.80	**1.2**	166	38.6	28	0.15	3.22	0	-	ND	15.8

Table 5. Bacteriological characteristics of Groundwater of Roorkee

Sample ID	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)
Acceptable Limit	**Not detectable**	**Not detectable**
Permissible Limit	**NR**	**NR**
R-1	ND	ND
R-2	ND	ND
R-3	ND	ND
R-4	ND	ND
R-5	ND	ND
R-6	ND	ND
R-7	ND	ND
R-8	ND	ND
R-9	**20**	**20**
R-10	**3**	ND
R-11	ND	ND
R-12	ND	ND
R-13	ND	ND
R-14	ND	ND
R-15	ND	ND
R-16	ND	ND
R-17	ND	ND
R-18	ND	ND
R-19	ND	ND
R-20	ND	ND

PHYSICO-CHEMICAL PARAMETERS

pH: pH has no direct impact on the consumers. Inspite of this fact, it is one of the most important water quality parameter due to effect on performance of treatment units and supply lines. It plays an important role in clarification and disinfection. For effective disinfection with chlorine, the pH should preferably be less than 8; however, lower- pH water (<7) is more likely to be corrosive. Failure to minimize corrosion can result in the contamination of drinking-water and adverse effect on its taste and appearance. BIS has prescribed permissible limit of 6.5-8.5. The pH value of groundwater samples in the study area were in the range 6.86 to 7.62 and the average value was 7.26 (Figure 4).

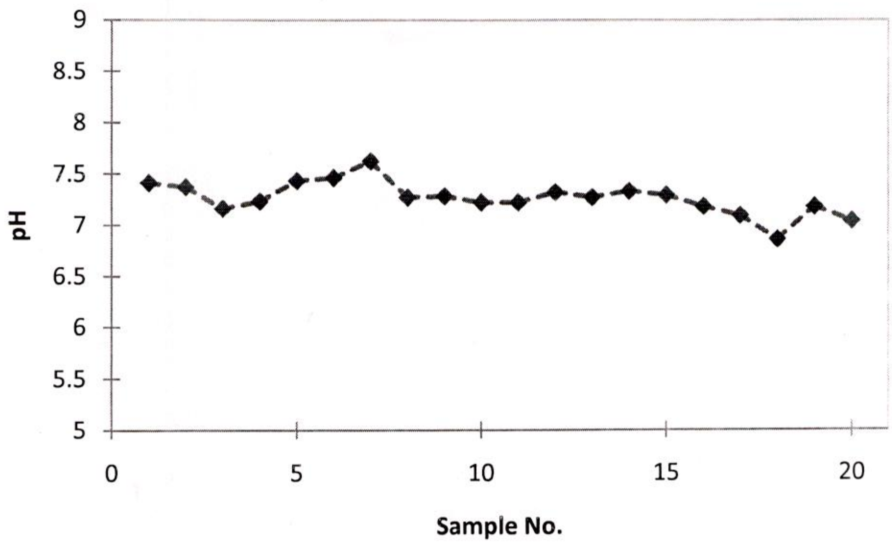

Figure 4: pH Variations in Groundwater Samples of Roorkee

Conductivity: Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. Conductivity in water is affected by the presence of dissolved ions such as sodium, potassium, calcium, magnesium, iron, chloride, nitrate, sulfate, phosphate etc. Organic compounds do not conduct electric current very well and hence their contribution to conductivity is very low. Conductivity of water is primarily affected by the geology of the area through which the water flows. Water flowing through granite terrain has lower conductivity, whereas when the water flows through clay soils the conductivity is generally high. Conductivity is useful parameter to establish water quality. Each source tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Significant changes in conductivity could then be an indicator that a discharge or some other source of pollution has entered the water resource. Conductivity of collected samples varies between 228 μS/cm to 1443 μS/cm (Figure 5).

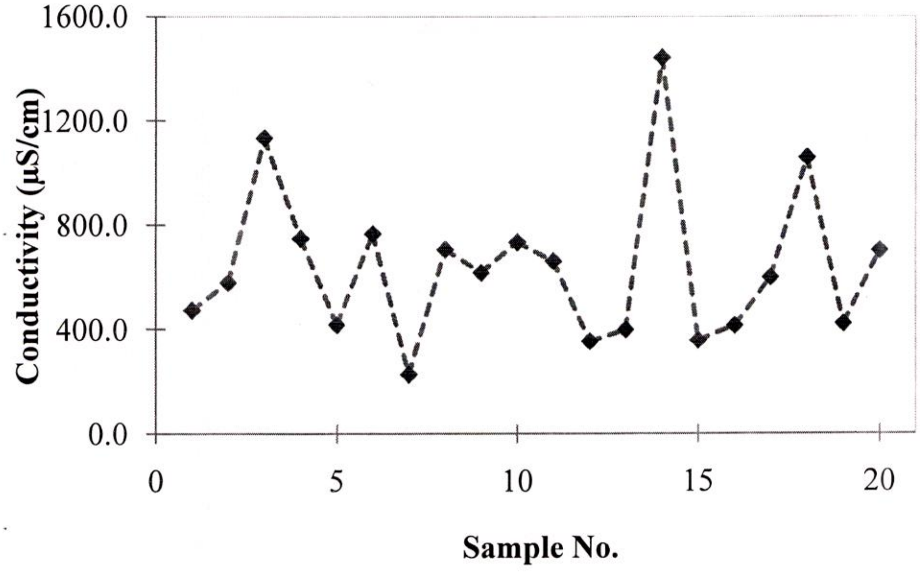

Figure 5. Electric conductivity Variations in Groundwater Samples of Roorkee

Total Dissolved Solids: Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in dissolved form. The presence of dissolved solids in water may affect its taste. The palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent (less than 300 mg/l), good (300-600 mg/l); fair (600-900 mg/l), poor (900-1200 mg/l), and unacceptable (>1200 mg/l). Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste. The presence of high levels of TDS may also be objectionable to consumers, owing to excessive scaling in water pipes, heaters, boilers and household appliances. BIS has prescribed 500 mg/L as the acceptable limit and 2000 mg/L as the permissible limit for TDS in absence of alternate source of drinking water. The guideline is not health based but on the basis of palatability. TDS in the groundwater of study area varies from 145.92 mg/l to 923.52 mg/L, with average values 410 mg/l (Figure 6). It can be concluded that the 85% analysed groundwater samples were having TDS less than 500 mg/l (acceptable limit) and TDS of all the samples were well within the permissible limit (2000 mg/l) prescribed by BIS (2012). Based on palatability, 35% analyzed samples were excellent, 50% samples were good, 10% samples were fair, and 5% samples were poor in terms of TDS.

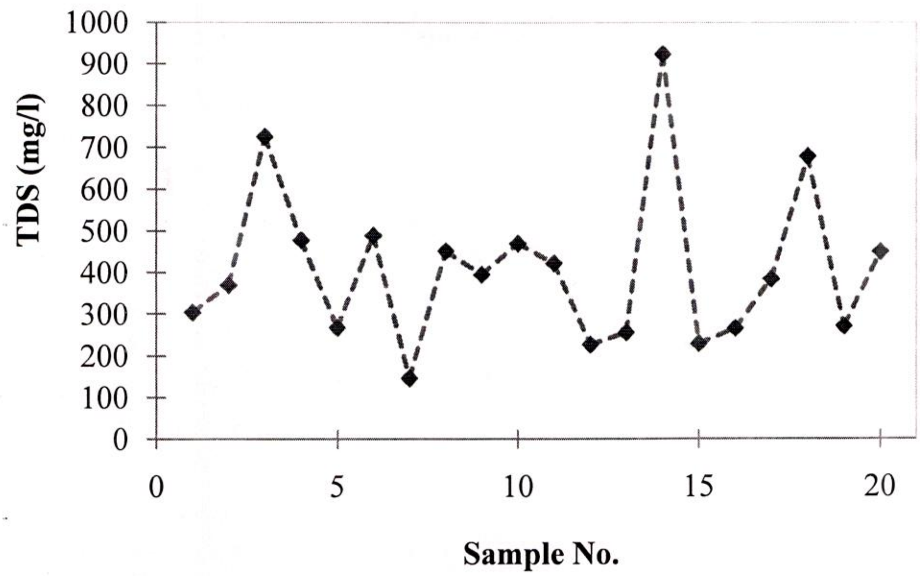

Figure 6. Total Dissolved Solids Variations in Groundwater Samples of Roorkee

Turbidity: Turbidity may be caused by inorganic or organic constituents. Turbidity in some groundwater sources is a consequence of inert clay or calcium carbonate particles or the precipitation iron and other oxides when water is pumped out. Presence of turbidity in drinking water has a negative impact on consumer acceptability. Although turbidity is not necessarily a threat to health, it is an important indicator of the possible presence of contaminants that would be of concern for health. Recent research establishes a correlation between gastro-intestinal infections with high turbidity and turbidity events in distribution. This may be because turbidity is acting as an indicator of possible sources of microbial contamination. Turbidity in the analyzed groundwater samples of study area varies from 0.23 NTU to 29.7 NTU, with average values 6.6 NTU (Figure 7). Turbidity of only 30% samples was well within the acceptable limit prescribed by BIS (2012) and turbidity of 70% samples were within the permissible limit. Turbidity of 35% samples exceeded the permissible limit prescribed by BIS and hence, can't be used as drinking water or should be used only after removal of treatment for removal of suspended solids.

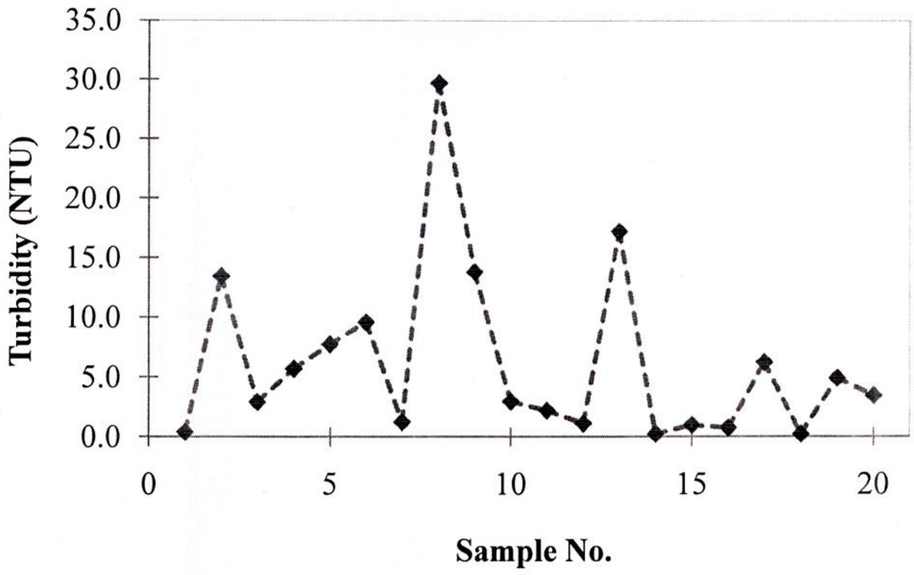

Figure 7. Turbidity Variations in Groundwater Samples of Roorkee

Color: Drinking-water should ideally have no visible color. Color in drinking-water is usually due to the presence of colored organic matter (primarily humic and fulvic acids) associated with the humus fraction of soil. Color is also strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products. It may also result from the contamination of the water source with industrial effluents and may be the first indication of a hazardous situation. Most people can detect color above 15 true color units (TCU) in a glass of water. Levels of color below 15 TCU are often acceptable to consumers. No health-based guideline value is proposed for color in drinking water (WHO, 2012).

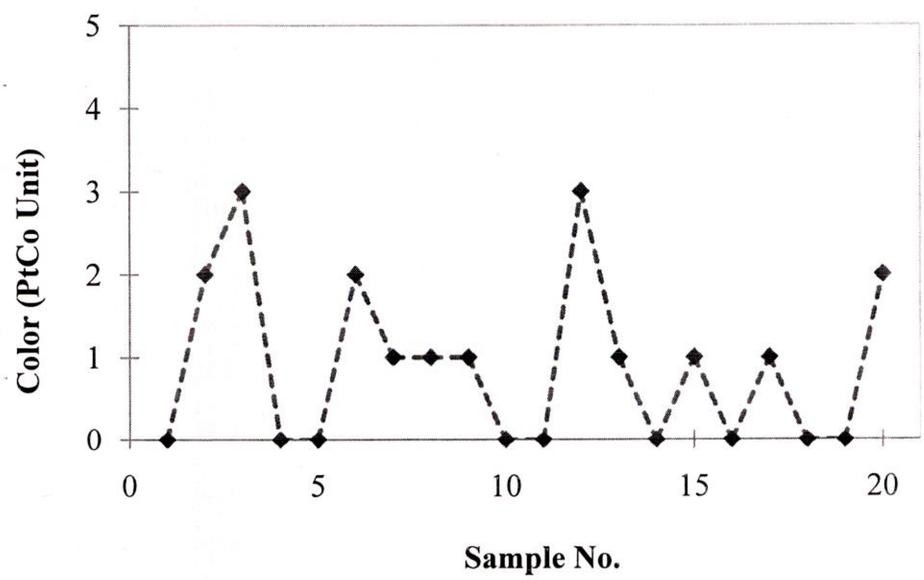

Figure 8. Color Variations in Groundwater Samples of Roorkee

BIS has prescribed 5 Hazen units as the acceptable limit and 15 Hazen units as the permissible limit for color in absence of alternate source of drinking water. Color of the analyzed groundwater samples varies from ND to 3.0 PtCo units, with average value 1.05 PtCo Unit (Figure 8).

Total Hardness: In fresh water sources, hardness is mainly due to presence of calcium and magnesium salts. Hardness does not pose a health risk. In fact, calcium and magnesium in drinking water ensure daily requirements for these minerals in diet. But hard water can be a nuisance due to the mineral build-up on plumbing fixtures and poor soap and detergent performance. It often causes aesthetic problems, such as an alkali taste to the water. Temporary hardness more than 200 mg/L as $CaCO_3$ may cause scale deposition in the treatment works, distribution system and pipe work and tanks within buildings. Water with hardness less than 100 mg/l may, in contrast, have a low buffering capacity and will be more corrosive for water pipes. BIS has prescribed 200 mg/l as the acceptable limit and 600 mg/l as the permissible limit for total hardness in absence of alternate source of drinking water. Total hardness in the analyzed groundwater samples of the study area ranges from varies from 96 to 482 mg/l as $CaCO_3$, with average value 228.35 mg/l as $CaCO_3$ (Figure 9). Total hardness in 35% samples was found below 200 mg/l (acceptable limit) and all the samples were well within the permissible limits prescribed by BIS (2012).

The value of calcium in groundwater samples of the study area ranges between 25.6 to 150.4 mg/l, with average value 56.7 mg/l (Figure 10). Calcium content of 85% samples was found well within the acceptable limit (75 mg/l) and all the samples were within the permissible limit (200 mg/l) prescribed by BIS (2012).

The value of magnesium in groundwater samples of the study area ranges between 4.32 to 48.96 mg/l, with average value 20.78 mg/l (Figure 11). Magnesium content in 95% samples was well within the acceptable limit (30 mg/l) and all the samples were within the permissible limit (100 mg/l) prescribed by BIS (2012).

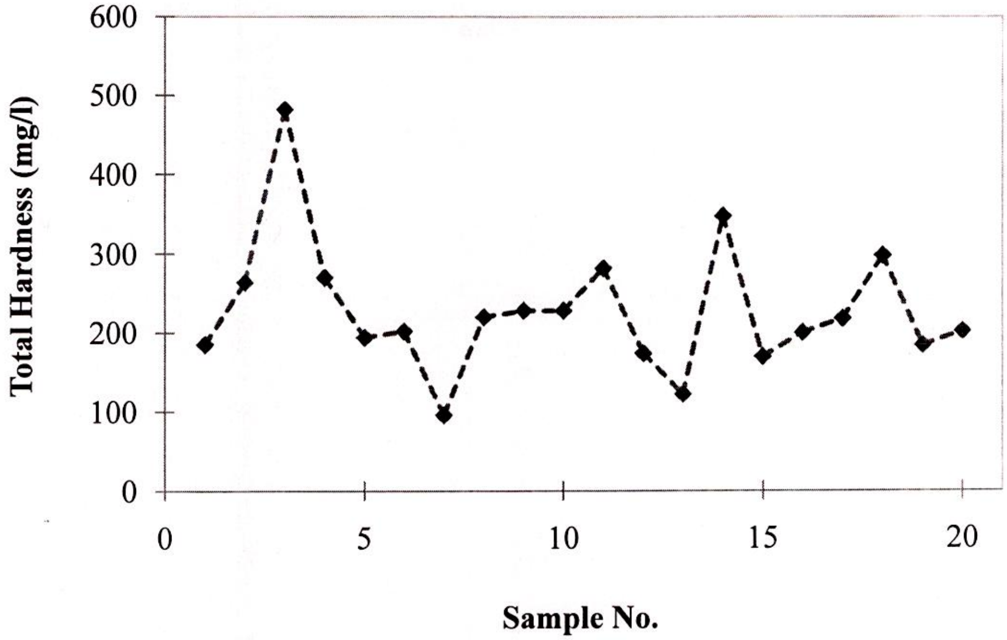

Figure 9. Total Hardness Variations in Groundwater Samples of Roorkee

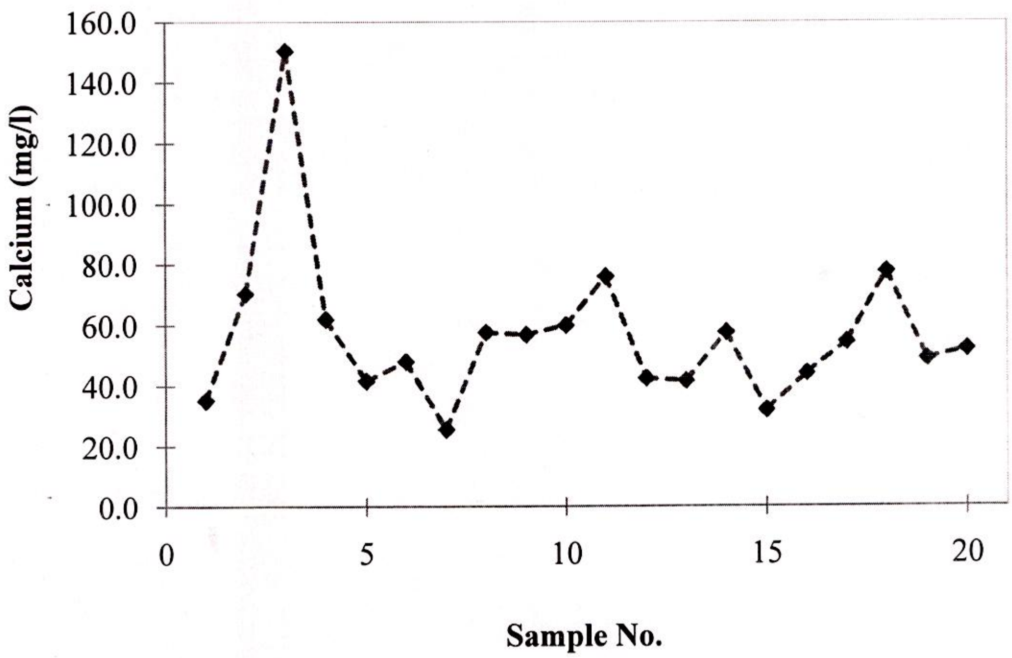

Figure 10. Calcium Variations in Groundwater Samples of Roorkee

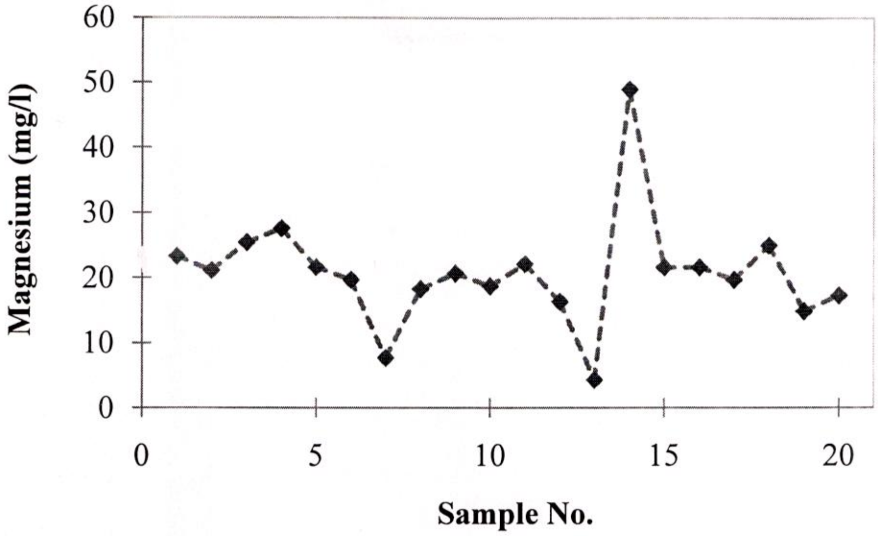

Figure 11. Magnesium Variations in Groundwater Samples of Roorkee

Sodium: Sodium is a very reactive metal, and therefore does not occur in its free form in nature. High sodium intake can have adverse effects on humans with high blood pressure or pregnant women suffering from toxaemia, but contribution from drinking water to daily intake is very small and hence, no health based guideline value has been derived. The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution. At room temperature, the average taste threshold for sodium is about 200 mg/l. Based on this, WHO has prescribed 200 mg/l as a limit for sodium in drinking water and BIS has not prescribed any limit. The concentration of sodium in groundwater samples of the study area ranges between 5 to 81.8 mg/l during study period (Figure 12). All the samples were with the limit prescribed by WHO.

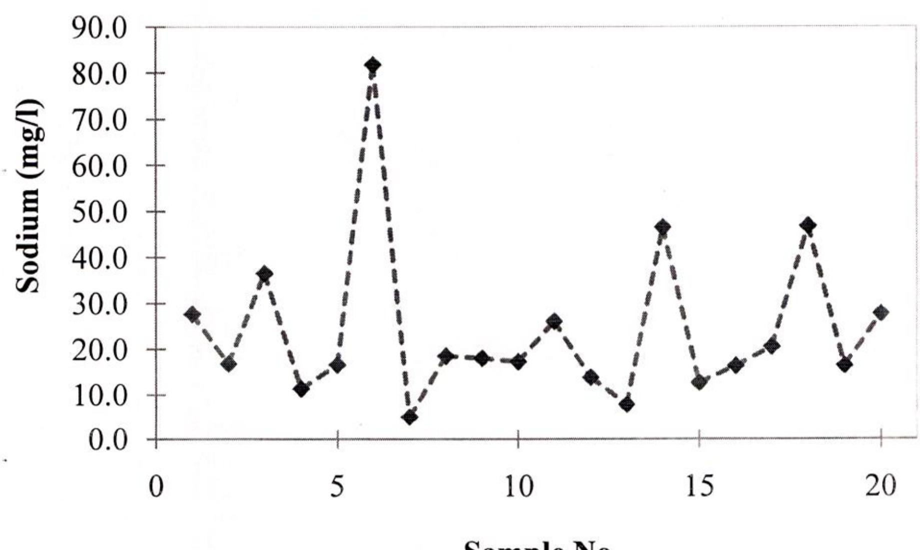

Figure 12. Sodium Variations in Groundwater Samples of Roorkee

Potassium: Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. Adverse health effects due to potassium consumption from drinking-water are unlikely to occur in healthy individuals. Potassium intoxication by ingestion is rare, because potassium is rapidly excreted in the absence of pre-existing kidney damage and because large single doses usually induce vomiting. The value of potassium in groundwater samples of the study area ranges between 0.2 to 212 mg/l (Figure 13).

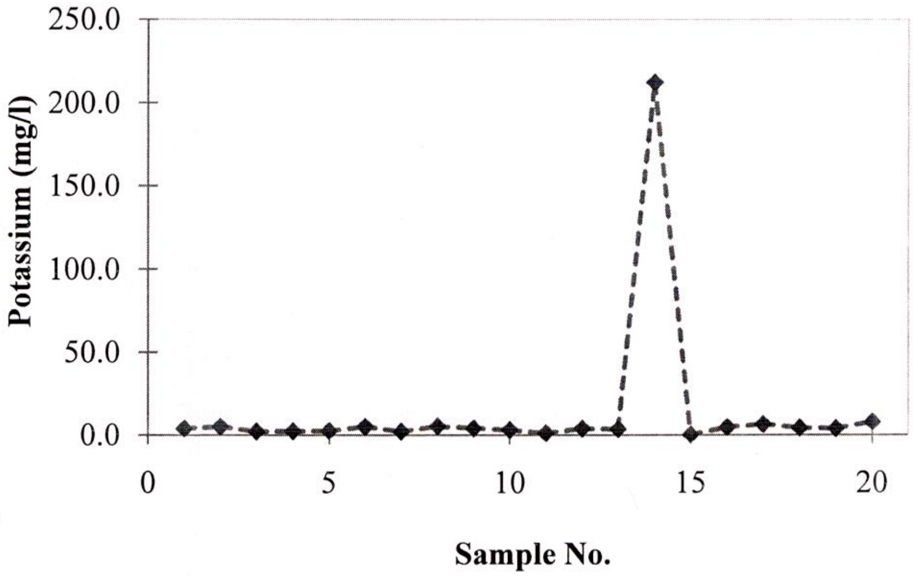

Figure 13. Potassium Variations in Groundwater Samples of Roorkee

Ammonium: Ammonia/ammonium in the environment originates from metabolic, agricultural and industrial processes and from disinfection with chloramines. Natural levels in groundwater and surface water are usually below 0.2 mg/l. Anaerobic groundwater may contain up to 3 mg/l. Intensive rearing of farm animals can give rise to much higher levels in surface water. Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution. Ammonia in drinking-water is not of immediate health relevance, and therefore no health-based guideline value is proposed. However, ammonia can compromise disinfection efficiency, result in nitrite formation in distribution systems, cause the failure of filters for the removal of manganese and cause taste and odor problems.

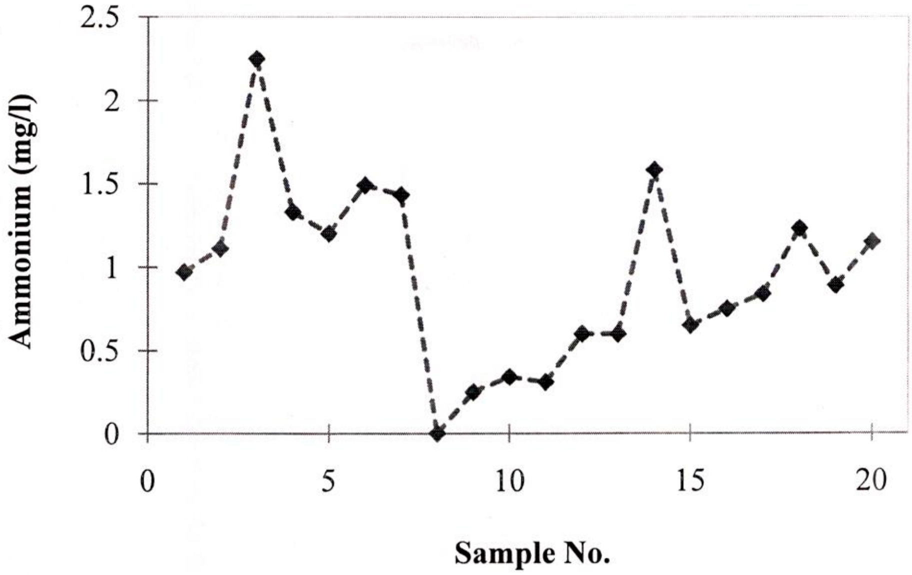

Figure 14. Ammonium Variations in Groundwater Samples of Roorkee

The concentration of ammonium in groundwater samples of the study area ranges between ND to 2.25 mg/l during study period (Figure 14). BIS has prescribed 0.5 mg/l as the acceptable limit with no relaxation. Ammonium content in the 80% samples found exceeding the limiting value.

Alkalinity: Alkalinity in the water may be due to hydroxides, carbonates, and bicarbonates. The main source of alkalinity is usually from carbonate rocks (limestone). Alkalinity provides buffering capacity to water and is essential to avoid corrosion of supply lines and fixtures. The relationship between pH, alkalinity and water stability is shown in Figure 15. BIS has prescribed 200 mg/l as the acceptable limit and 600 mg/l as the permissible limit for total alkalinity as $CaCO_3$ in absence of alternate source of drinking water.

Alkalinity of samples varies between 54 mg/l to 408 mg/l, with average value 192.8 mg/l as $CaCO_3$ (Figure 16). Alkalinity of 40% samples exceeded the acceptable limit, whereas all the samples were well within the permissible limit prescribed by BIS (2012).

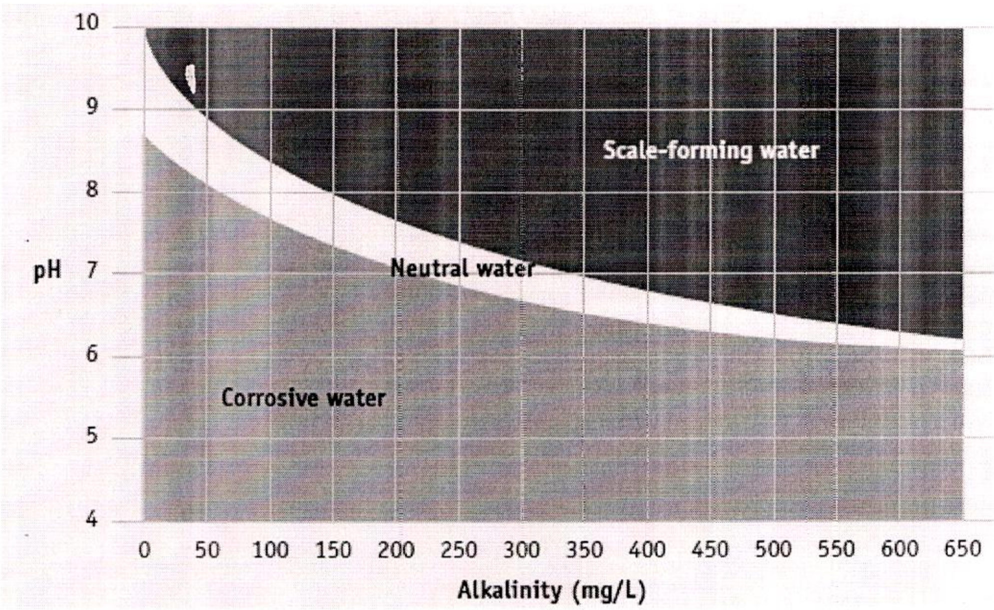

Figure 15. The relationship between pH, alkalinity and water stability

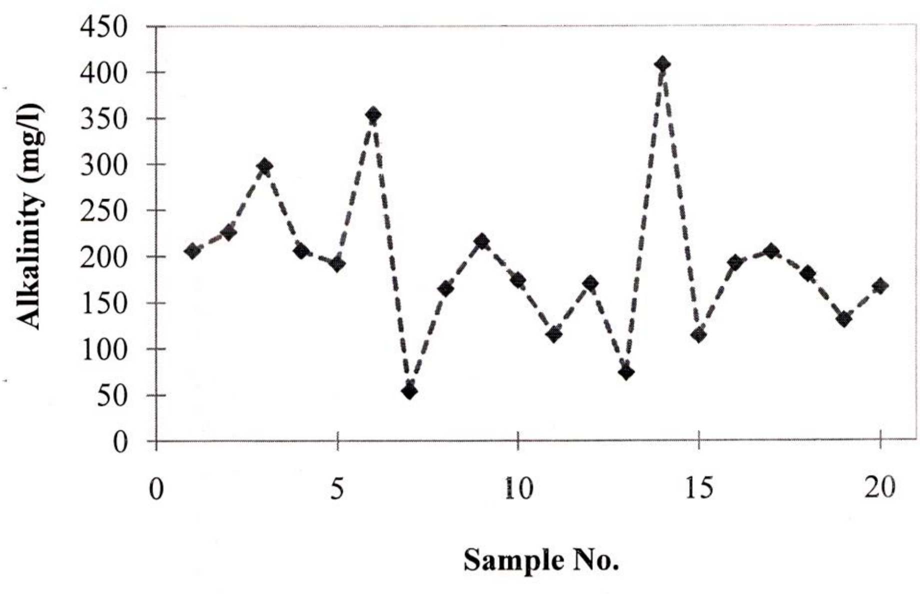

Figure 16. Alkalinity Variations in Groundwater Samples of Roorkee

Chlorides: Some common chlorides compounds found in natural water are sodium chloride (NaCl), potassium chloride (KCl), Calcium chloride ($CaCl_2$), and magnesium chloride ($MgCl_2$). High concentrations of chloride give a salty taste to water and beverages. Taste thresholds for the chloride anion depend on the associated cations and are in the range of 200–300 mg/l for sodium, potassium and calcium chloride. Based on taste threshold, BIS has prescribed 250 mg/l as the acceptable limit and 1000 mg/l as the permissible limit for chloride in absence of alternate source of drinking water.

The concentration of chloride in the collected samples were in the range of 5 to 92 mg/l (Figure 17). Chloride level in samples was well within the acceptable limit.

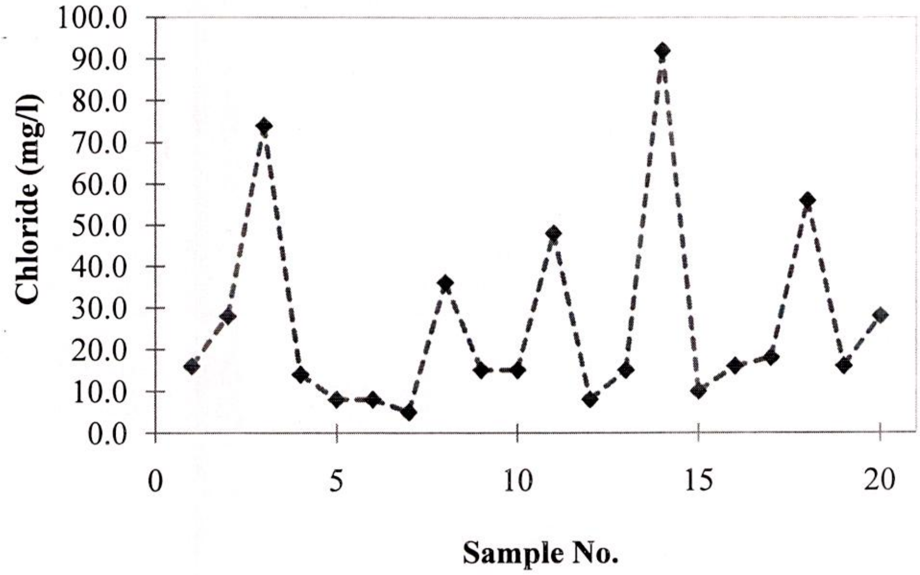

Figure 17. Chloride Variations in Groundwater Samples of Roorkee

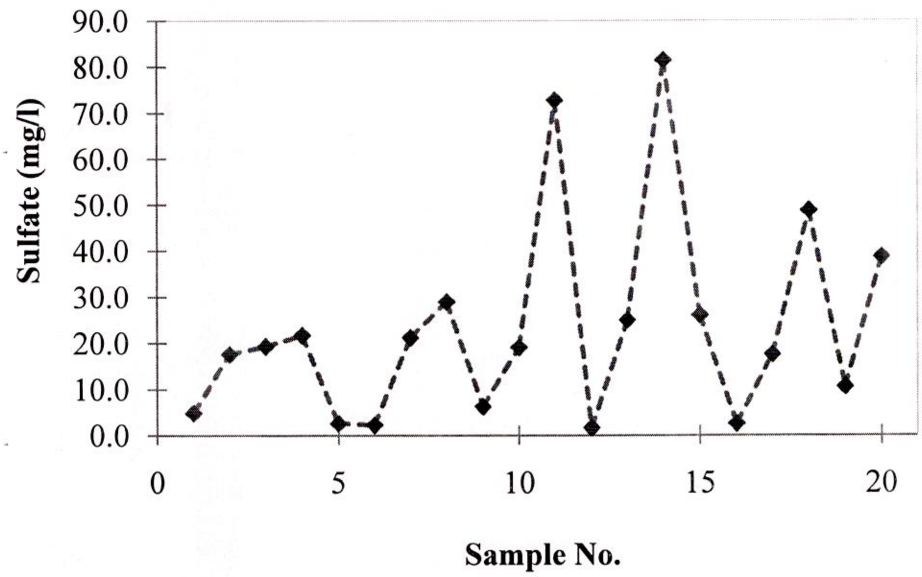

Figure 18. Sulfate Variations in Groundwater Samples of Roorkee

Sulfate: The most common form of sulfur in well-oxygenated waters is sulfate. The presence of sulfate in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers. Taste impairment varies with the nature of the associated cations. Taste thresholds have been found to range from 250 mg/l for sodium sulfate to 1000 mg/l for calcium sulfate. BIS has prescribed 200 mg/l as the acceptable limit and 400 mg/l as the permissible limit for sulfate in absence of alternate source of drinking water. Sulfate concentration of groundwater samples in the study area varies from 1.6 mg/l to 81.4 mg/l, with average value 23.4 mg/l (Figure 18). Sulfate content in all the analyzed samples were well within the acceptable limit prescribed by BIS (2012)

Nitrate: Nitrate (NO_3) is found naturally in the environment and is an important plant nutrient. It is present at varying concentrations in all plants and is a part of the nitrogen cycle. Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. Some groundwaters may also have nitrate contamination as a consequence of leaching from natural vegetation. The presence of nitrate in drinking water is a potential health hazard when present in large quantities. Nitrites are formed by reduction of nitrate in the human body, which combines with haemoglobin in the blood to form methemoglobin that leads to methaemoglobinaemia (blue baby syndrome) in infants. The combination of nitrates with amines, amides, or other nitrogenous compounds through the action of bacteria in the digestive tract results in the formation of nitrosamines, which are potentially carcinogenic. According to the Indian Standard for drinking water, the maximum allowable nitrate concentration in drinking water is 45 mg/L as NO_3. The concentration of nitrate in groundwater samples of the study area ranges between ND to 119.96 mg/l (Figure 19). Nitrate content in 4 samples exceeded the maximum allowable concentration prescribed by BIS.

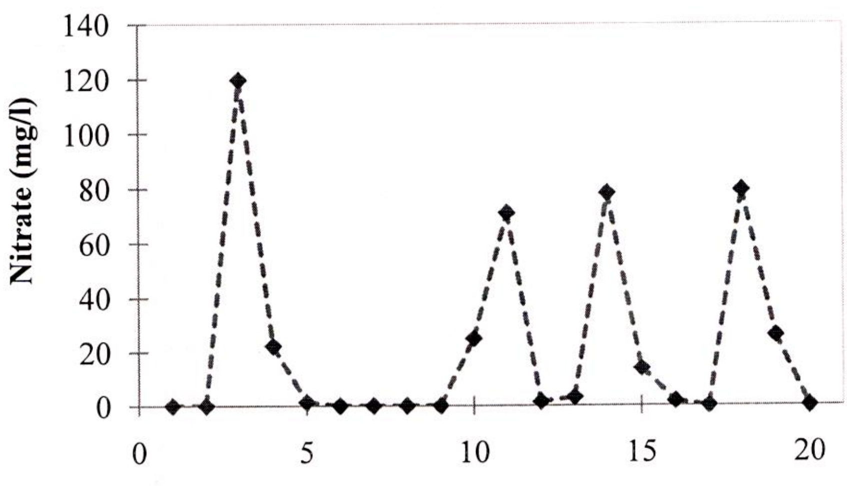

Figure 18. Nitrate Variations in Groundwater Samples of Roorkee

Nitrite: Although BIS has not prescribe any limit for nitrite in the drinking water but the concentration of nitrite is important in the sense, it get oxidized to nitrite and moreover, it is more toxic than nitrate. The nitrite content in the analyzed groundwater samples of the study area varies from were 2.69 to 5.95 mg/l (Figure 19).

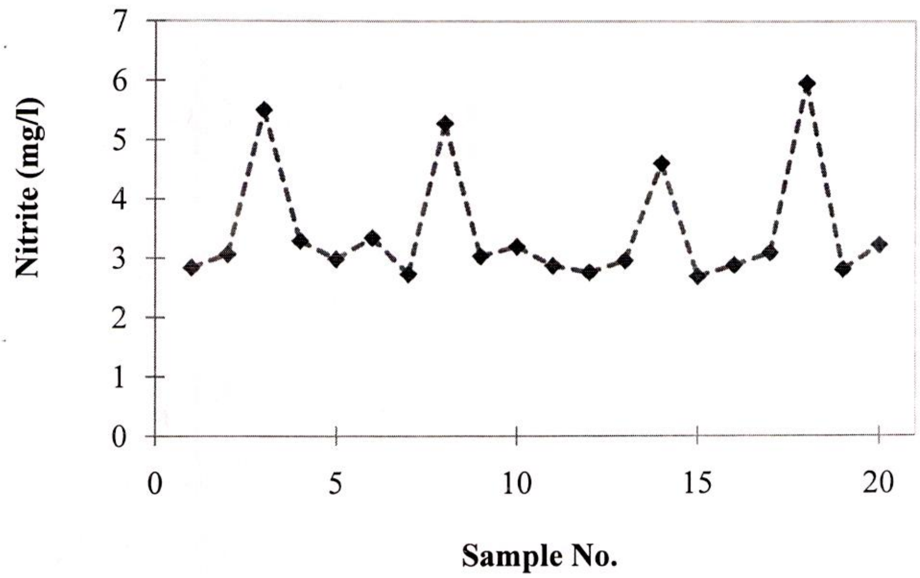

Figure 18. Nitrite Variations in Groundwater Samples of Roorkee

Fluoride: Fluoride is found in all natural waters at some concentration. Seawater typically contains about 1 mg/L while rivers and lakes generally exhibit concentrations of less than 0.5 mg/L. In groundwater, however, low or high concentrations of fluoride can occur, depending on the nature of the rocks and the occurrence of fluoride-bearing minerals. Concentrations in water are limited by fluorite solubility, so that in the presence of 40 mg/L calcium it should be limited to 3.1 mg/L. It is the absence of calcium in solution which allows higher concentrations to be stable. High fluoride concentrations may therefore be expected in groundwater from calcium-poor aquifers and in areas where fluoride-bearing minerals are common. Many epidemiological studies have shown that fluoride in drinking water has a narrow range between intakes that cause beneficial and detrimental health effects. Fluoride intake to humans is necessary as long as it does not exceed the limits. Excess fluoride intake causes different types of fluorosis, primarily dental and skeletal fluorosis. BIS has prescribed 1 mg/l as the acceptable limit and 1.5 mg/l as the permissible limit for fluoride in absence of alternate source of drinking water. The fluoride concentration in the groundwater samples of the study area were in the range 0.02 to 1.06 mg/l (Figure 20) and fluoride content in all the samples were within the acceptable limit prescribed by BIS (2012).

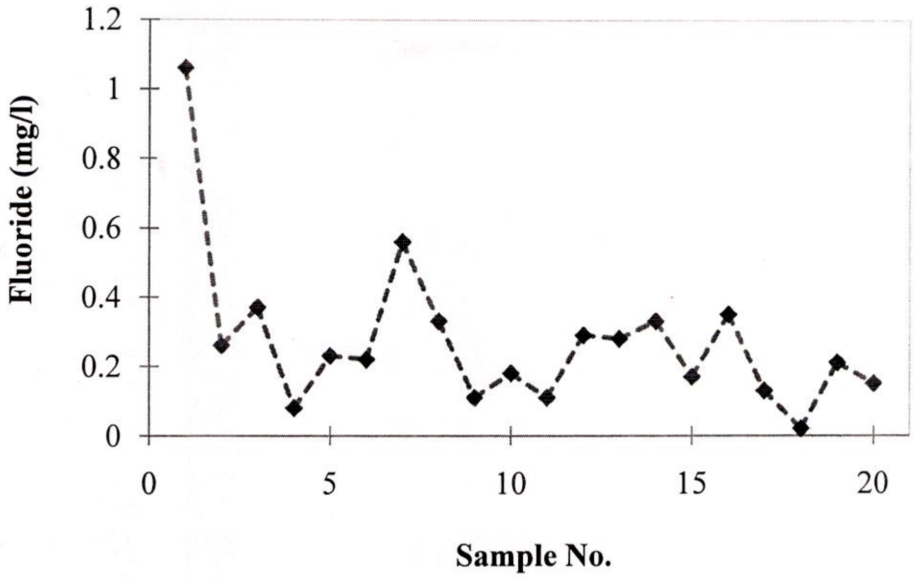

Figure 20. Fluoride Variations in Groundwater Samples of Roorkee

Iron: Iron is one of the most abundant metals in Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/l. Iron may also be present in drinking water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Iron is an essential element in human nutrition, particularly in the iron(II) oxidation state.

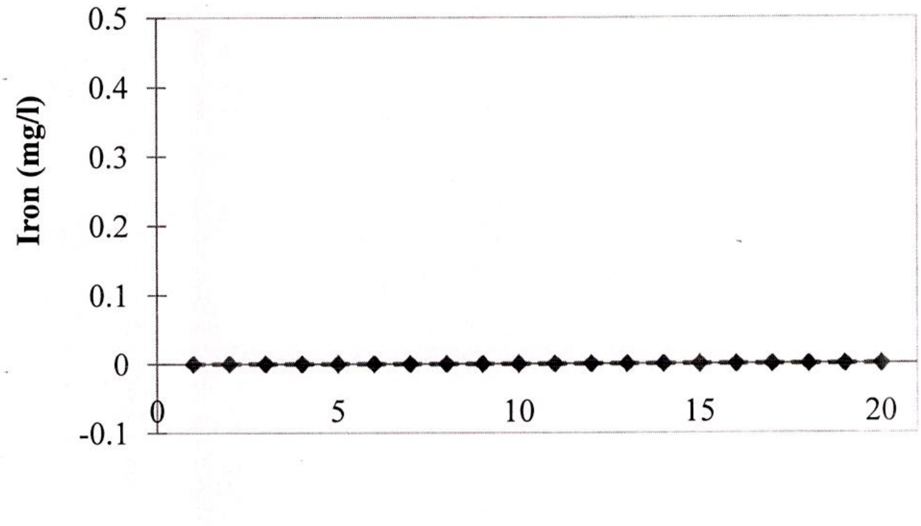

Figure 21. Iron Variations in Groundwater Samples of Roorkee

According to the Indian Standard for drinking water, the maximum allowable iron concentration in drinking water is 0.3 mg/L. The concentration of iron in groundwater samples of the study area not detected.

Total Coliform Bacteria: Total coliform bacteria include a wide range of aerobic and facultative anaerobic, Gram-negative, non-spore-forming bacilli capable of growing in the presence of relatively high concentrations of bile salts with the fermentation of lactose and production of acid or aldehyde within 24 hours at 35–37 °C. Total coliforms include organisms that can survive and grow in water. Hence, they are not useful as an indicator of fecal pathogens, but they can be used to assess the cleanliness and integrity of distribution systems and the potential presence of bio-films. This test is first in line to micro-biological analysis. Negative results indicate absent of any pathogens. To confirm pathogenic bacterial contamination, *Escherichia coli (Fecal Coli)* has traditionally been used to monitor drinking-water quality, and it remains an important parameter in monitoring undertaken as part of verification or surveillance. Water intended for human consumption should contain no fecal indicator organisms. In the majority of cases, monitoring for E. coli or thermotolerant coliforms provides a high degree of assurance because of their large numbers in polluted waters.

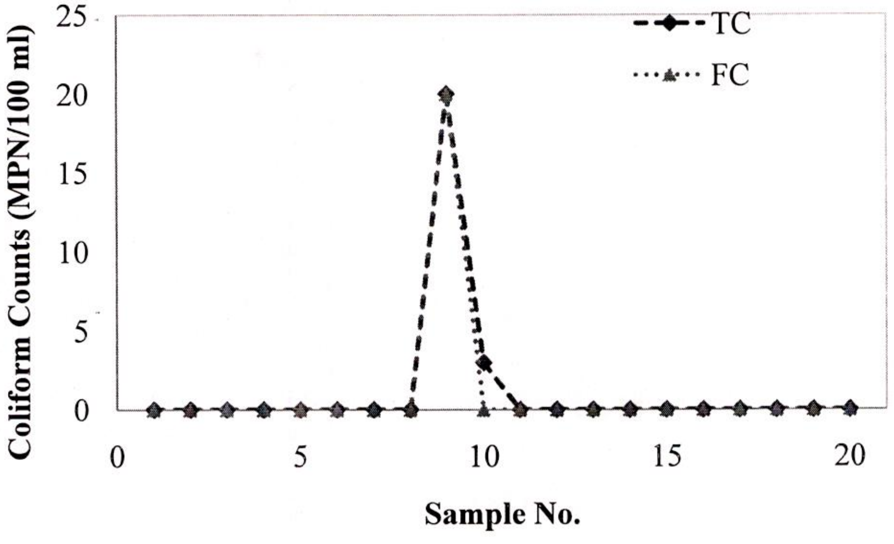

Figure 22. Bacteriological Quality of Groundwater Samples of Roorkee

Total Coliform was detected in 02 samples and Fecal Coliform in one sample (Figure 20). Disinfection of the water drawn from the contaminated sources should be disinfected before domestic application.

CHAPTER 6: CONCLUSION

Based on this study, following conclusions can be drawn for groundwater of Roorkee-

1. The pH of groundwater samples in the study area were in the range 6.86 to 7.62 and the average value was 7.26, and were conforming the limits prescribed by BIS (2012) for drinking water.

2. Conductivity of collected samples varies between 228 μS/cm to 1443 μS/cm. TDS in the groundwater of study area varies from 145.92 mg/l to 923.52 mg/L, with average values 410 mg/l. It can be concluded that the 85% analysed groundwater samples were having TDS less than 500 mg/l (acceptable limit) and TDS of all the samples were well within the permissible limit (2000 mg/l) prescribed by BIS (2012). Based on palatability, 35% analyzed samples were excellent, 50% samples were good, 10% samples were fair, and 5% samples were poor in terms of TDS.

3. Turbidity in the analyzed groundwater samples of study area varies from 0.23 NTU to 29.7 NTU, with average values 6.6 NTU. Turbidity of only 30% samples was well within the acceptable limit prescribed by BIS (2012) and turbidity of 70% samples were within the permissible limit. Turbidity of 35% samples exceeded the permissible limit prescribed by BIS and hence, can't be used as drinking water or should be used only after removal of treatment for removal of suspended solids.

4. Color of the analyzed groundwater samples varies from non detectable to 3.0 PtCo units, with average value 1.05 PtCo Unit, and all the samples were conforming the limits prescribed by BIS (2012) for drinking water.

5. Total hardness in the analyzed groundwater samples of the study area ranges from varies from 96 to 482 mg/l as $CaCO_3$, with average value 228.35 mg/l as $CaCO_3$. Total hardness in 35% samples were found below acceptable limit and all the samples were well within the permissible limits prescribed by BIS (2012).

The value of calcium in groundwater samples of the study area ranges between 25.6 to 150.4 mg/l, with average value 56.7 mg/l. Calcium content of 85% samples was found well within the acceptable limit and all the samples were within the permissible limit prescribed by BIS.

The value of magnesium in groundwater samples of the study area ranges between 4.32 to 48.96 mg/l, with average value 20.78 mg/l. Magnesium content in 95% samples was well within the acceptable limit and all the samples were within the permissible limit prescribed by BIS for drinking water.

6. The concentration of sodium in groundwater samples of the study area ranges between 5 to 81.8 mg/l during study period. The potassium content in the groundwater samples of the study area ranges between 0.2 to 212 mg/l.

7. The concentration of ammonium in groundwater samples of the study area ranges between ND to 2.25 mg/l during study period. Ammonium content in the 80% samples found exceeding the limiting value indicating contamination due to anthropogenic activity and the remedial measures should be done to shun water borne diseases.

8. Alkalinity of samples varies between 54 mg/l to 408 mg/l, with average value 192.8 mg/l as $CaCO_3$. Alkalinity of 40% samples exceeded the acceptable limit, whereas all the samples were well within the permissible limit prescribed by BIS.
9. Chloride content in the collected samples were in the range of 5 to 92 mg/l and was well within the acceptable limit.

10. Sulfate concentration of groundwater samples in the study area varies from 1.6 mg/l to 81.4 mg/l, with average value 23.4 mg/l and was well within the acceptable limit.

11. The concentration of nitrate in groundwater samples of the study area ranges between ND to 119.96 mg/l. Nitrate content in 4 samples exceeded the maximum allowable concentration prescribed by BIS. The nitrite content in the analyzed groundwater samples of the study area varies from were 2.69 to 5.95 mg/l.
12. The fluoride concentration in the groundwater samples of the study area were in the range 0.02 to 1.06 mg/l and was within the acceptable limit prescribed by BIS.

13. Iron was not detected in any of the analyzed samples.

14. Total Coliform was detected in 02 samples and Fecal Coliform in one sample. Disinfection of the water drawn from the contaminated sources should be disinfected before domestic application.

CHAPTER 7: REFERENCE

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