ASSESSMENT OF WATER QUALITY OF RIVER GANGA AT HARIDWAR

A DISSERTATION

Submitted in Partial Fulfillment of the Requirements for the Award of the Degree of

MASTER OF TECHNOLOGY (CIVIL ENGINEERING)
In
ENVIRONMENTAL ENGINEERING

SUBMITTED BY

ABHISHEK SINGH KHEVARIYA
14/EEN/001

CO-SUPERVISOR **SUPERVISOR**

DR. RAJESH SINGH **DR. ATHAR HUSSAIN**

SCHOOL OF ENGINEERING
GAUTAM BUDDHA UNIVERSITY, GREATER NOIDA
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CANDIDATE'S DECLARATION

I hereby assert that the work being presented in this Dissertation titled **"Assessment of Water Quality of River Ganga at Haridwar"** by Abhishek Singh Khevariya, Roll no: 14/EEN/001, is submitted as partial fulfillment of the requirement for the award of the Degree of **Master of Technology with specialization in Environmental Engineering**, submitted to the School of Engineering, Gautam Buddha University, Greater Noida. This is genuine work carried out under the supervision of **Dr. Athar Hussain, Assistant Professor, School of Engineering, Gautam Buddha University, Greater Noida and Dr. Rajesh Singh, Scientist C, National Institute of Hydrology, Roorkee.**

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

Date: May, 2016

Abhishek Singh Khevariya

CERTIFICATE

This is to state that the above declaration made by the candidate is true to the best of our knowledge. However, responsibility for any plagiarism related issue solely stands with the student.

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&

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The viva-voce of Mr. Abhishek Singh Khevariya has been held on has been held on……………

(Signature of External Examiner)

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ABSTRACT

The present study deals with physico-chemical and bacteriological analysis of sacred water of river Ganga at five sites namely, Chilla Dam, Bheem Goda Barrage, Kashnik Ghat, Har Ki Pauri and Vishnu Ghat. Water quality of river Ganga was observed to be deteriorating due to mass bathing, floral offerings, cremation of dead bodies on its banks, discharge of untreated waste water from ashrams,construction of dams, barrages and discharge of industrial and domestic sewage which causes both organic and bacteriological pollution.

Water samples were collected and analyzed for a period of three months from February 2016 to April 2016. The different parameters measured were pH, Electrical conductivity ,turbidity, Total dissolved solids (TDS), Dissolved oxygen (DO), Biological oxygen demand (BOD) and Total coliform. From the analyzed data it was found that The value of turbidity was also quite high making it aesthetically unpleasant for bathing at ghats.

The total coliform count exceed significantly the permissible values for 'Organized Outdoor Bathing' or 'Use class-B' according to CPCB standards at all the five sampling location.

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ABBREVIATIONS

Abbreviations	Description
WHO	World Health Organisation
BIS	Bureau Of Indian Standards
APHA	American Public Health Association
WQI	Water Quality Index
CCME	Canadian Council of Ministers of the Environment
TC	Total Coliform
FC	Faecal Coliform
Cl	Chloride
F	Fluoride
Na	Sodium
K	Potassium
NO_3	Nitrate
NO_2	Nitrite
NH_4	Ammonia
SO_4	Sulfate
BOD	Biological Oxygen Demand

CHAPTER 1

INTRODUCTION

General

Water contamination is a noteworthy worldwide issue which requires progressing assessment and update of water asset arrangement at all levels. Water borne ailments cause around 1.8 million passings every year. Loose bowels happen worldwide and cause 4% of all passings and 5% of wellbeing misfortune to incapacity. It is most normally brought on by gastrointestinal contaminations which lead to death of around 2.2 million individuals all inclusive every year, generally youngsters in developing nations (WHO 2015). Not with standing the intense issues of water contamination in creating nations, created nations likewise keep on struggling with contamination issues.

Water is normally alluded to as contaminated when it is debilitated by anthropogenic contaminants and either does not bolster a human use, for example, drinking water, or experiences a stamped shift in its capacity to bolster its constituent biotic groups, for example, fish. Common wonders, for example, volcanoes, green growth blossoms, tempests, and seismic tremors additionally cause significant changes in water quality and the environmental status of water. Surface water is on the surface of the planet, for example, in stream, waterway, lake, wetland, or sea. It can be appeared differently in relation to groundwater and air water.

With just 3 % of aggregate crisp water accessible for life ashore. Perfect, crisp drinking water is key to human and other life. In any case, in numerous parts of the world particularly in creating nations there's a water emergency, and it is evaluated that by 2025 more than half of the world populace will confront water-based defenselessness. Water assumes a critical part on the planet economy, as it capacities as a dissolvable for a wide assortment of compound substances and encourages mechanical cooling and transportation.

Numerous Indian urban areas are encountering moderate to serious water deficiencies because of understood impacts of rural development, industrialization and urbanization. These deficiencies would be further disturbed by populace anxiety and watering system necessities. A standout amongst the best approaches to impart data on water quality status and pattern is by utilizing lists. Water quality Index (WQI) is generally utilized for compressing water quality into a single value which can be used by the decision makers and users in understanding the suitability of water.

Contamination of water resources can be assembled into two classifications in light of their starting point - Point and Non-Point Sources. Point source water contamination alludes to contaminants that enter a conduit from a solitary, identifiable source, for example, a channel or discard while Nonpoint source contamination alludes to diffuse tainting that does not begin from a solitary discrete source.

Cooperations amongst groundwater and surface water are mind boggling. By its exceptionally nature, groundwater aquifers are vulnerable to tainting from sources that may not straightforwardly influence surface water bodies. A spill or continuous arrival of concoction or radionuclide contaminants into soil may not make point or non-point source contamination but rather can debase the aquifer beneath, making a harmful tuft. The development of the crest, called a crest front, might be broke down through a hydrological transport model or groundwater model. Examination of groundwater defilement may concentrate on soil attributes and site geography, hydrogeology, hydrology, and the way of the contaminants.

Oxygen-exhausting substances might be common materials, for example, plant matter (e.g. leaves and grass) and also man-made chemicals. Other common and anthropogenic substances may bring about turbidity (shadiness) which pieces light and disturbs plant development, and stops up the gills of some fish species. Adjustment of water's physical science incorporates corrosiveness (change in pH), electrical conductivity, temperature, and eutrophication.

Despite the fact that by far most of microscopic organisms are either safe or helpful, a couple of pathogenic microbes can bring about ailment. Coliform microorganisms are ordinarily utilized as a bacterial marker of water contamination. Large amounts of pathogens may enter the water supply schemes because of on location sanitation frameworks (septic tanks, pit lavatories) or insufficiently treated sewage releases.

Choices on the sort and level of treatment control of squanders, and the transfer and utilization of sufficiently treated wastewater depends on the end goal or mischief to nature.

In urban ranges of created nations, household sewage is ordinarily treated by transporting to the sewage treatment plants. Planned and worked frameworks (i.e., auxiliary treatment or better) can romove 90 percent or a greater amount of the poison load in sewage.

1. River Ganga

There is an all inclusive veneration to water in the greater part of the significant religions of the world. Most religious convictions include some stately utilization of "sacred" water. The immaculateness of such water, the faith in its known recorded and obscure fanciful causes, and the detachment of remote sources, lift its significance considerably further. In India, the water of the River Ganga is treated with such adoration. Legend says that the river has plunged from Heaven on earth as an after effect of the long and laborious supplications of King Bhagirathi for the salvation of his perished precursors. From times immemorial, the Ganga has been India's stream of confidence, commitment and love. Many Hindus acknowledge its water as hallowed. Indeed, even today, individuals convey cherished Ganga water all over India and abroad in light of the fact that it is "blessed" water and known for its "remedial" properties. In any case, the waterway is not only a legend; it is likewise an existence emotionally supportive network for the general population of India. It is vital in light of the fact that:

- The thickly populated Ganga basin is inhabited by 37% of India's masses.
- The entire Ganga basin effectively drains eight states of India.
- About 47% of the total irrigated land in India is located in Ganga basin alone.

1.2 The Ganga Stream

The Ganga ascends on the southern inclines of the Himalayan extents from the Gangotri ice sheet at 4,000 m above mean ocean level. It travels 250 km in the mountains, slipping steeply to a height of 288 m above mean ocean level. In the Himalayan area the Bhagirathi is joined by the tributaries Alaknanda and Mandakini to structure the Ganga. In the wake of entering the fields at Hardiwar, it winds its way to the Bay of Bengal, covering 2,500 km through the regions of Uttar Pradesh, Bihar and West Bengal. In the fields, it is joined by Ramganga, Yamuna, Sai, Gomti, Ghaghara, Sone, Gandak, Kosi and Damodar alongside numerous other littler streams.

1.3 Objective

India's growing population is putting a heavy strain on water resources of the country, most of which is contaminated mostly by sewage and agricultural runoff. Only a part of the Indian population has access to safe drinking water (WHO, 2015). Although access to drinking water has improved, the World Bank estimates that about 21% of the communicable diseases in India is related to unsafe water. The water borne diseases are jaundice, cholera, typhoid and gastro enteritis etc. This surface water and groundwater is mainly polluted by anthropogenic activities viz. urbanization, industrialization, disposing garbage etc.

Water quality of River Ganga is deteriorating due to disposal of untreated domestic sewage directly into the river, agricultural runoff, bathing & washing of cattle's in rivers. Rivers being the running water bodies are less prone to pollution than the lakes whose self-purification process are less effective than rivers. Any contamination or pollution of river affects greatly the flora and fauna and also the human health if the water is used for domestic supply. The environmental health of any river system depends upon the nature of that river and its exposure to various environmental factors such as temperature, depth of water, wind speed, soil types and land uses of the catchment of the river. Thus, there is a great need of regular monitoring & assessment of river water quality. The present study aims at evaluating the water quality of river Ganga at Haridwar at 5 selected sites including chilla & thus, evaluating the level of pollution in the river to understand its suitability for drinking and bathing.

1.4 Aim

The objectives of this study are to evaluate:

- Characterization of River water quality in terms of physico-chemical & Bacteriological parameters.
- WQI for Domestic (drinking) and Spiritual (bathing) usage.
- Effect of mass bath on river water quality.

CHAPTER 2

LITERATURE REVIEW

The aim of this study is study is evaluation of surface water (River Ganga at Haridwar) for drinking and irrigation by using water quality indices. Haridwar is a holy city where people (pilgrims) from all over the world come to take a dip in the holy river Ganga so that they could get rid of all their sins they did in this life, according to the Hindu mythology. But the river water is being affected due to increase in the population settlement around the city over the past decade. A detailed review has been carried out for the estimation of surface water quality index on a number of studies done by various researchers. These reviews are presented in brief as following:

1. **Determining Water Quality Index for the Evaluation of Water Quality of River Godavari; *Er. Srikanth Satish Kumar Darapu et al. (2011)***
   Water is most critical resource of lifetime and an important factor to judge environmental changes. The study is aimed at assessing the temporal variation of the physico-chemical data & water quality index (WQI) of river Godavari (upstream & downstream). Physico-chemical assessment data has been obtained from Central Water Commission. He gave stress on the fact that variation in the river flow also affects the physico-chemical parameters significantly. The WQI for majority of the samples was Class IV type. The high value of WQI was mainly due to the higher values of fluoride while other parameters were within the limits. The analysis reveals that the river water needs some degree of treatment before consumption.

2. **Water Quality Assessment in Terms of Water Quality Index; *Shweta Tyagi et al. (2013)***
   The water quality index (WQI) is valuable and unique to depict the water quality status in single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues. She has discussed about the merits & demerits of various water quality index used by various countries.

3. **Analysis of water quality parameters of river ganga during Maha-Kumbh, Haridwar; *Naveen Kumar Arora et al. (2012)***

Water Quality of River Ganga during mass bathing (Maha Kumbh) at Haridwar in terms of microbiological & chemical parameters was investigated. The study showed that mass bathing events results in contamination of River Ganga due to mixing of untreated sewage and organic matter.

4. **Assessment of Ganga river ecosystem at Haridwar, Uttarakhand, India with reference to water quality indices; *R. Bhutiani et al. (2014)***

The water quality index of River Ganga ranged between medium and good quality. As per the NSF, the WQI of the river is good whereas as per the weighted Arithmetic method the quality of river water is poor. Analysis was being carried out at Rishikesh & Haridwar, Uttarakhand. Parameters such as turbidity, COD, total alkalinity and total hardness, phosphate and nitrate were higher in some locations; this was because of increase in pollution load by domestic sewage, addition of nutrients, agricultural runoff and organic matter in water. This study establishes that sewerage, solid and liquid waste contaminants or organic nature are the prime sources of pollution.

5. **A proposed new diagram for geochemical classification of natural waters and interpretation of chemical data; *D. K. Chadha (1999)***

Chadha proposed a new hydro chemical diagram for the classification of natural waters & identification of hydro chemical processes. The proposed diagram differs from the Piper & Durov diagrams and the shape of main study is different. Also, the proposed diagram can be constructed on most of the spreadsheet software packages. The proposed diagram is constructed by plotting the differences in mill equivalent percentage between alkaline earths and alkali metals, expressed as percentage reacting values, on the X axis; and the difference in mill equivalent percentage between weak acidic anions and strong acidic anions, also expressed as percentage reacting values, on the Y axis.

6. **Evaluation of Ganga Water for Drinking Purpose by Water Quality Index at Rishikesh, Uttarakhand, India; *Avnish Chauhan and Suman Singh (2011)***

The authors intended to calculate water quality index (WQI) for river Ganga at Rishikesh for drinking, recreation and other purpose by using eight water quality parameters. At site 1, 2 & 3 water quality index ranged from 13.87-1714.76, 14.59-1386 & 27.29-1077.9 respectively but the results of the water quality index clearly indicated that the Ganga water at Rishikesh is unfit for drinking, recreation and other purposes.

7. **Evaluation of water quality index for drinking purposes of river Subernarekha in Singhbhum District; *Kavita Parmar & Vineeta Parmar (2010)***

Explained that WQI values at various sampling stations there is progressing decline in WQI values along the downstream indicated that an increase in pollution is due to effluent discharge by various industries along the stretch. Water quality in Subarnarekha varied from excellent to marginal range by Bhargava WQI method. The poorer water quality index at S4 Sampling station is due to anthropogenic activities.

8. **Seasonal Variation of Water Quality in Betwa River at Bundelkhand Region, India; *Sarita Verma (2009)***

Explained that the purpose of study was to investigate the water quality and to find out the variations in physico-chemical properties. This study is being carried out at Bundelkhand Region & 19 samples were collected from the Betwa River. EC has positive correlation with chloride and sodium whereas its show negative correlation with phosphate hardness and chloride show strong positive correlations with fluoride and sodium respectively which indicate that is one parameter will raise the other dependent will be also increased calcium shows a strong negative correlation with magnesium.

9. **Studies On Physicochemical Parameters To Assess The Water Quality Of River Ganga For Drinking Purpose In Haridwar District; *Dhirendra Mohan Joshi, Alok Kumar,(2009)***

Explained that A systematic study has been carried out to assess the water quality index of River Ganga in Haridwar District. 90 water samples from five sampling stations were collected and analysed for physico-chemical parameters The study area experiences aseasonal climate and broadly divided into three seasons as winter (November to February), Summer (March to June) and rainy (July to October). The samples were collected and analysed for two consecutive years 2007 and 2008. Each parameter was compared with the standard desirable limit of that parameter in river water as prescribed by different agencies. The analytical data of various physicochemical parameters indicates that some parameters like pH, electrical conductivity, total dissolved solids , total suspended solids, turbidity and sodium are found to be in excess than the prescribed limit in some water samples of the study areas. The WQI value indicates that water samples of some sampling stations are quite unfit for drinking purpose because of high value of dissolved solids and sodium. It was also observed that the water in the year 2007 was of a better quality than in the year 2008. Suitable suggestions were made to improve the quality of river water.

10. **Assessment Of Some Physico-Chemical Properties For Water In Ganga River At Varanasi, India; *Suhad A. Abed(2014).***

Explained that the purpose of study was to investigate the water quality The water is getting polluted day by day by the increasing concentrations of different pollutants. possibly due to rising anthropogenic influence. In this study it was found that the properties like hardness, TDS and BOD were increased in all the sites of the study, while DO and pH were decreased. Ganga River water also was changed from fresh bluish to dirty turbid.

11. **Physicochemical Properties of Polluted Water of River Gang at Varanasi. *Singh Namrata (2010)***

Explained that the purpose of study was to investigate the water quality and to find out the variations in physico-chemical properties From the observation made during study it may be concluded that Raj Ghat site was found polluted whereas, Shiwala Ghat site was found least polluted

12. **Physiochemical Analysis of River Ganges at Mirzapur In Uttar Pradesh, India.** ***Shahid Khan, Satyendra Nath (2014)***

The high value in the present study may be attributed to the presence of bacterial load from the nearby surrounding areas (Fecal matter) and due to this reason the River Ganges is absolutely unfit for drinking and unhealthy for bathing.

CHAPTER 3

STUDY AREA

3.1 General

This study was being carried out on river Ganga at Haridwar (2995600 N, 78.17000 E). Haridwar is an ancient city, which is regarded as one of the seven holiest places (Sapta puri) to the Hindus. Sampling was being carried out for 3 months at an interval of 15 days and on the occasion of ardh kumbh snaan days starting during February 2016 to April 2016 (Table 1). Samles were collected from 5 location (Table 2).

Table 1: Snan days

Date	Snan Day	Date	Snan Day
8/02/2016	Somwati Amavasya	**8/04/2016**	Chaitra Shukla Pratipada
12 /02/ 2016	Vasant Panchami	**14/04/2016**	Mesha Sankranti
22/02/ 2016	Magh Purnima	**15/04/2016**	Ram Navami
7/03/2016	Mahashivratri	**22/04/2016**	Chaitra shukla Purnima
7/04/2016	Chaitra Amavasya		

Table 2 : Sampling Locations

Site	Locations	Latitude	Longitude
1	Chilla (Under The Bridge)	**$29^0$58'37.5'' N**	**$78^0$12'56.2'' E**
2	Bhimgoda Barrage	**$29^0$57'26.5'' N**	**$78^0$10'39.3'' E**
3	Guru Kashnik Ghat	**$29^0$58'21.5'' N**	**$78^0$11'07.6'' E**
4	Har Ki Pauri	**$29^0$57'23.1'' N**	**$78^0$10'15.3'' E**
5	Vishnu Ghat	**$29^0$57'04.3'' N**	**$78^0$09'56.7'' E**

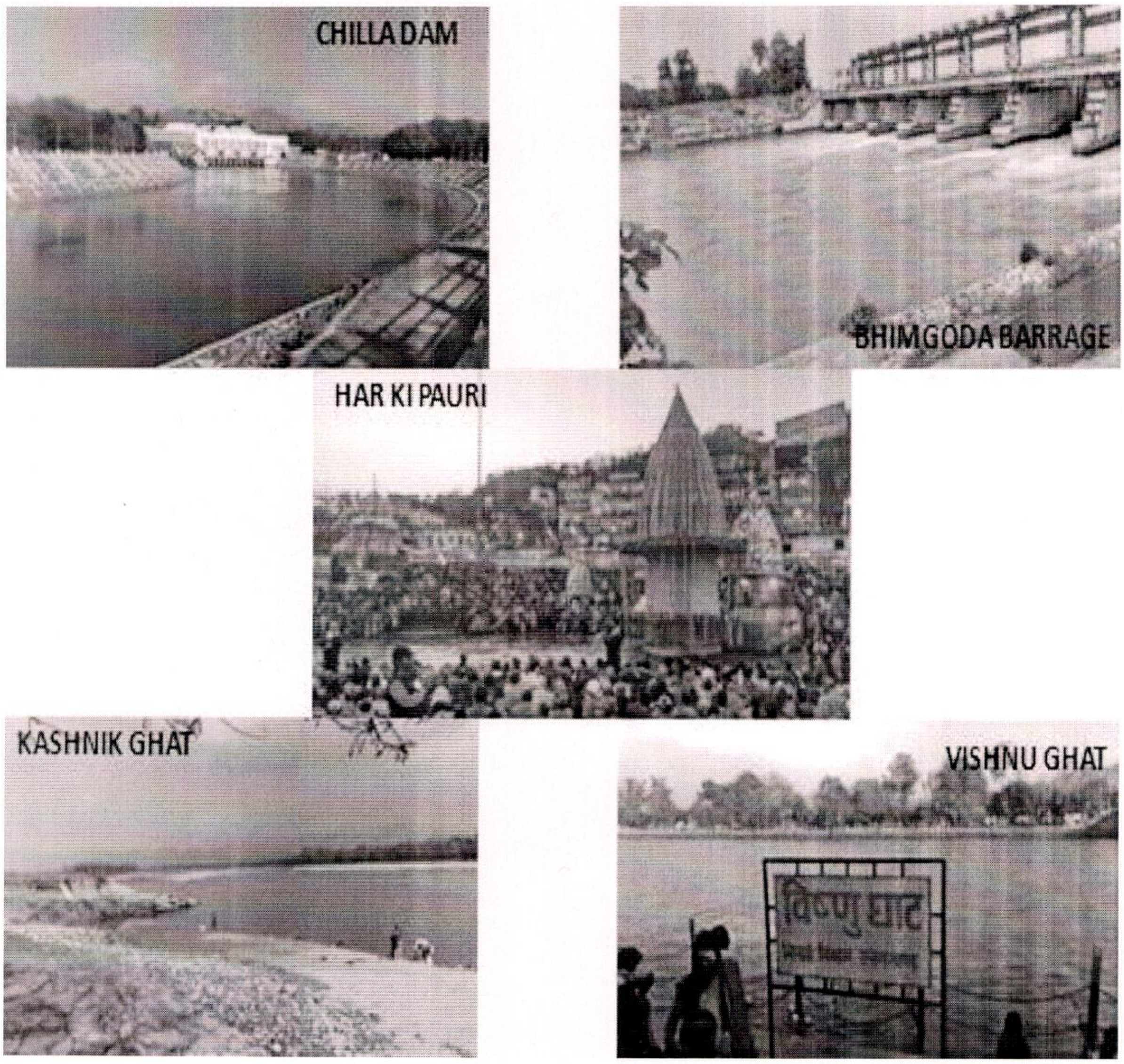


Figure 1: Pictures of Sampling Locations

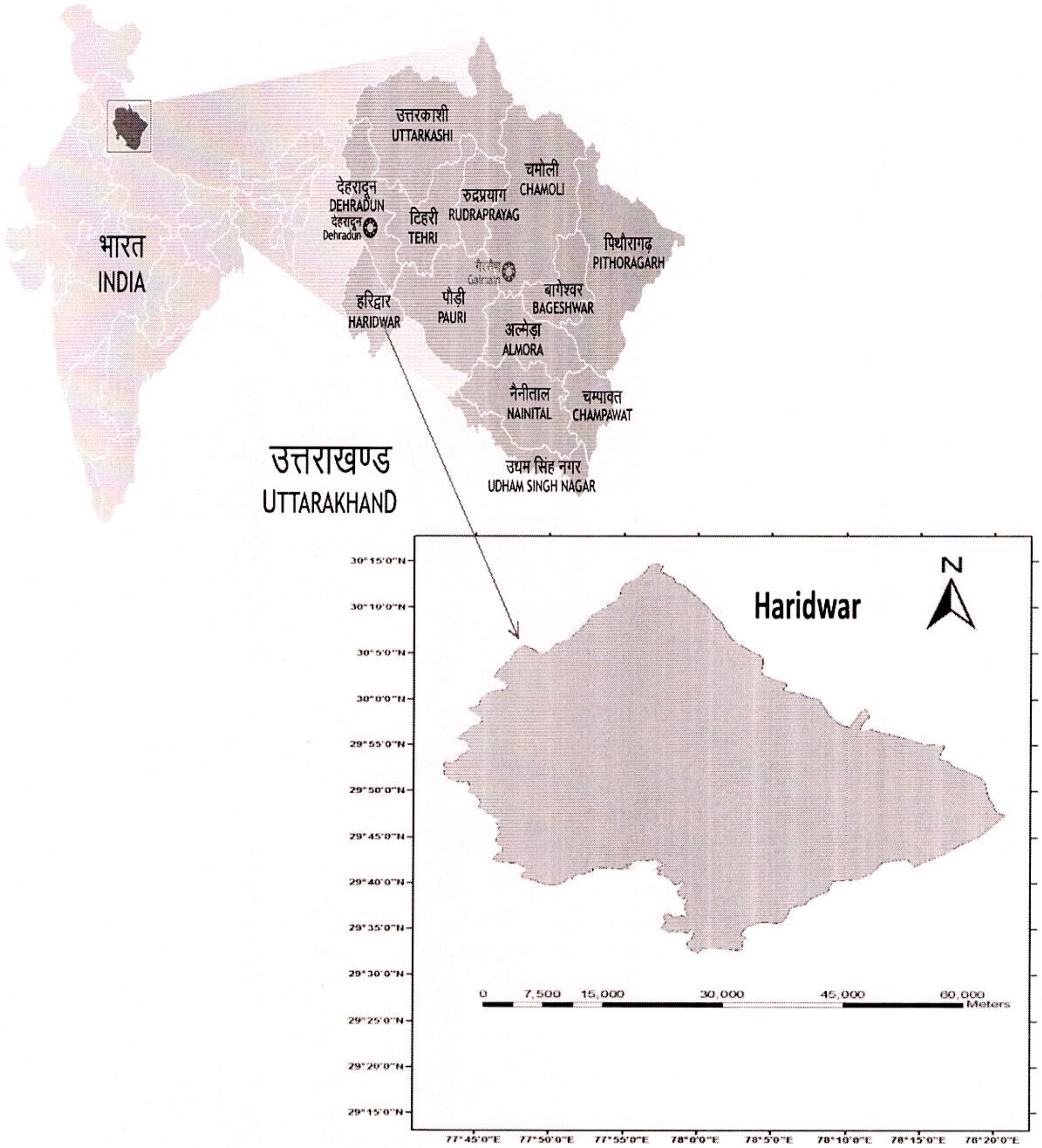


Figure 2: Index Map of Study Area

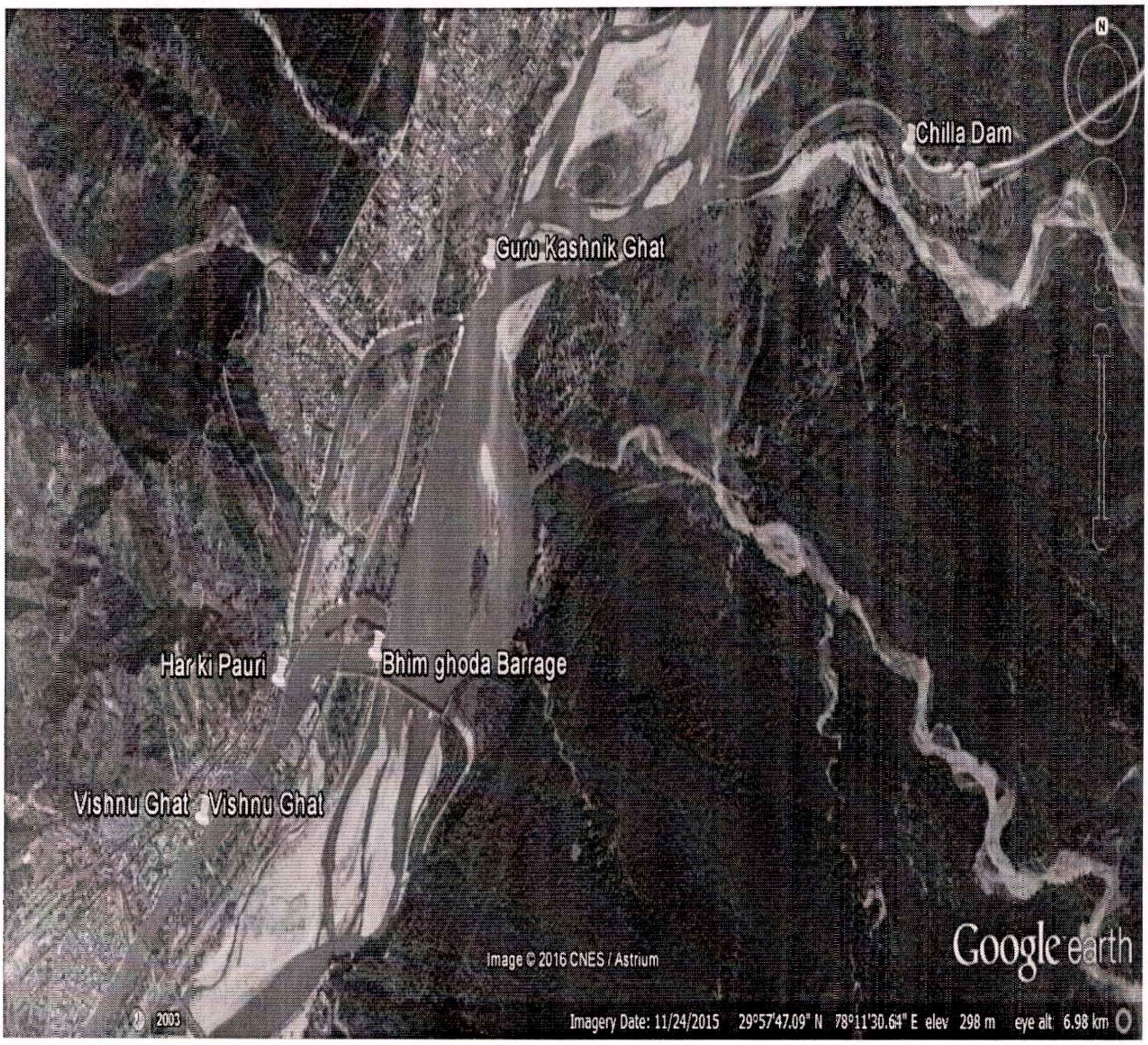


Figure 3: Aerial View of Sampling Locations

CHAPTER 4

MATERIALS & METHODOLOGY

4.1GENERAL

Samples were collected in 1litre clean plastic bottles at about 20cm depth for physico-chemical parameters. Samples were also collected in 500ml clean sterilized bottles and carried to the laboratory in an ice box within 24 hrs. Samples for DO are collected in clean BOD bottles & fixed by Manganous Sulphate & Alkali azide on the site itself. Bottles were rinsed All the parameters were analyzed as per standards APHA methods for 11 different physico-chemical parameters namely pH, EC, Turbidity, Alkalinity, Hardness, Calcium Hardness, Magnesium Hardness, Cl, SO4, PO4, NO3, Na, K, Si, DO, BOD, TDS, TSS & Bacteriological parameters.

4.2 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 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 reagent used for bacteriological analysis were thoroughly cleaned and sterilized before use. All glassware for pesticides analysis were rinsed with chromatography grade solvents prior to use.

4.3 PHYSICO-CHEMICAL AND BACTERIOLOGICAL ANALYSIS

The physic-chemical and bacteriological analysis was performed was performed as per standard method (Jain and Bhatia, 1988; APHA, 1992). The details of analytical method and equipment used in the study are described in Table 6. Ionic balance was calculated, the error in the ionic balance for majority of the samples was within 5%. The total number of selected parameters is eighteen for calculating the ground water quality index.

Table 4.1: Samples were analyzed for various parameters using following methods

S. No.	PARAMETERS	METHOD	EQUIPMENT
1	pH	Electrometric	pH METER
2	EC	Electrometric	EC Meter
3	Turbidity	Turbiditric	Turbidity Meter
4	Total Dissolved Solids	Gravimetric Method	----
5	Total Suspended Solids	Gravimetric Method	----
6	Total Alkalinity	Titration by H_2SO_4	Titration Method
7	Total Hardness	Titration by EDTA	Titration Method
8	Calcium Hardness	Titration by EDTA	Titration Method
9	Calcium	Titration by EDTA	Titration Method
10	Magnesium	Titration by EDTA	Titration Method
11	Chloride	Titration by $AgNO_3$	Titration Method
12	Dissolved Oxygen	Winkler Azide Method	Titration Method
13	Biological Oxygen Demand	Winkler Azide Method	Titration Method
14	Sulphate	Turbiditric Method	Nephelometeric Method
15	Sodium	Flame Emission	Flame Photometric Method
16	Potassium	Flame Emission	Flame Photometric Method
17	Nitrate	Chromatography	Ion Chromatograph
18	Phosphate	Chromatography	Ion Chromatograph
19	Silica	Ammonium Molybdate	UV-VIS Spectrometer
20	Total Coliform	MPN Method	BacteriologicalIncubator
21	Fecal Coliform	MPN Method	Bacteriological Incubator

4.4 Water Quality Index for Drinking And Bathing

Water Quality Indices are tools to determine conditions of water quality. It is a well-known method of expressing water quality that offers a stable and reproducible unit of measure which responds to changes in the principal characteristics of water. In this study **Canadian Water Quality Index** was used for evaluating the status of water quality. It consists of three measures of variance from selected water quality objectives: Scope (F1), the number of variables not meeting water quality objectives; Frequency (F2), the number of times these objectives are not met; and Amplitude (F3), the amount by which the objectives are not met. The index produces a number between zero (worst water quality) and 100 (best water quality)

The present study describes the application of the Canadian Council ME Water Quality Index to monitor the changes in water quality at five sites within River Ganga at Haridwar.

4.4.1 CCME Water Quality Index (CCME WQI)

The CCME WQI was originally developed as the Canadian Water Quality Index (CWQI). It is comprises of 3 factors:

F1 (**Scope**) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration ("failed variables"), relative to the total number of variables measured:

$$F1 = (\text{No. of failed parameters/Total no. of parameters}) * 100$$

F2 (**Frequency**) represents the percentage of individual tests that do not meet objectives ("failed tests"):

$$F2 = (\text{No. of failed tests/Total no. of tests}) * 100$$

F3 (**Amplitude**) represents the amount by which failed test values do not meet their objectives.

F3 is calculated in three steps:
i) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and is expressed as follows. When the test value must not exceed the objective:

$$\text{Excursion} = (\text{failed test value/guideline value}) - 1$$

For the cases in which the test value must not fall below the guideline:

$$Excursion = (guideline\ value / failed\ test\ value) - 1$$

ii) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or *nse*, is calculated as:

$$\mathbf{nse = (\sum excursion / total\ no\ of\ tests)}$$

iii) *F3* is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (*nse*) to yield a range between 0 and 100.

$$F3 = (nse/(0.01*nse+0.01)$$

Once the factors have been obtained, the index itself can be calculated by summing the three factors as if they were vectors. The sum of the squares of each factor is therefore equal to the square of the index. This approach treats the index as a three-dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors.

The CCME Water Quality Index (CCME WQI):

$$\mathbf{WQI = 100-((\sqrt{}\ F1^2 + F2^2 + F3^{3)}/1.732)}$$

The divisor 1.732 normalizes the resultant values to a range between 0 and 100, where 0 represents the "worst" water quality and 100 represents the "best" water quality (Table 4.2).

Table 4.2: Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)

WQI value	Rating of Water Quality
95-100	Excellent water quality
80-94	Good water quality
60-79	Fair water quality
45-59	Marginal water quality
0-44	Poor water quality

Table 4.3: CPCB classification for water use

Designated Best Use	Class of Water	Criteria
Drinking water Source Without conventional treatment but after disinfection	A	• Total Coliforms Organism MPN/100ml shall be 50 or less • pH between 6.5 and 8.5 • Dissolved Oxygen 6mg/l or more • Biochemical Oxygen Demand 5 days 20°C 2mg/l or less
Outdoor (Bathing)	B	• Total Coliforms Organism MPN/100ml shall be 500 or less • pH between 6.5 and 8.5 • Dissolved Oxygen 5mg/l or more • Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	• Total Coliforms Organism MPN/100ml shall be 5000 or less • pH between 6 to 9 • Dissolved Oxygen 4mg/l or more • Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Propagation Of Wild Life and fisheries	D	• pH between 6 to 8.5 • Dissolved Oxygen 4mg/l or more • Free Ammonia (as N) 1.2 mg/L or Less
Irrigation, Industrial Cooling, Controlled Waste Disposal	E	• pH between 6 to 8.5 • Electrical Conductivity at 25°C micro mhos/cm Max.2250 • Sodium absorption Ratio Max. 26 • Boron Max. 2mg/l

CHAPTER 5

RESULT AND ANALYSIS

5.1 Drinking Water Quality

The Bureau of Indian Standards (BIS) has framed the specifications for Drinking Water and published as IS 10500:2012. The standard specifies the acceptable and permissible limits for water used for drinking applications. It is the recommended that the water with acceptable limit should be provided for drinking whereas in absence of the water satisfying the acceptable limits, water satisfying the permissible limits can be used. If the parameters exceed the permissible limits, the source should be rejected. The important water quality characteristics as laid down in the BIS Standards are given in table 5.1:

Table 5.1: Drinking water – Specification (Second Revision of IS 10500:2012)

S. No.	Characteristics	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source
Physical Parameters			
1	pH	6.5 to 8.5	No Relaxation
2	EC, 25°C micro mhos/cm Max	2250	
3	Turbidity , NTU, Max	1	5
4	TDS , mg/L	500	2000
General Parameters Concerning Substances Undesirable in Excessive Amounts			
5	Calcium (as Ca) , mg/L, Max	75	200
6	Chlorides (as Cl), mg/L, Max	250	1000
7	Fluoride (as F), mg/L, Max	1	1.5
8	Magnesium (as Mg), mg/L, Max	30	100
9	Nitrate (as NO_3), mg/L, Max	45	No Relaxation
10	Sulphate (as SO_4), mg/L, Max	200	400
11	Total Alkalinity (as $CaCO_3$), mg/L, Max	200	600
12	Total Hardness (as $CaCO_3$), mg/L, Max	200	600
Bacteriological Quality of Drinking Water			
	Organisms	**Requirements**	
13	All water Intended for Drinking: a) E. coli	Shall not be detectable in any 100ml sample	
14	Treated water entering the distribution system. • E. coli & Total Coliform Bacteria	Shall not be detectable in any 100ml sample.	

Table 5.2 : Physical Parameters

S.NO.	DATE	LOCATION SOURCE	LATITUDE	LONGITUDE	pH	EC (µS/cm)	TDS (mg/l)	TURBIDITY (NTU)
	Acceptable Limit				6.5 – 8.5	----	500	1
	Permissible Limit				NR	-----	2000	5
1	3 FEB	Chilla (Under The Bridge)	N29^{0}58'38"	E78^{0}12'56"	7.48	160.7	95	0.9
2		Bhimgoda Barrage	N29^{0}57'27"	E 78^{0}10'39"	7.49	192.5	103	1.2
3		Guru Khashnik Ghat	N29^{0}58'22"	E 78^{0}11'08"	7.5	190.7	123	1.2
4		Har Ki Pauri	N29^{0}57'23"	E 78^{0}10'15"	7.43	190.6	122	0.9
5		Vishnu Ghat	N29^{0}57'04"	E 78^{0}09'57"	7.42	160.7	122	2.1
6	8FEB	Chilla(Under The Bridge)	N29^{0}58'38"	E78^{0}12'56"	7.33	159.4	102	4.7
7		Bhimgoda Barrage	N29^{0}57'27"	E 78^{0}10'39"	6.93	162.5	104	5.2
8		Guru Khashnik Ghat	N29^{0}58'22"	E 78^{0}11'08"	6.87	191.2	122	5.2
9		Har Ki Pauri	N29^{0}57'23"	E 78^{0}10'15"	6.85	190.5	122	5.6
10		Vishnu Ghat	N29^{0}57'04	E 78^{0}09'57"	6.81	189.7	121	4.6
11	12 FEB	Chilla(Under The Bridge)	N29^{0}58'38"	E78^{0}12'56"	8.47	138.5	89	2.66
12		Bhimgoda Barrage	N29^{0}57'27"	E 78^{0}10'39"	8.10	156.6	100	3.3
13		Guru Khashnik Ghat	N29^{0}58'22"	E 78^{0}11'08"	7.47	194.7	125	3
14		Har Ki Pauri	N29^{0}57'23"	E 78^{0}10'15"	7.23	198.9	127	3.2
15		Vishnu Ghat	N29^{0}57'04"	E 78^{0}09'57"	7.08	195.2	125	5

Table 5.2 : Physical Parameters

S. NO.	DATE	LOCATION	LATITUDE	LONGITUDE	pH	EC (µS/cm)	TDS (mg/l)	TURBIDITY (NTU)
			Acceptable Limit		6.5 – 8.5	----	500	1
			Permissible Limit		NR	-----	2000	5
16	18 FEB	Chilla(Under The Bridge)	N29^{0}58'37.5''	E78^{0}12'56.2''	6.70	142.2	91	5.88
17		Bhimgoda Barrage	N29^{0}57'26.5''	E 78^{0}10'39.3''	6.73	152.5	98	5.48
18		Guru Khashnik Ghat	N29^{0}58'21.5''	E 78^{0}11'07.6''	6.66	195.4	125	5.9
19		Har Ki Pauri	N29^{0}57'23.1''	E 78^{0}10'15.3''	6.69	151.6	97	3.12
20		Vishnu Ghat	N29^{0}57'04.3''	E 78^{0}09'56.7''	6.66	196.3	126	3.1
21	22FEB	Chilla(Under The Bridge)	N29^{0}58'37.5''	E78^{0}12'56.2''	7.33	159.4	95	4.6
22		Bhimgoda Barrage	N29^{0}57'26.5''	E 78^{0}10'39.3''	6.93	162.5	104	4.8
23		Guru Khashnik Ghat	N29^{0}58'21.5''	E 78^{0}11'07.6''	6.87	191.2	134	3.6
24		Har Ki Pauri	N29^{0}57'23.1''	E 78^{0}10'15.3''	6.85	190.5	118	1.6
25		Vishnu Ghat	N29^{0}57'04.3''	E 78^{0}09'56.7''	6.81	189.7	120	5.36
26	4 MARCH	Chilla(Under The Bridge)	N29^{0}58'37.5''	E78^{0}12'56.2''	8.47	138.5	88	11.8
27		Bhimgoda Barrage	N29^{0}57'26.5''	E 78^{0}10'39.3''	8.10	156.6	102	6
28		Guru Khashnik Ghat	N29^{0}58'21.5''	E 78^{0}11'07.6''	7.47	194.7	125	1.6
29		Har Ki Pauri	N29^{0}57'23.1''	E 78^{0}10'15.3''	7.23	198.9	126	2.9
30		Vishnu Ghat	N29^{0}57'04.3''	E 78^{0}09'56.7''	7.08	195.2	128	1.8

S.NO.	DATE	LOCATION	LATITUDE	LONGITUDE	pH	EC (µS/cm)	TDS (mg/l)	TURBIDITY (NTU)
			Acceptable Limit		6.5 – 8.5	----	500	1
			Permissible Limit		NR	-----	2000	5
31	7 MARCH	Chilla(Under The Bridge)	N29^{0}58'37.5"	E78^{0}12'56.2"	7.7	141.3	90	0.5
32		Bhimgoda Barrage	N29^{0}57'26.5"	E 78^{0}10'39.3"	7.9	148.6	95	0.33
33		Guru Khashnik Ghat	N29^{0}58'21.5"	E 78^{0}11'07.6"	7.9	221.0	141	5.2
34		Har Ki Pauri	N29^{0}57'23.1"	E 78^{0}10'15.3"	7.9	196.2	126	0.3
35		Vishnu Ghat	N29^{0}57'04.3"	E 78^{0}09'56.7"	7.7	199.4	128	1
36	21 MARCH	Chilla(Under The Bridge)	N29^{0}58'37.5"	E78^{0}12'56.2"	7.3	136.1	87	2
37		Bhimgoda Barrage	N29^{0}57'26.5"	E 78^{0}10'39.3"	7.6	158.9	102	3
38		Guru Khashnik Ghat	N29^{0}58'21.5"	E 78^{0}11'07.6"	7.7	180.5	116	5
39		Har Ki Pauri	N29^{0}57'23.1"	E 78^{0}10'15.3"	7.7	181.8	116	3
40		Vishnu Ghat	N29^{0}57'04.3"	E 78^{0}09'56.7"	7.9	183.7	118	4
41	7 APRIL	Chilla(Under The Bridge)	N29^{0}58'37.5"	E78^{0}12'56.2"	7.5	143.5	92	6
42		Bhimgoda Barrage	N29^{0}57'26.5"	E 78^{0}10'39.3"	7.6	151.8	97	4
43		Guru Khashnik Ghat	N29^{0}58'21.5"	E 78^{0}11'07.6"	7.7	179.7	115	5
44		Har Ki Pauri	N29^{0}57'23.1"	E 78^{0}10'15.3"	7.7	183.4	117	6
45		Vishnu Ghat	N29^{0}57'04.3"	E 78^{0}09'56.7"	7.8	181.9	116	5

Table 5.2 : Physical Parameters

S.NO.	DATE	LOCATION	LATITUDE	LONGITUDE	pH	EC (µS/cm)	TDS (mg/l)	TURBIDITY (NTU)
			Acceptable Limit		6.5 – 8.5	----	500	1
			Permissible Limit		NR	-----	2000	5
46	8 April	Chilla(Under The Bridge)	N29^{0}58'37.5''	E78^{0}12'56.2''	7.8	131.4	84	4
47		Bhimgoda Barrage	N29^{0}57'26.5''	E 78^{0}10'39.3''	7.7	146.3	94	9
48		Guru Khashnik Ghat	N29^{0}58'21.5''	E 78^{0}11'07.6''	7.8	179.9	115	2
49		Har Ki Pauri	N29^{0}57'23.1''	E 78^{0}10'15.3''	7.9	181.6	116	8
50		Vishnu Ghat	N29^{0}57'04.3''	E 78^{0}09'56.7''	7.8	182.9	117	4
51	14 April	Chilla(Under The Bridge)	N29^{0}58'37.5''	E78^{0}12'56.2''	8.12	142.9	91	3
52		Bhimgoda Barrage	N29^{0}57'26.5''	E 78^{0}10'39.3''	7.89	160.7	103	2
53		Guru Khashnik Ghat	N29^{0}58'21.5''	E 78^{0}11'07.6''	7.6	194.1	124	3.38
54		Har Ki Pauri	N29^{0}57'23.1''	E 78^{0}10'15.3''	7.74	191	122	9.81
55		Vishnu Ghat	N29^{0}57'04.3''	E 78^{0}09'56.7''	7.8	196	125	3.49
56	15 April	Chilla(Under The Bridge)	N29^{0}58'37.5''	E78^{0}12'56.2''	7.6	165.4	106	0.43
57		Bhimgoda Barrage	N29^{0}57'26.5''	E 78^{0}10'39.3''	7.7	174.4	112	0.53
58		Guru Khashnik Ghat	N29^{0}58'21.5''	E 78^{0}11'07.6''	7.7	196.3	126	0.6
59		Har Ki Pauri	N29^{0}57'23.1''	E 78^{0}10'15.3''	7.8	196.2	126	0.34
60		Vishnu Ghat	N29^{0}57'04.3''	E 78^{0}09'56.7''	8.04	196.8	126	0.39

Table 5.2 : Physical Parameters

S. NO.	DATE	LOCATION	LATITUDE	LONGITUDE	pH	EC (µS/cm)	TDS (mg/l)	TURBIDITY (NTU)
			Acceptable Limit		6.5 – 8.5	----	500	1
			Permissible Limit		NR	-----	2000	5
61	8 APRIL	CHILLA(UNDER THE BRIDGE)	N29^{0}58'37.5''	E78^{0}12'56.2''	7.5	152.8	98	1.21
62		BHIMGODA BARRAGE	N29^{0}57'26.5''	E 78^{0}10'39.3''	7.9	159.3	102	1.34
63		GURU KHASHNIK GHAT	N29^{0}58'21.5''	E 78^{0}11'07.6''	7.2	185.2	119	0.88
64		HAR KI PAURI	N29^{0}57'23.1''	E 78^{0}10'15.3''	7.3	188.4	121	0.67
65		VISHNU GHAT	N29^{0}57'04.3''	E 78^{0}09'56.7''	7.7	196.1	126	2.84

Table 5.3 : Chemical Parameters

S NO		DO (mg/l)	TA (mg/l)	T Hard (mg/l)	Ca Hard (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	NH_4 (mg/l)	SO_4 (mg/l)	Cl (mg/l)	F (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	Silica (mg/L)	BOD (mg/l)
Acceptable Limit		5	200	200	200	75	30	------	--------	0.5	200	250	1.0	----	45	--------	3
Permissible Limit		NR	600	600	600	200	100	-------	-------	NR	400	1000	1.5	----	NR	---------	NR
1		10.1	108	118.0	56.0	22.40	19.96	2.7	1.6	0.00	20.6	1.6	0.07	0.00	1.29	2.80	0.8
2		9.7	72	92.0	42.0	16.80	18.77	2.5	1.6	0.00	22.1	1.7	0.07	0.76	2.67	2.60	0.20
3		17.4	82	104.0	60.0	24.00	22.49	3.1	1.7	0.13	27.9	2.1	0.07	0.69	2.21	2.80	0.0
4		9.9	90	86.0	64.0	24.80	40.83	3.2	1.7	0.16	26.7	0.8	0.08	1.38	0.74	3.30	0.00
5		10.2	128	90.0	88.0	31.20	42.34	3.0	1.6	0.14	26.7	0.8	0.08	1.25	0	3.60	0.20
6		10.0	50	78.0	46.0	18.40	20.31	2.2	1.9	0.00	21.5	1.8	0.06	1.41	0.86	3.30	0.20
7		10.4	60	72.0	56.0	22.40	19.90	2.6	1.3	0.00	22.6	1.8	0.07	1.43	1.4	2.70	0.20
8		11.3	68	92.0	48.0	19.20	23.73	2.8	2.2	0.00	27.4	1.9	0.06	1.31	2.43	3.20	0.0
9		10.3	68	100.0	52.0	20.80	25.17	3.2	1.6	0.00	27.7	1.9	0.07	1.43	2.1	3.20	0.60
10		9.9	66	96	58	23.20	23.41	3	1.7	0.00	27.1	1.9	0.07	1.46	1.49	3.80	0.00
													0				
11		10.2	60	62	22	12.80	17.51	3.5	1.8	0.40	19.6	1.6	0.08	0	1.3	2.70	0
12		9.8	42	72	42	16.80	20.20	3.8	1.8	0.13	21.5	1.7	0.07	1.37	1.4	2.70	0
13		11.0	74	96	52	20.80	24.58	4.6	2.2	0.09	27.90	1.9	0.06	1.39	2.74	3.70	0.2
14		10.2	76	90	76	30.40	24.34	4.6	1.8	0.16	28.2	1.9	0.07	1.38	1.76	3.00	0.2
15		9.8	78	104	48	19.20	24.42	4.5	1.9	0.18	27.10	2.1	0.07	0.73	3.71	3.80	0

Table 5.3 : Chemical Parameters

S. NO.		DO (mg/l)	TA (mg/l)	T Hard (mg/l)	Ca Hard (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	NH_4 (mg/l)	SO_4 (mg/l)	Cl (mg/l)	F (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	Silica (mg/L)	BOD (mg/L)
Acceptable Limit		5	200	200	200	75	30	------	--------	0.5	200	250	1.0	----	45	--------	3
Permissible Limit		NR	600	600	600	200	100	-------	-------	NR	400	1000	1.5	----	NR	---------	NR
16		7.4	84	70	46	18.40	5.86	4.2	1.7	0.21	18.70	1.7	0.07	1.38	2.19	2.80	0
17		10.0	68	60	58	19.20	4.15	3.9	1.7	0.18	18.40	1.8	0.07	0.69	2.14	2.10	0.00
18		2.4	84	82	56	26.40	3.90	4.7	1.9	0.30	26.90	2.0	0.08	0.72	3.81	3.00	0
19		12.5	80	92	60	24.00	7.81	4.7	1.7	0.18	25.60	2.1	0.07	0.7	3.27	2.80	0.20
20		5.0	76	92	60	24.00	7.81	4.8	1.8	0.20	25.50	2.0	0.08	0.71	3.94	3.40	0.2
21		8.5	8.5	70	50	20.00	4.88	4.0	2.1	0.09	18.50	2.4	0.07	1.38	2.08	3.10	0.6
22		7.8	7.8	80	44	17.60	8.78	4.3	2.0	0.10	17.90	1.8	0.07	1.36	0.67	2.70	0.4
23		9.9	9.9	100	54	21.60	11.22	4.9	1.2	0.09	23.7	2.3	0.07	0.7	2.29	3.50	0
24		8.9	8.9	86	40	16.00	11.22	4.40	2.4	0.13	25.20	1.9	0.07	0.72	2.88	3.10	0
25		9.0	9.0	90	78	31.20	2.93	5.1	2.3	0.12	21.20	1.9	0.07	1.39	1.88	3.90	1.2
26		9.8	9.8	50	36	14.40	3.42	3.6	1.6	0.21	18.30	1.6	0.08	1.27	1.34	3.80	0
27		8.7	8.7	70	40	16.00	7.32	4.0	1.7	0.16	20.30	1.7	0.08	1.38	1.07	4.00	1.6
28		10.2	10.2	80	50	20.00	7.32	4.6	1.8	0.28	22.80	1.9	0.07	1.41	2	4.60	0.2
29		9.6	9.6	84	50	20.00	8.30	4.5	1.7	0.28	24.00	2.0	0.07	0.69	1.52	4.10	0.8
30		8.8	8.8	80	52	20.80	6.83	4.7	1.7	0.30	23.60	2.0	0.07	0.78	2.71	4.20	0

Table 5.3 : Chemical Parameters

S. NO.		DO (mg/l)	TA (mg/l)	T Hard (mg/l)	Ca Hard (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	NH_4 (mg/l)	SO_4 (mg/l)	Cl (mg/l)	F (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	Silica (mg/L)	BOD (mg/L)
Acceptable Limit		5	200	200	200	75	30	------	--------	0.5	200	250	1.0	----	45	--------	3
Permissible Limit		NR	600	600	600	200	100	-------	-------	NR	400	1000	1.5	----	NR	---------	NR
31		10.1	10.1	60	34	13.60	6.34	4.2	1.7	0.40	17.80	2.1	0.08	0	1.78	2.60	1
32		8.9	8.9	76	54	21.60	5.37	3.8	1.7	0.35	18.20	1.8	0.08	1.4	1.19	2.80	0
33		9.1	9.1	86	50	20.00	8.78	4.6	2.3	0.36	24.90	2.0	0.08	0.7	2.42	3.10	0
34		9.5	9.5	98	48	19.20	12.20	4.8	1.7	0.40	24.10	2.0	0.07	1.43	2.07	2.90	0.6
35		8.9	8.9	90	52	20.80	9.27	4.7	1.7	0.48	23.10	2.1	0.08	0.73	1.88	3.60	0
													0				
36		9.1	9.1	56	40	16.00	3.90	3.8	1.6	0.49	19.90	1.6	0.08	0	1.27	3.60	1.4
37		8.9	8.9	70	50	20.00	4.88	4	1.7	0.50	22.80	1.8	0.08	1.42	2.18	3.50	0
38		9.5	9.5	82	54	21.60	6.83	4.3	1.6	0.52	25.60	1.9	0.07	0.79	3.03	2.60	0.2
39		9.1	9.1	82	52	20.80	7.32	4.4	1.8	0.54	25.60	2.1	0.07	0.69	1.77	2.30	1.4
40		9.0	9.0	88	52	20.80	8.78	4.4	1.5	0.00	26.60	1.8	0.07	0.69	1.67	3.80	0
													0				
41		8.3	8.3	76	50	20.00	6.34	4.6	1.10	0.00	21.20	1.7	0.06	1.52	1.57	2.10	0.30
42		9.0	9.0	64	50	20.00	3.42	2.30	1.40	0.29	21.50	1.7	0.06	0.69	3.39	2.40	0.8
43		9.5	9.5	72	44	17.60	6.83	2.90	1.30	0.12	26.50	0.8	0.06	0.69	3.52	2.60	0
44		9.6	9.6	88	64	25.60	5.86	3.70	1.40	0.00	25.70	0.9	0.07	0.69	2.2	1.60	0.4
45		8.9	8.9	90	56	22.40	8.30	3.50	1.50	0.00	25.10	0.8	0.07	0.69	2.26	2.80	0.4

Table 5.3 : Chemical Parameters

S. NO.		DO (mg/l)	TA (mg/l)	T Hard (mg/l)	Ca Hard (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	NH_4 (mg/l)	SO_4 (mg/l)	Cl (mg/l)	F (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	Silica (mg/L)	BOD (mg/L)
Acceptable Limit		**5**	**200**	**200**	**200**	**75**	**30**	------	--------	**0.5**	**200**	**250**	**1.0**	----	**45**	--------	**3**
Permissible Limit		**NR**	**600**	**600**	**600**	**200**	**100**	-------	-------	**NR**	**400**	**1000**	**1.5**	----	**NR**	---------	**NR**
46		9.2	9.2	62	58	23.20	0.98	3.10	1.30	0.00	19.50	1.7	0.08	0.69	2.08	1.30	0
47		9.2	9.2	76	46	18.40	7.32	3.00	1.40	0.12	20.90	1.6	0.07	0.69	2.22	2.90	0.2
48		9.4	9.4	90	66	26.40	5.86	3.40	1.30	0.14	26.00	1.9	0.07	0.7	1.89	2.40	0.2
49		9.6	9.6	88	58	23.20	7.32	3.50	15.00	0.19	25.70	0.9	0.07	0.7	5.2	2.90	0
50		9.3	9.3	92	52	24.80	7.32	3.10	1.40	0.17	26.30	0.9	0.07	0.7	2.22	2.50	1
51		8.9	8.9	70	56	22.40	3.42	2.90	1.60	0.23	21.40	1.8	0.07	0.70	1.32	2.20	1.10
52		8.5	8.5	76	60	24.00	3.90	3.50	1.70	0.21	22.80	1.8	0.07	0.70	2.01	1.60	0.20
53		9.0	9.0	94	64	25.60	7.32	3.40	1.70	0.23	27.40	2.0	0.07	0.70	2.04	3.30	0
54		9.1	9.1	90	60	24.00	7.32	4.00	1.70	0.19	27.50	0.8	0.07	0.72	2.07	1.20	0
55		9.1	9.1	90	62	24.80	6.83	3.90	1.60	0.22	27.50	0.9	0.07	0.70	1.94	1.70	0
													0				
56		8.6	8.6	70	50	20.00	4.88	3.50	1.70	0.27	24.40	1.8	0.08	0.70	1.30	0.90	0.6
57		8.5	8.5	92	56	22.40	8.78	3.40	1.90	0.25	28.50	1.9	0.08	0.70	1.92	3.00	0.2
58		9.0	9.0	90	60	24.00	7.32	4.00	1.60	0.29	27.20	1.9	0.07	0.71	1.88	2.80	0.2
59		9.6	9.6	92	56	22.40	8.78	4.10	1.50	0.31	27.80	2.1	0.07	0.70	2.76	2.80	0
60		8.9	8.9	92	72	28.80	4.88	4.10	1.30	0.26	21.10	0.9	0.07	0.72	1.99	2.50	0.2

Table 5.3 : Chemical Parameters

S NO.		DO (mg/l)	TA (mg/l)	T Hard (mg/l)	Ca Hard (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	NH_4 (mg/l)	SO_4 (mg/l)	Cl (mg/l)	F (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	Silica (mg/L)	BOD (mg/L)
Acceptable Limit		5	200	200	200	75	30	------	--------	0.5	200	250	1.0	----	45	--------	3
Permissible Limit		NR	600	600	600	200	100	-------	-------	NR	400	1000	1.5	----	NR	---------	NR
61		8.5	8.5	75	60	22.00	4.88	3.50	1.60	0.00	21.10	1.8	0.07	0.69	1.50	1.30	0
62		8.6	8.6	85	50	20.00	8.54	3.00	1.30	0.00	21.70	1.7	0.07	0.71	1.73	2.20	0.2
63		10.0	10.0	90	50	20.00	9.76	3.60	1.50	0.00	25.70	1.9	0.06	0.70	2.06	3.10	0.4
64		9.1	9.1	88	58	23.20	7.32	3.70	1.40	0.00	26.50	2.0	0.07	0.69	2.69	2.20	0
65		9.7	9.7	106	70	28.00	8.78	3.40	1.20	0.00	26.00	3.1	0.10	0.94	2.72	2.40	0

TABLE NO. 5.4 :- **Bacteriological Parameters**

S No.	DATE	LOCATION	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)
		Acceptable Limit	Not detectable	Not detectable
		Permissible Limit	NR	NR
1	3 FEB	Chilla(Under The Bridge)	2400	2400
2		Bhimgoda Barrage	1100	1100
3		Guru Khashnik Ghat	2400	2400
4		Har Ki Pauri	1100	460
5		Vishnu Ghat	460	460
6	8FEB	Chilla(Under The Bridge)	460	460
7		Bhimgoda Barrage	240	240
8		Guru Khashnik Ghat	2400	2400
9		Har Ki Pauri	460	460
10		Vishnu Ghat	1100	1100
11	12 FEB	Chilla(Under The Bridge)	150	240
12		Bhimgoda Barrage	75	43
13		Guru Khashnik Ghat	460	240
14		Har Ki Pauri	150	150
15		Vishnu Ghat	460	460
16	18 FEB	Chilla(Under The Bridge)	1100	1100
17		Bhimgoda Barrage	15	15
18		Guru Khashnik Ghat	460	460
19		Har Ki Pauri	1100	460
20		Vishnu Ghat	210	210
21	22FEB	Chilla(Under The Bridge)	2400	2400
22		Bhimgoda Barrage	240	240
23		Guru Khashnik Ghat	2400	2400
24		Har Ki Pauri	2400	1100
25		Vishnu Ghat	150	75
26	4 MARCH	Chilla(Under The Bridge)	93	93
27		Bhimgoda Barrage	93	93
28		Guru Khashnik Ghat	75	75
29		Har Ki Pauri	210	210
30		Vishnu Ghat	2400	2400

TABLE NO. 5.4 :- Bacteriological Parameters

S No.	DATE	LOCATION	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)
		Acceptable Limit	Not detectable	Not detectable
		Permissible Limit	NR	NR
31	7 MARCH	Chilla(Under The Bridge)	43	43
32		Bhimgoda Barrage	43	43
33		Guru Khashnik Ghat	93	93
34		Har Ki Pauri	43	43
35		Vishnu Ghat	93	43
36	21 MARCH	Chilla(Under The Bridge)	43	43
37		Bhimgoda Barrage	93	93
38		Guru Khashnik Ghat	23	23
39		Har Ki Pauri	240	240
40		Vishnu Ghat	210	210
41	7 APRIL	Chilla(Under The Bridge)	93	93
42		Bhimgoda Barrage	93	93
43		Guru Khashnik Ghat	1100	1100
44		Har Ki Pauri	460	460
45		Vishnu Ghat	1100	1100

TABLE NO. 5.4 :- Bacteriological Parameters

S No.	DATE	LOCATION	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)
		Acceptable Limit	Not detectable	Not detectable
		Permissible Limit	NR	NR
46	8 APRIL	Chilla(Under The Bridge)	75	75
47		Bhimgoda Barrage	15	9
48		Guru Khashnik Ghat	240	240
49		Har Ki Pauri	460	460
50		Vishnu Ghat	460	460
51	14 APRIL	Chilla(Under The Bridge)	43	43
52		Bhimgoda Barrage	23	23
53		Guru Khashnik Ghat	460	460
54		Har Ki Pauri	240	240
55		Vishnu Ghat	240	240
56	15 APRIL	Chilla(Under The Bridge)	43	43
57		Bhimgoda Barrage	43	43
58		Guru Khashnik Ghat	93	93
59		Har Ki Pauri	1100	1100
60		Vishnu Ghat	460	460
61	8 APRIL	Chilla(Under The Bridge)	75	75
62		Bhimgoda Barrage	150	150
63		Guru Khashnik Ghat	150	150
64		Har Ki Pauri	460	240
65		Vishnu Ghat	460	240

Surface/River Water Assessment is being carried out in order to determine its suitability for Drinking, Irrigation, and Bathing purposes. It is also being carried out for determination of changes in River Water Quality. Physico-Chemical & Bacteriological parameters of River Ganga were compared with Bureau of Indian Standards (BIS, 2012).

p[H]

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 river Ganga samples in the study area were in the range 6.06 to 8.47.

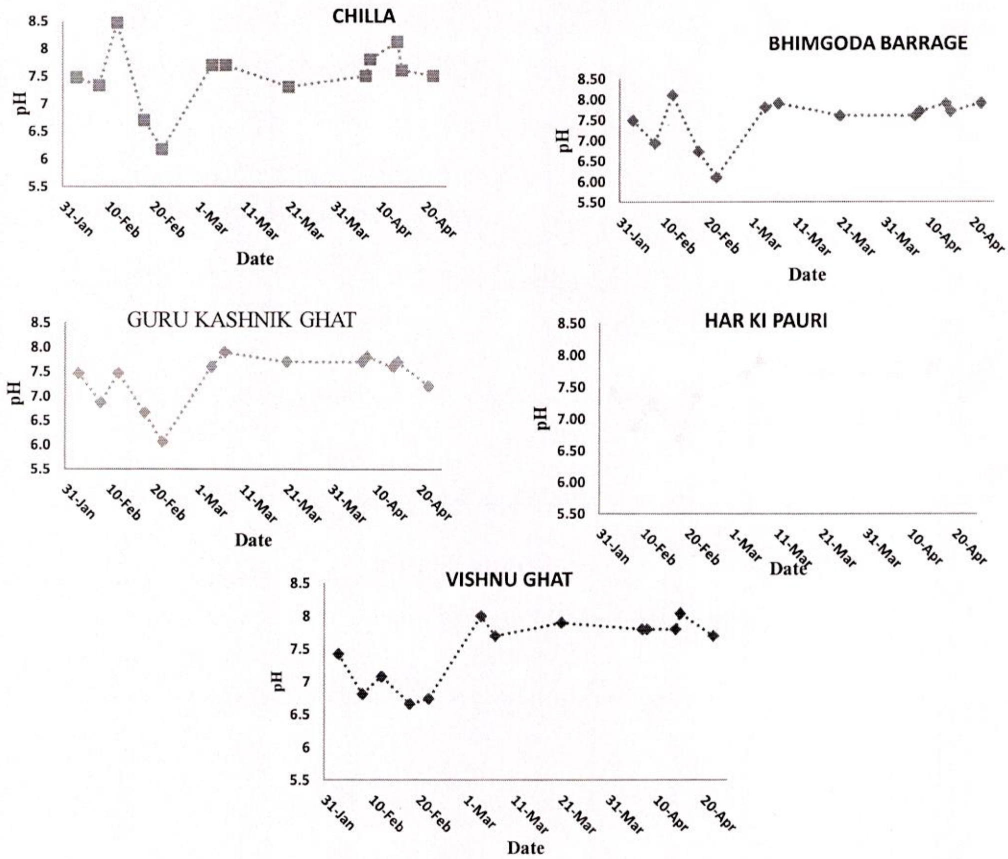


Figure 4: Variations in pH values at different study sites

Electrical Conductivity (μS/cm)

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 131 μS/cm to 221 μS/cm

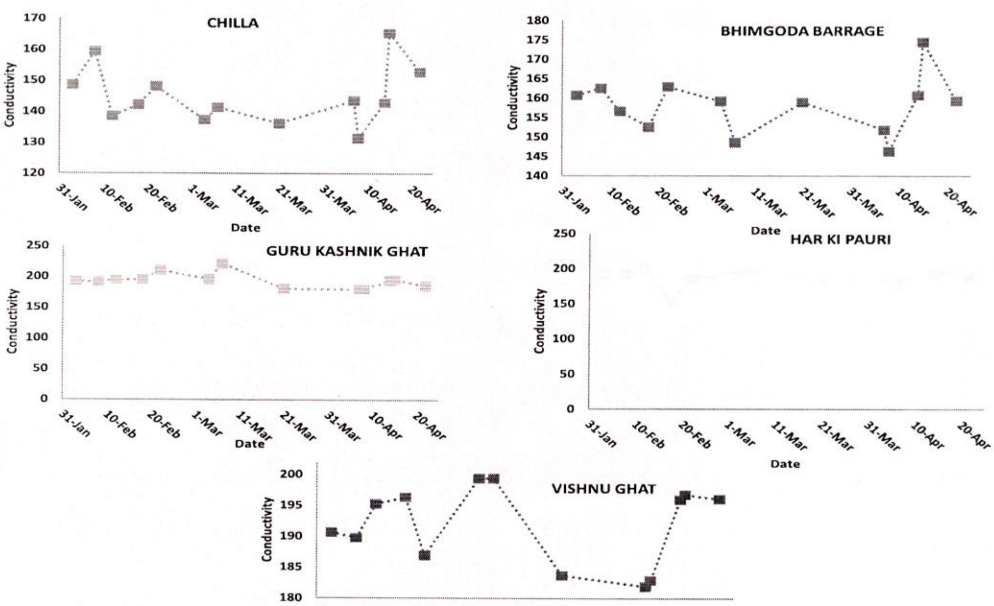


Figure 5 : Variations in EC values at different study sites

Total Dissolved Solids (mg/L)

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 river Ganga of study area varies from 84 mg/l to 141 mg/L, (Figure 6). It can be concluded that the all analysed river water 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).

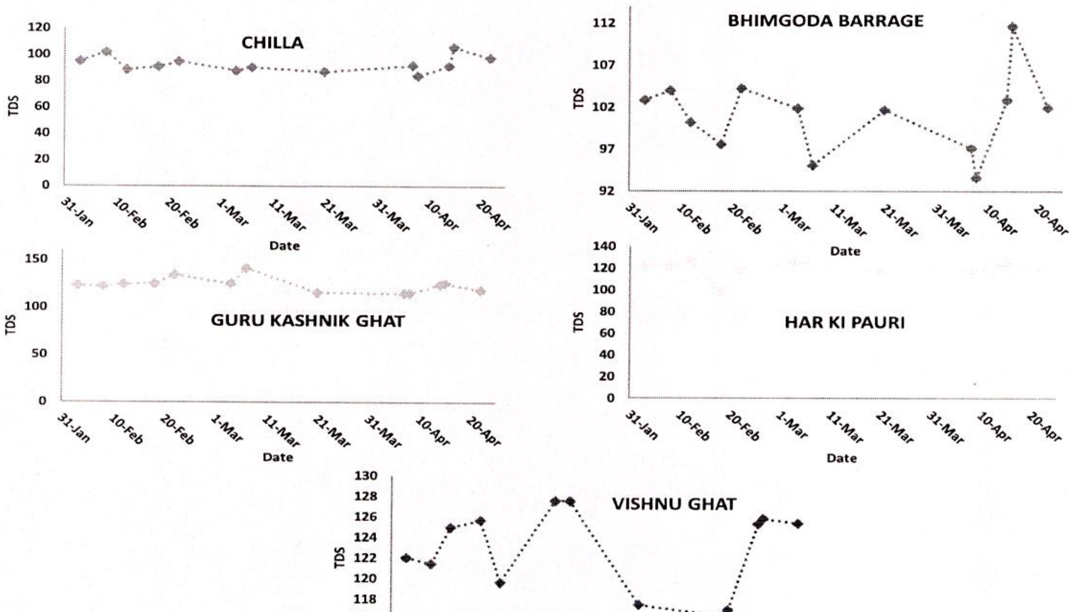


Figure 6 : Variations in TDS values at different study sites

Turbidity(NTU)

Turbidity may be caused by inorganic or organic constituents. 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 river ganga samples of study area varies from 0.3 NTU to 11.8 NTU.Turbidity of only 15% samples was well within the acceptable limit prescribed by BIS (2012) and turbidity of 50% 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.

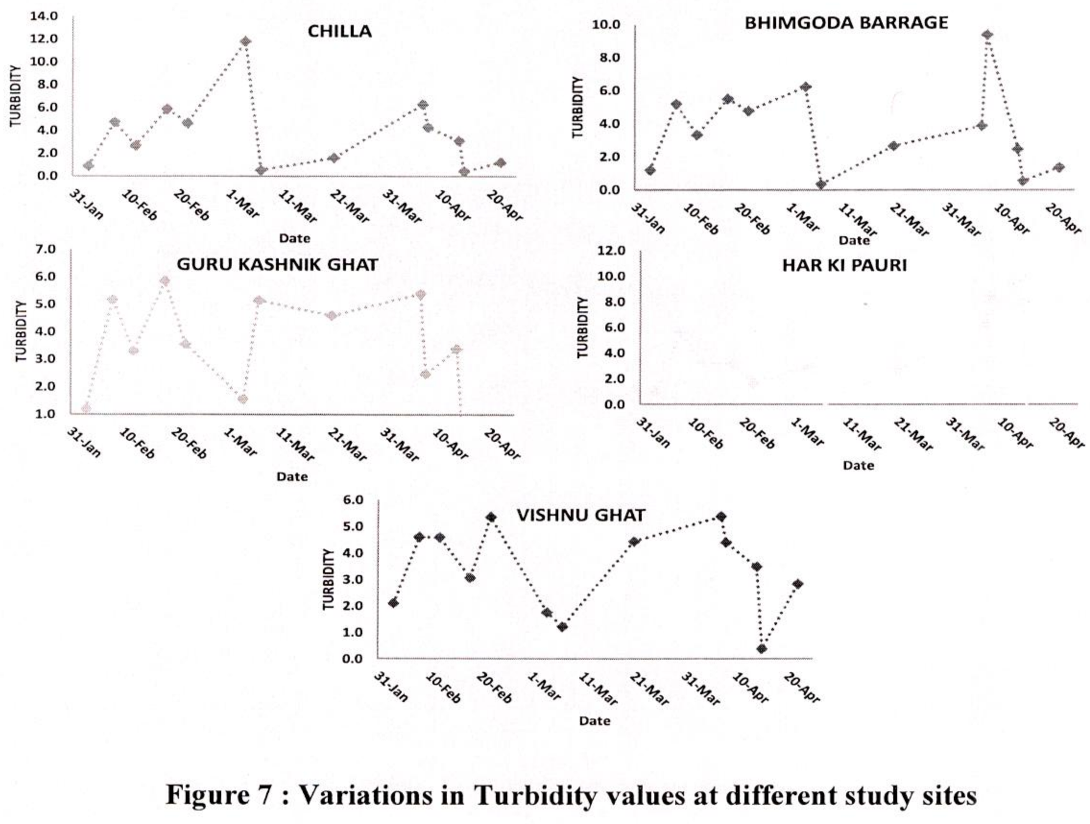


Figure 7 : Variations in Turbidity values at different study sites

Dissolved Oxygen (mg/L)

The Monthly variation in the disintegrated oxygen of waterway Ganga at Haridwar city. Temperature assumes a critical part in deciding DO in an amphibian body. Disintegrated oxygen information are profitable in deciding the water quality criteria of an amphibian framework. In the framework where rate of breath and natural disintegration are high, the DO values remain lower than those of framework where the rate of photosynthesis is high. A high contamination burden may likewise diminish the DO qualities to extensive level. The DO level in the analyzed river ganga sample lies between 2.4 – 17.4 mg/L.

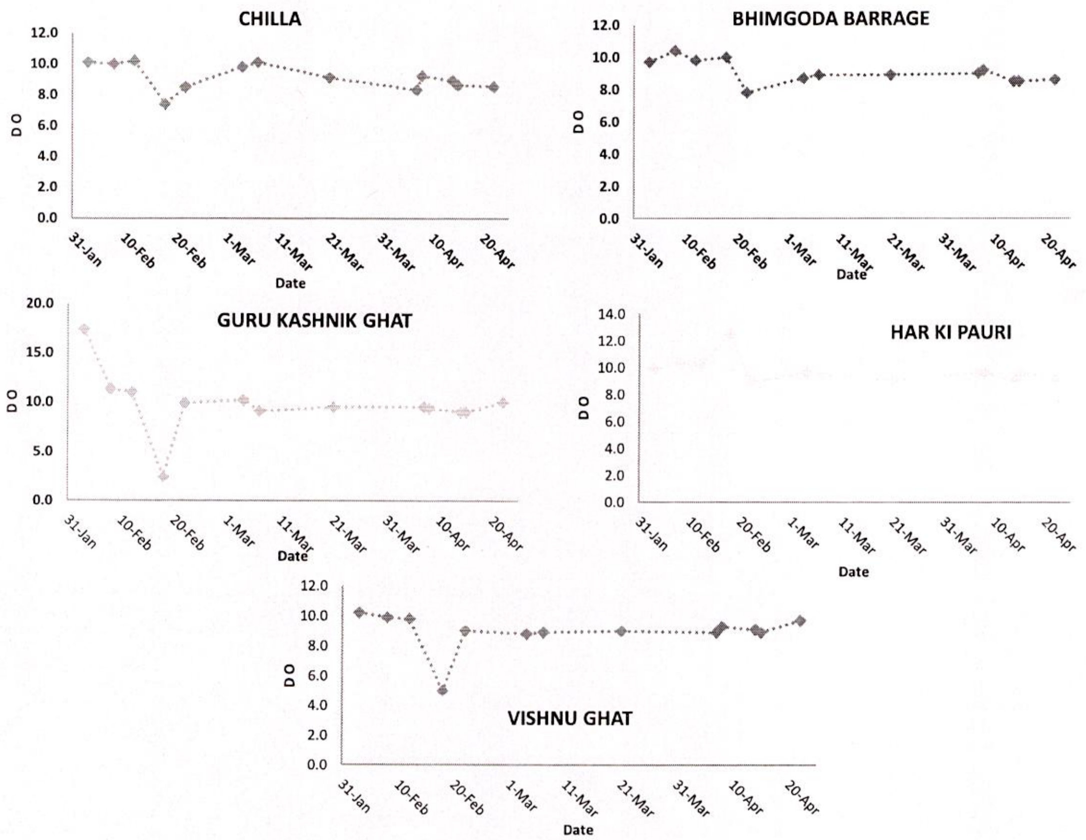


Figure 8 : Variations in DO values at different study sites

Alkalinity (mg/L)

Alkalinity in natural wateris mainly due to presence of carbonates, bicarbonates and hydroxides. It constitutes an important parameter in determining the quality of water. The alkalinity values having lower concentration as compared to BIS standards recommended. The alkalinity values were found to be significant at the Ganges and at different study sites. Total Alkalinity ranged from 42mg/l to 98.4mg/l which was well within the permissible limits of BIS standards (200-600mg/l).

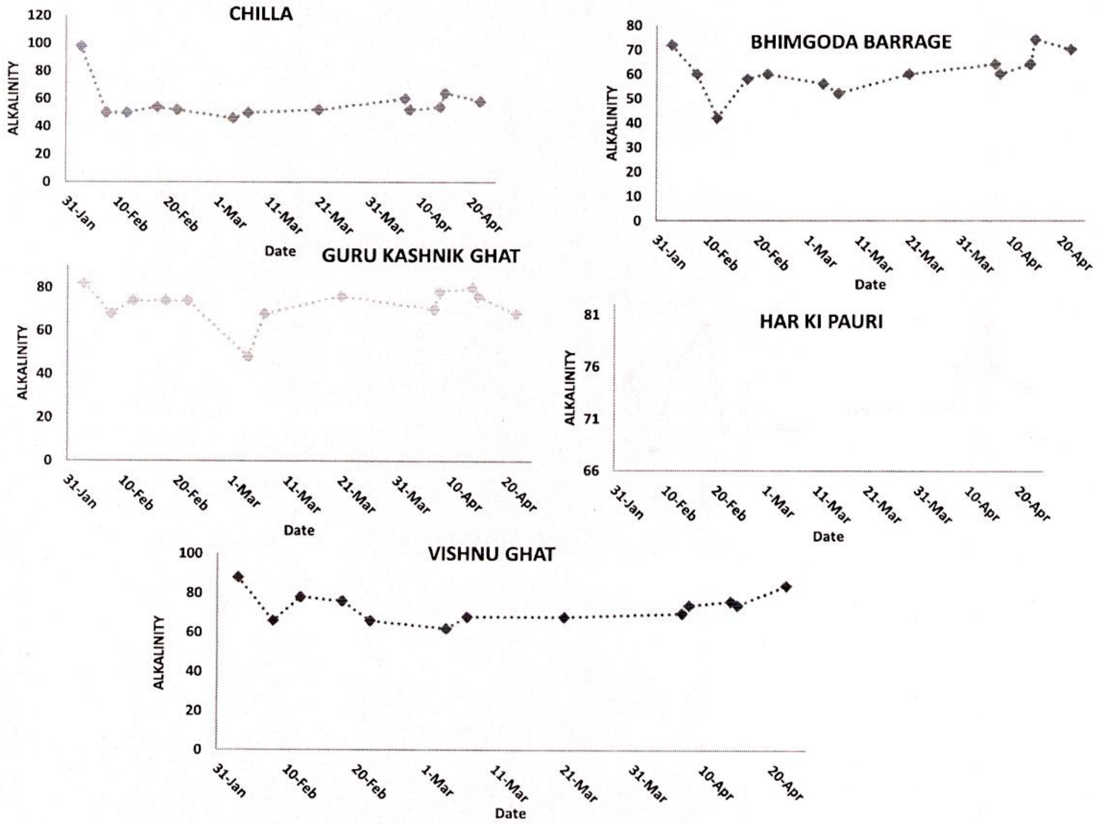


Figure 9: Variations in Alkalinity values at different study sites

Total Hardness (mg/L)

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 was found to be within 50-108 mg/l as $CaCO_3$ (Fig:10).Total hardness in 100% samples was found below 200 mg/l (acceptable limit) and all the samples were well within the permissible limits prescribed by BIS (2012).

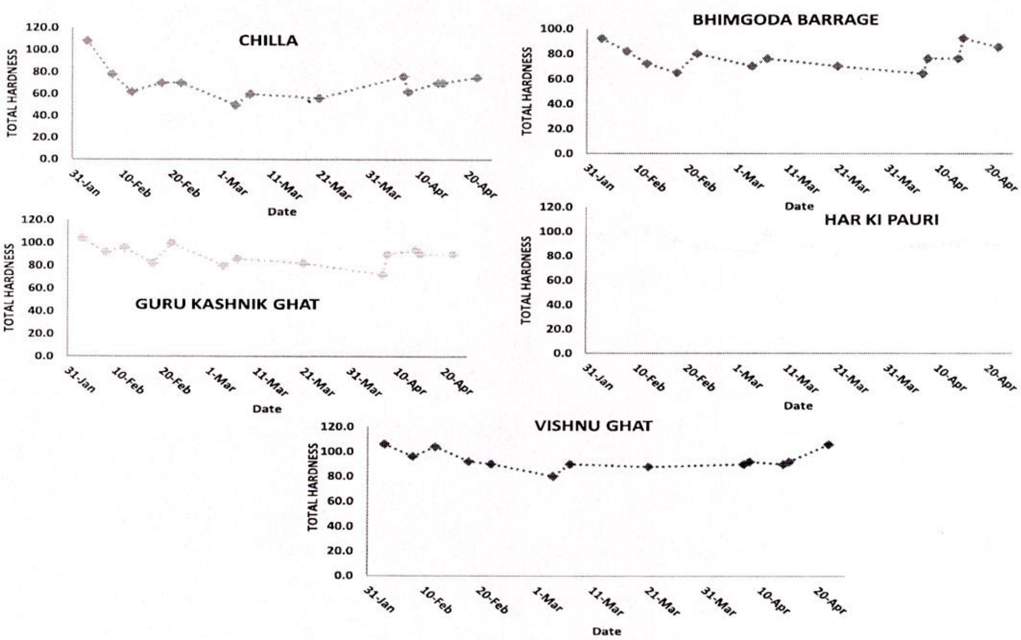


Figure 10: Variations in Total Hardness values at different study sites

Calcium Hardness (mg/L)

The value of calcium hardness in river ganga samples of the study area ranges between 32 to 78 mg/l, (Figure 11). Calcium Hardness content of all samples was found well within the acceptable limit and the permissible limit prescribed by BIS (2012).

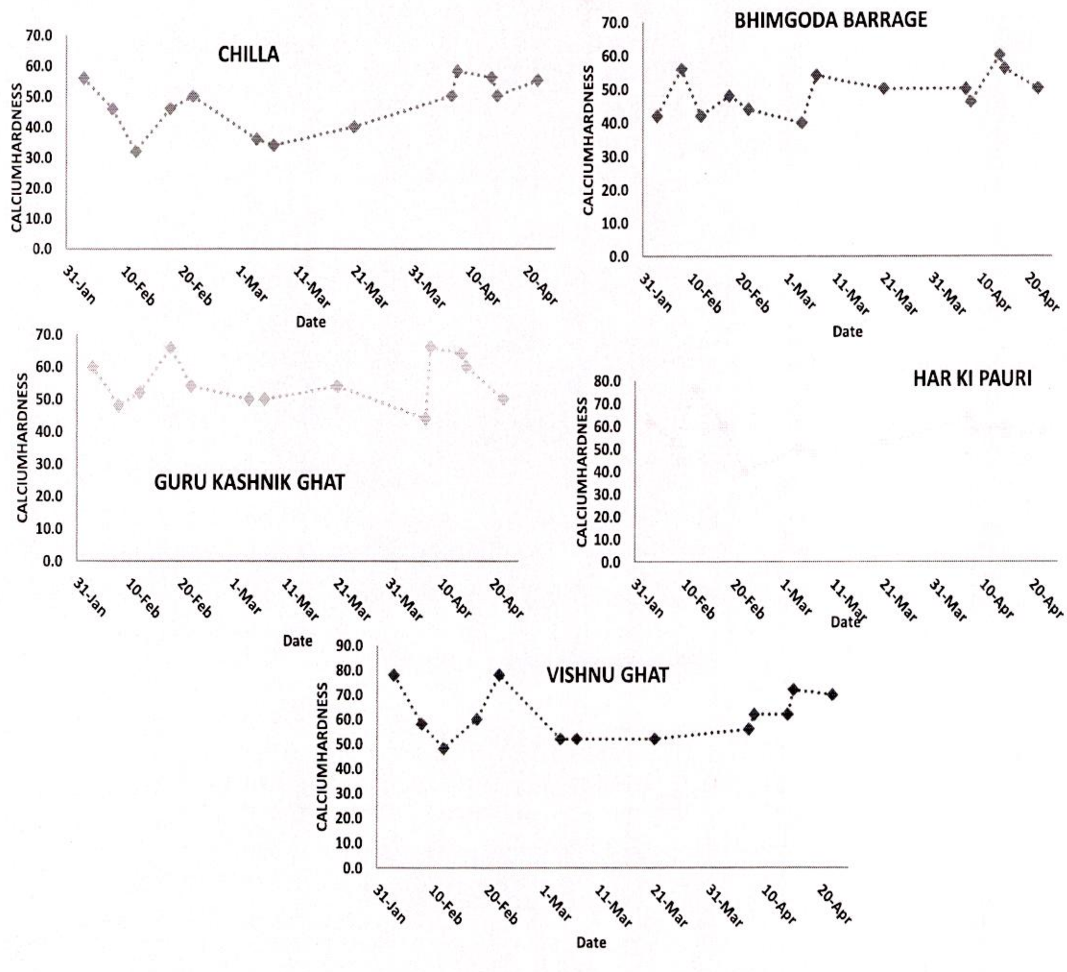


Figure 11: Variations in Calcium Hardness values at different study sites

Sodium (mg/L)

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 river water of the study area ranges between 2 to 5.1 mg/l during study period (Figure 12). All the samples were with the limit prescribed by WHO.

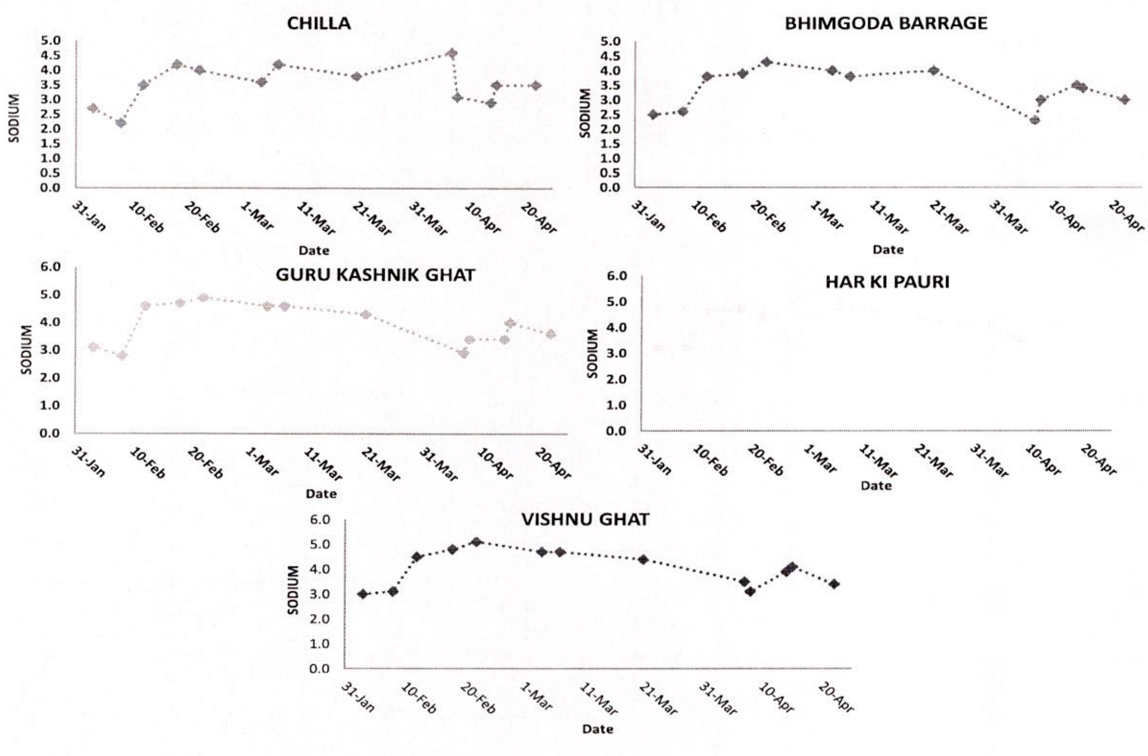


Figure 12: Variations in Sodium values at different study sites

Potassium (mg/L)

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 1.1 to 15 mg/l (Figure 13).

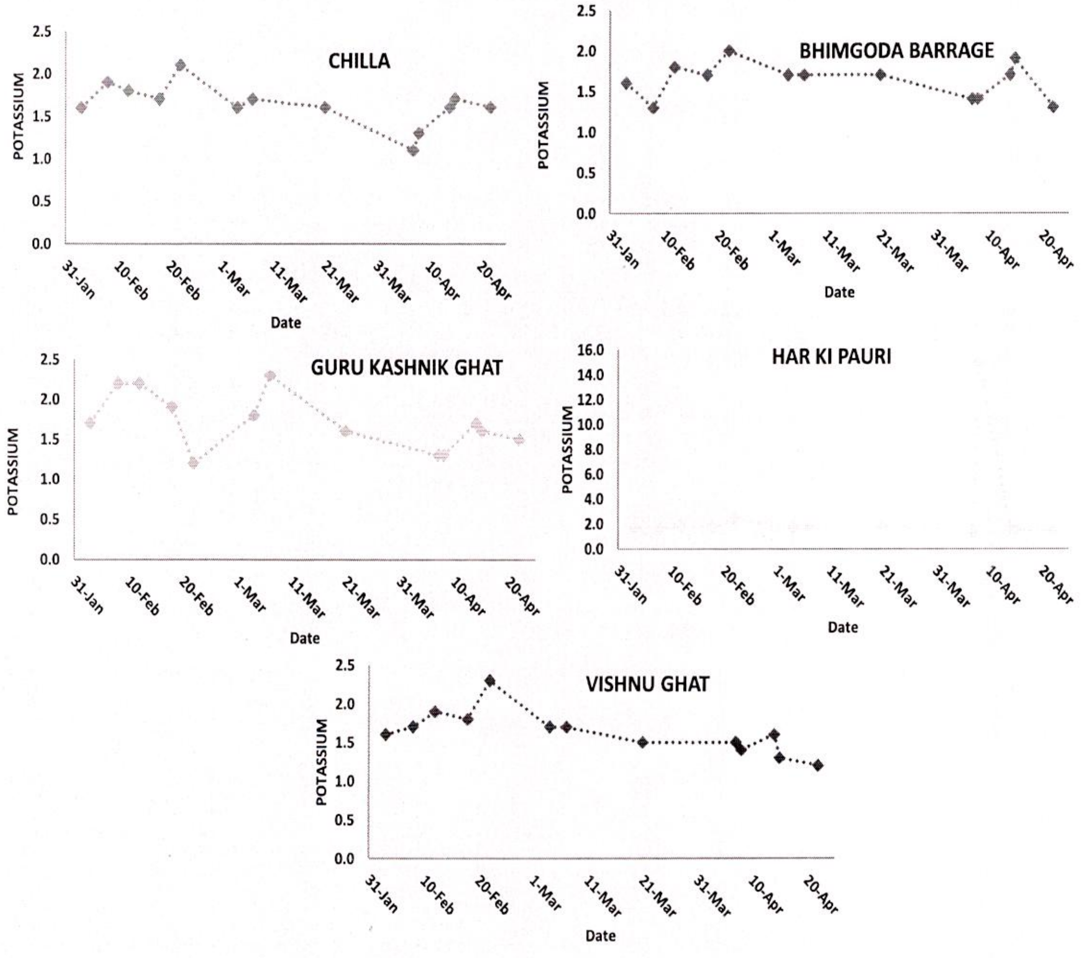


Figure 13: Variations in Potassium values at different study sites

Calcium (mg/L)

The value of calcium in groundwater samples of the study area ranges between 26.40 to 12 mg/l, (Figure 14). Calcium content of all samples was found well within the acceptable limit (75 mg/l) and the permissible limit (200 mg/l) prescribed by BIS (2012).

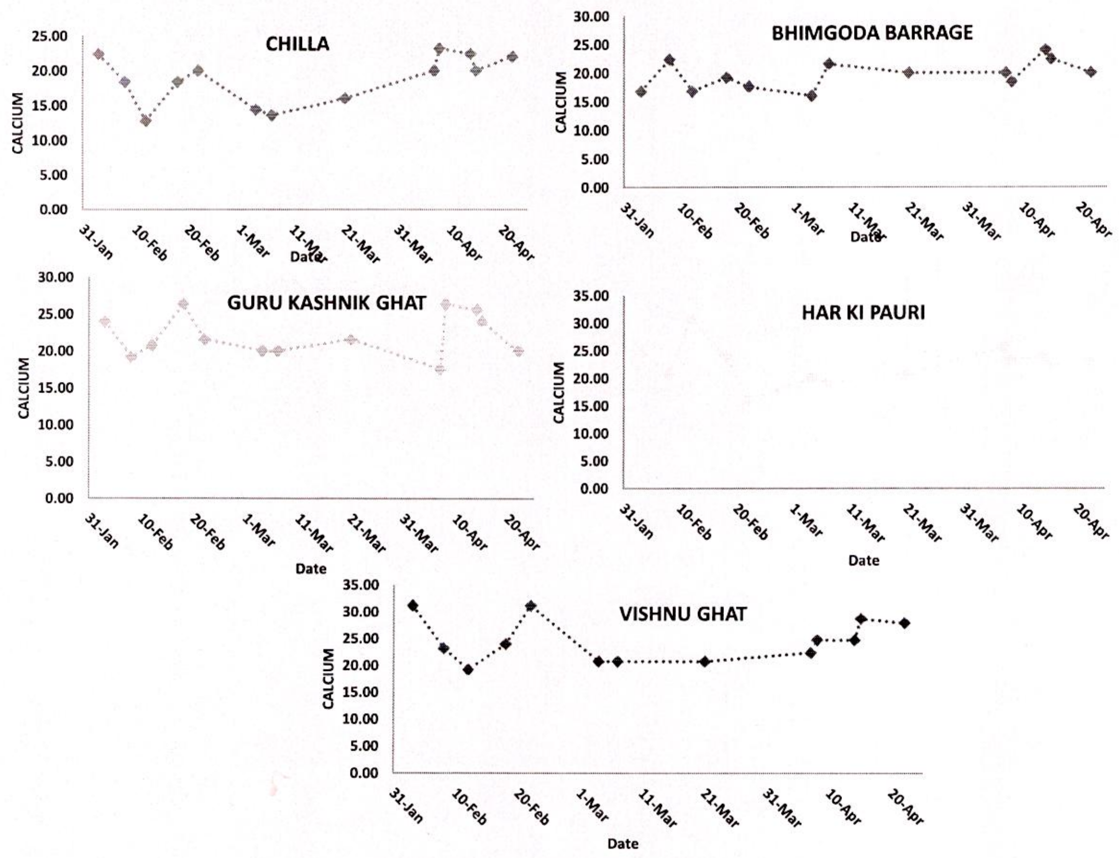


Figure 14: Variations in Calcium values at different study sites

Magnesium (mg/L)

The value of magnesium in groundwater samples of the study area ranges between 0.98 to 13.66 mg/l, (Figure 15). Magnesium content in all samples was well within the acceptable limit (30 mg/l) and the permissible limit (100 mg/l) prescribed by BIS (2012).

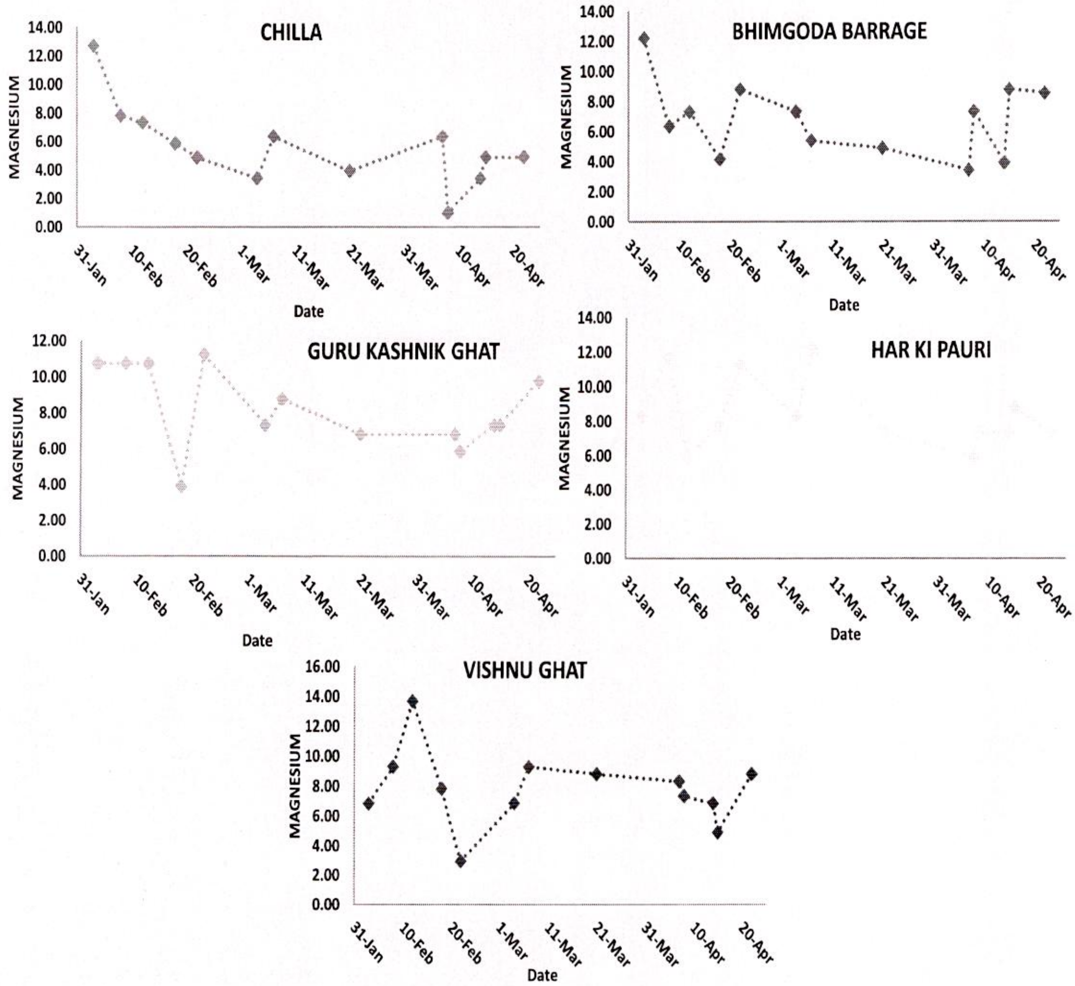


Figure 15 : Variations in Magnesium values at different study sites

Ammonia (mg/L)

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. 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.

The concentration of ammonium in river water samples of the study area ranges between ND to 0.54 mg/l during study period (Figure 16). BIS has prescribed 0.5 mg/l as the acceptable limit with no relaxation. Ammonium content in the 5% samples found exceeding the limiting value.

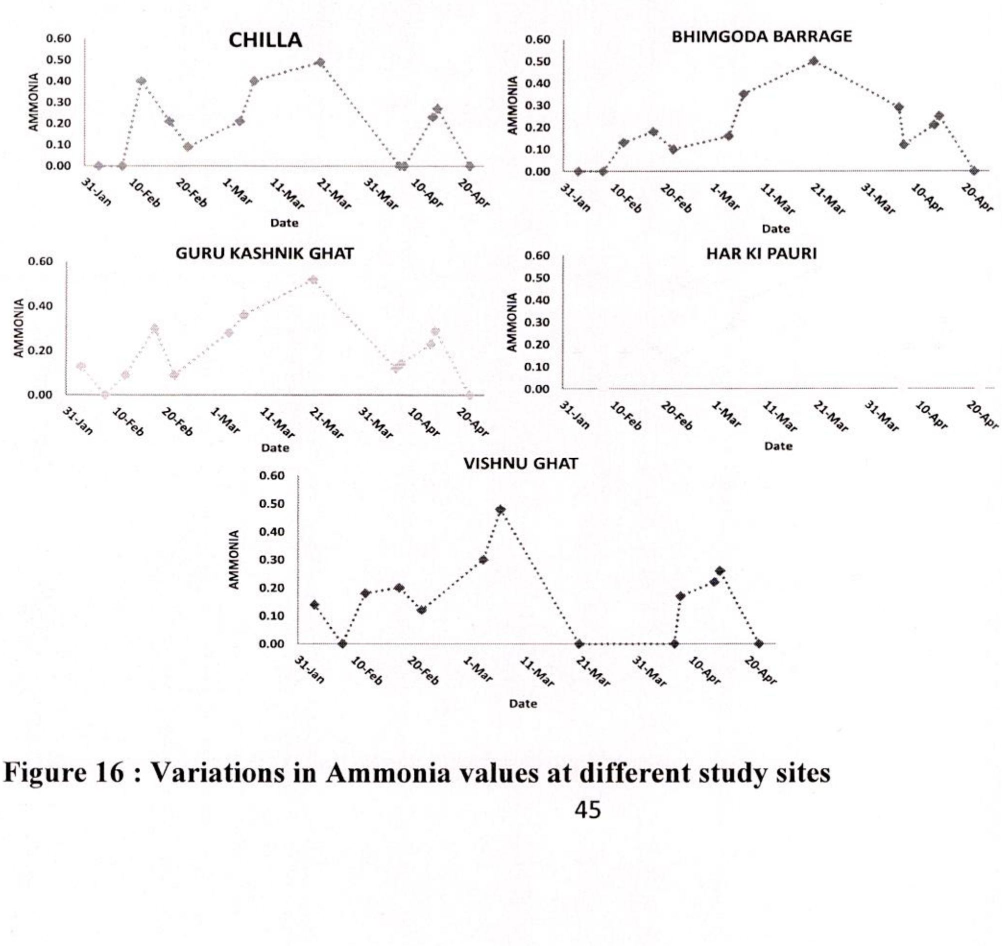


Figure 16 : Variations in Ammonia values at different study sites

Chlorides (mg/L)

Chloride ion is one of the major anions found in water and are generally combined with calcium, magnesium or sodium. Chlorides are leached from various rocks into soil and ground water by weathering. 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 0.8 to 3.11 mg/l (Figure 17). Chloride level in samples was well within the acceptable limit.Chlorides in River Ganges waters can be credited to release of neighbourhood effluents or local sewage transfer at various focuses which may bring about moderate increment in levels of chlorides.

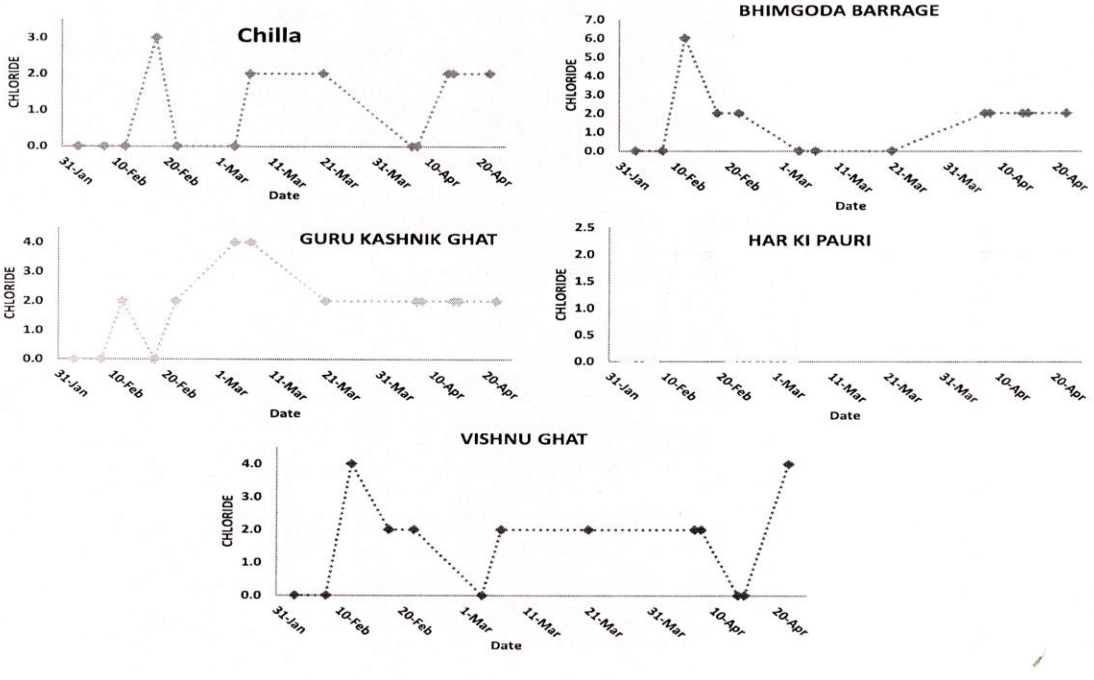


Figure 17 : Variations in Chlorides values at different study sites

Sulfate (mg/L)

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 river Ganga samples in the study area varies from 17.80 mg/l to 28.50 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).

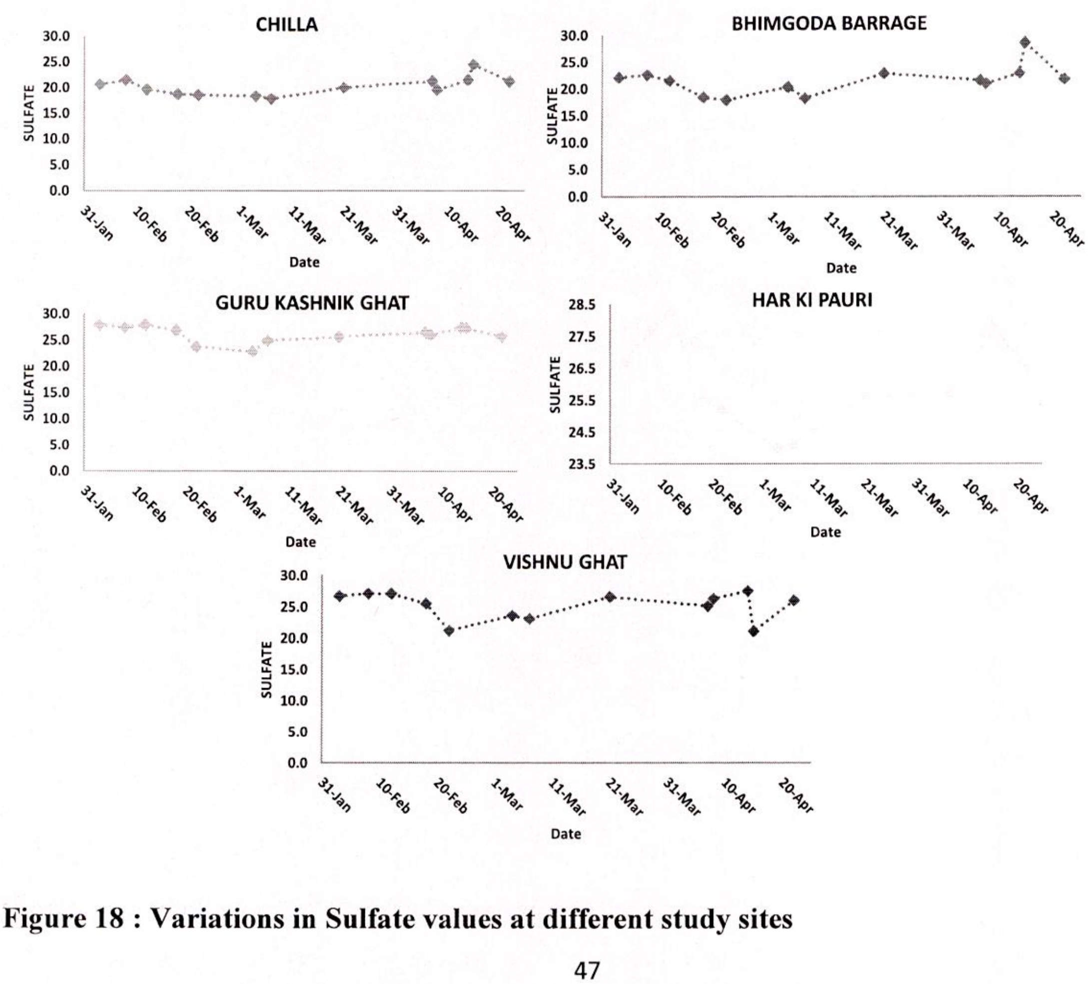


Figure 18 : Variations in Sulfate values at different study sites

Silica (mg/L)

Silica normally exists as an oxide (SiO_2 as in sand) or as a silicate . Silicon, the world's second most abundant element, is presented in most waters and is considered one of the basic nutrients in water essential to thegrowth of certain phytoplankton and zooplankton species. Silica is only slightly soluble in water. The presence of most silica in natural waters comes from the gradual degradation of silica-containing minerals. The type and composition of the silica-containing minerals in contact with the water and the pH of the water are the primary factors controlling both the solubility and the form of silica in the resulting solution. Silica may exist in suspended particles, as a colloid, or in solution. It may be monomeric or polymeric

Silica ranged from 0.9 to 4.60 mg/l.

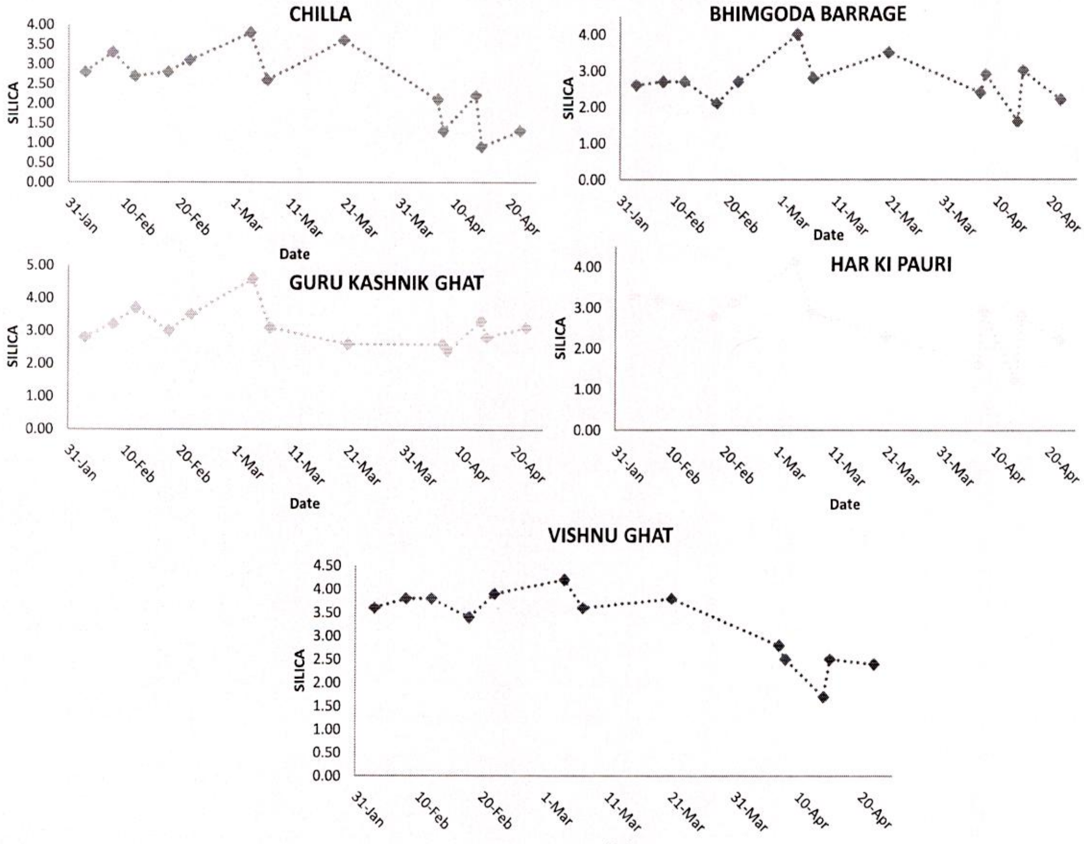


Figure 19 : Variations in Silica values at different study sites

Nitrate (mg/L)

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. 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 river Ganga water samples of the study area ranges between ND to 3.94 mg/l (Figure 19). which were well within the BIS guidelines of acceptable limit.

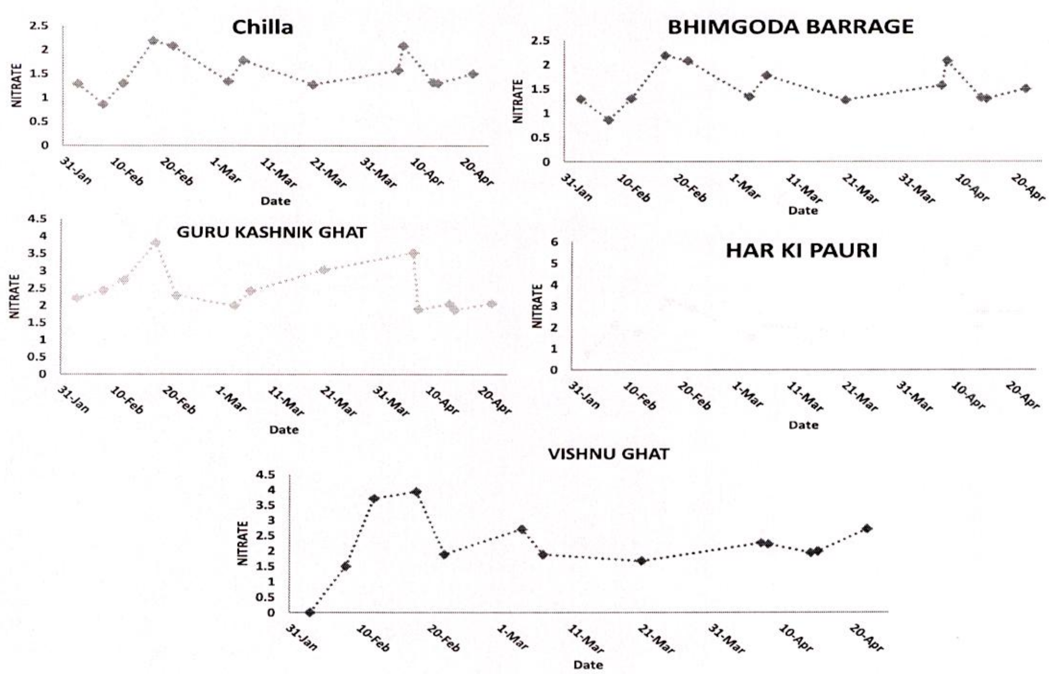


Figure 20 : Variations in Nitrate values at different study sites

Nitrite (mg/L)

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 river Ganga water samples of the study area varies from were 0 to 1.46 mg/l (Figure 21).

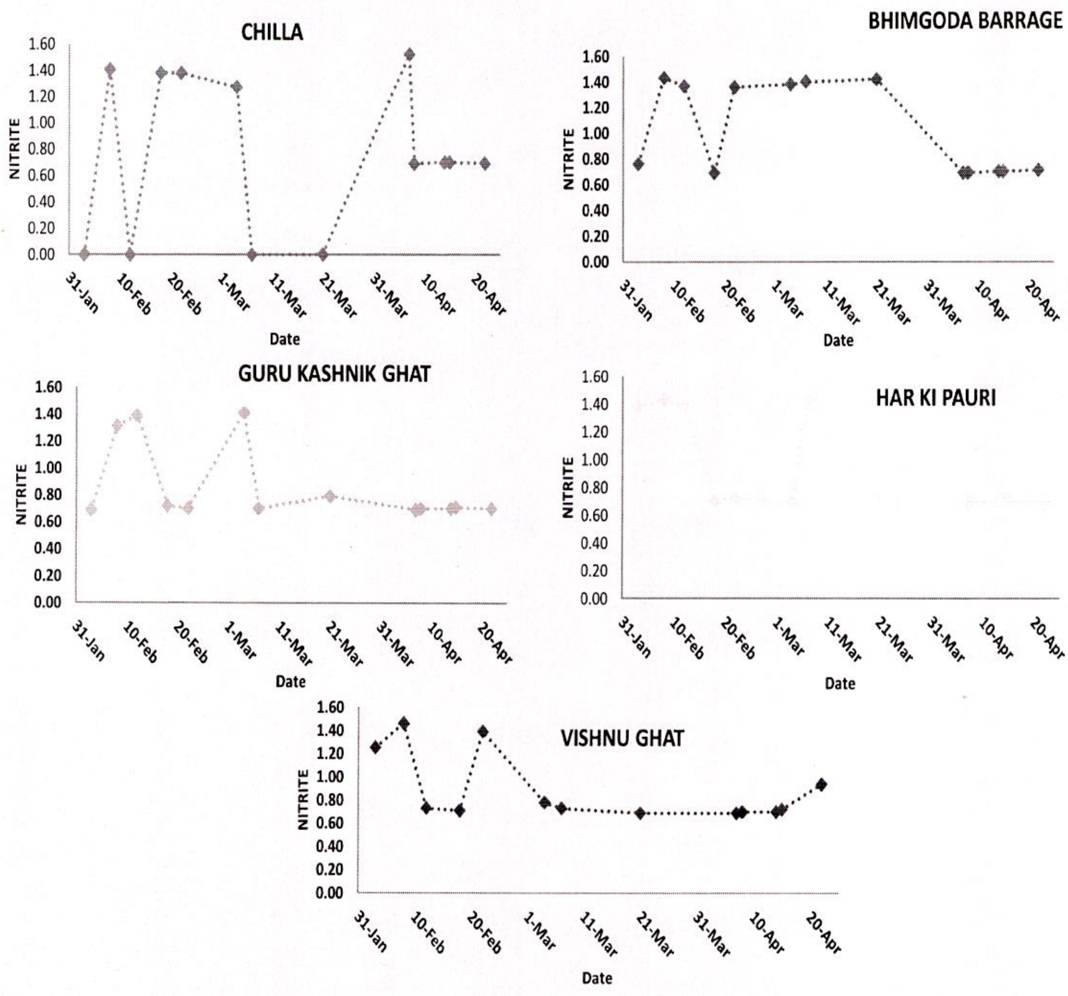


Figure 21 : Variations in Nitrite values at different study sites

Biolochemical Oxygen Demand (mg/L)

The month to month variation in the biochemical oxygen interest of stream Ganga at Haridwar city. BOD is the quantity of oxygen required by bacteria and other microorganisms during the biochemical degradationand transformation of organic matter present in wastewater under aerobic condition. It is valuable parameter for assess of water quality.Higher estimations of BOD demonstrate a higher utilization of oxygen and a higher contamination load. The BOD content in the analyzed river Ganga water samples of the study area varies from were 0 to 1.6 mg/l (Figure 22) which were well within the BIS guidelines of acceptable limit.

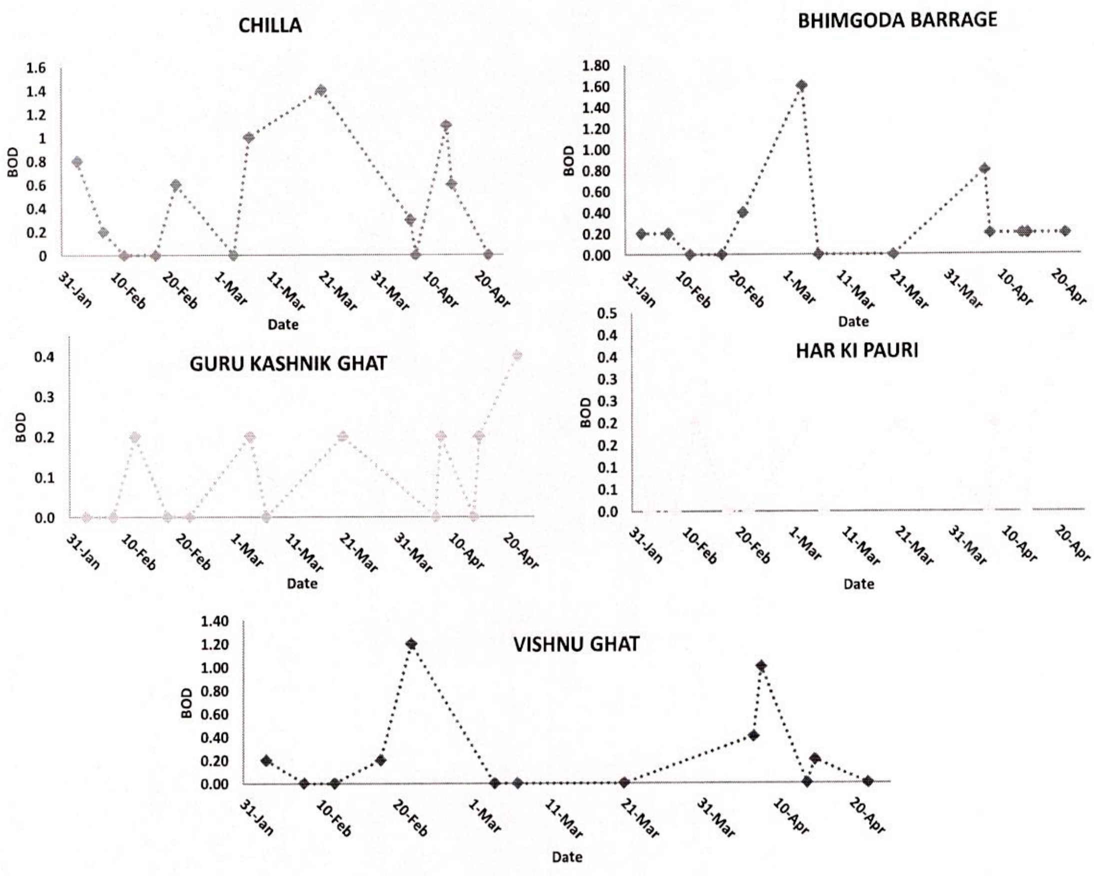


Figure 22 : Variations in BOD values at different study sites

Fluoride (mg/L)

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. 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 river Ganga water samples of the study area were in the range 0.06 to 0.1 mg/l (Figure 23) and fluoride content in all the samples were within the acceptable limit prescribed by BIS (2012).

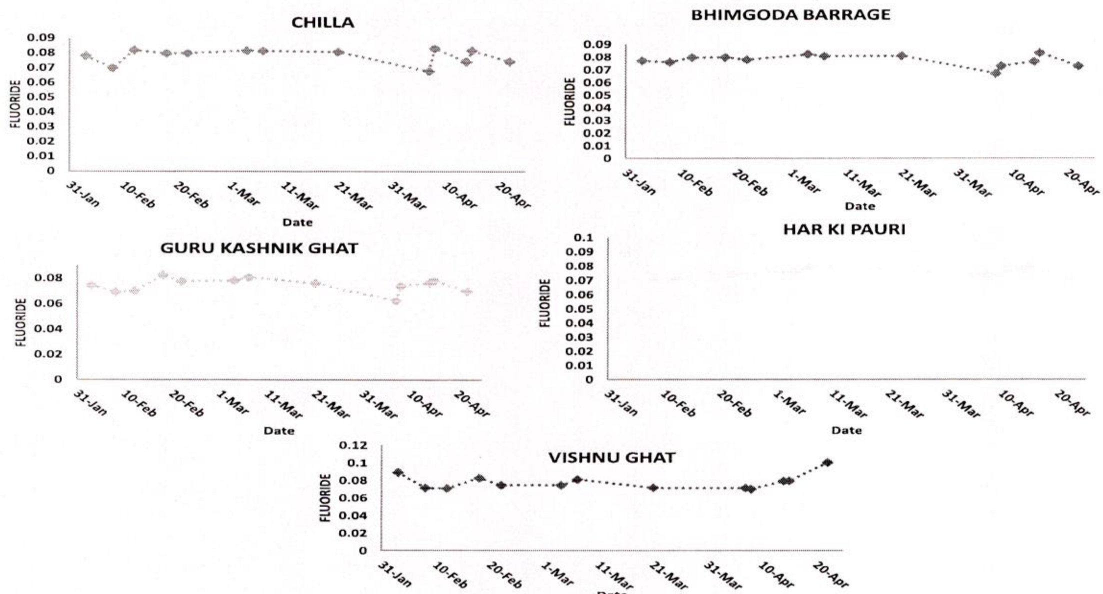


Figure 23 : Variations in Fluoride values at different study sites

TOTAL COLIFORM

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.

As represented in fig.24, Total coliform of river Ganga was found to be maximum at Site 3, Site 4, Site 5 and minimum at Site 2. Variation in TC values may be due to water flow sewage and mass bathing and anthropogenic activities.

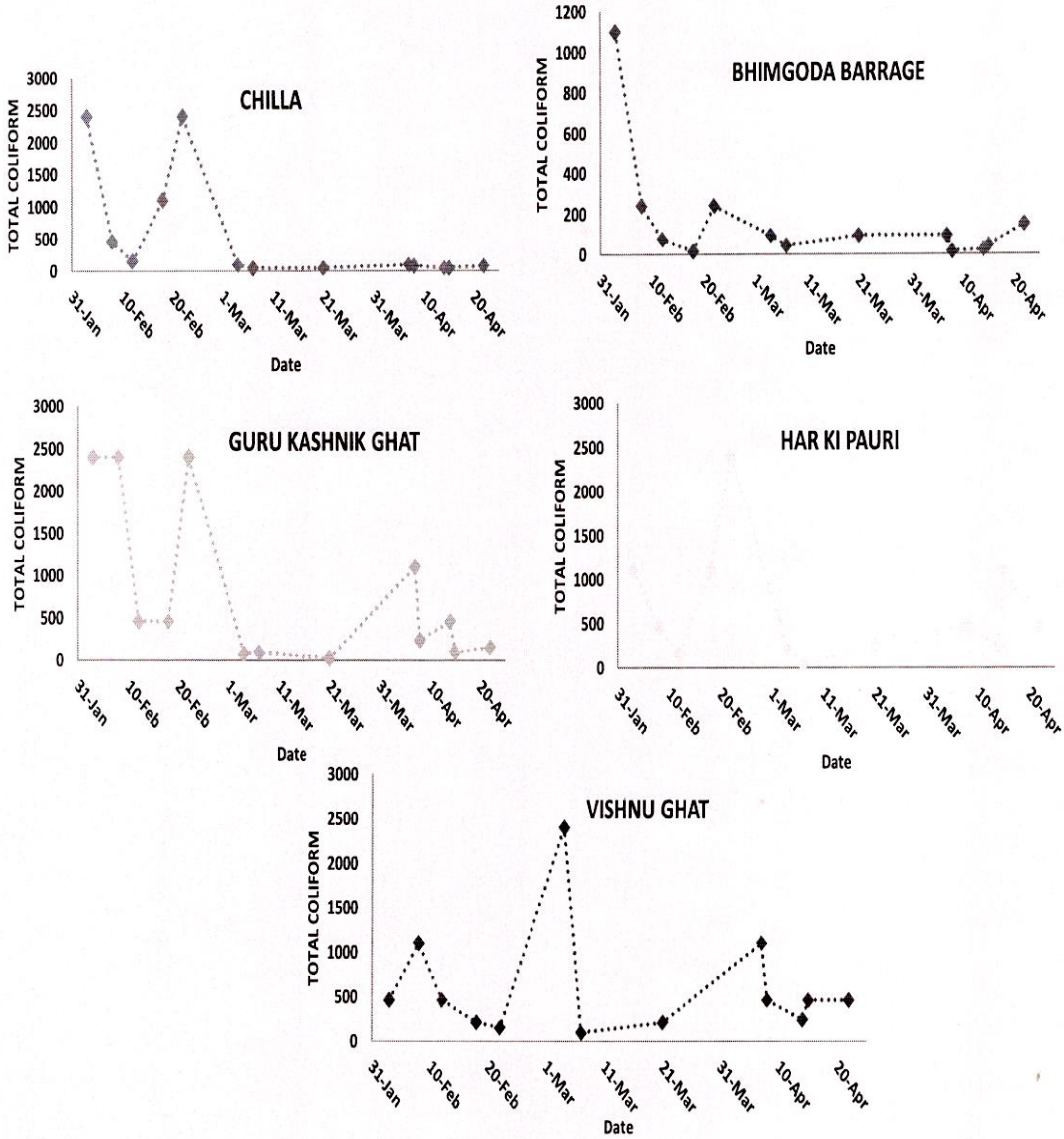


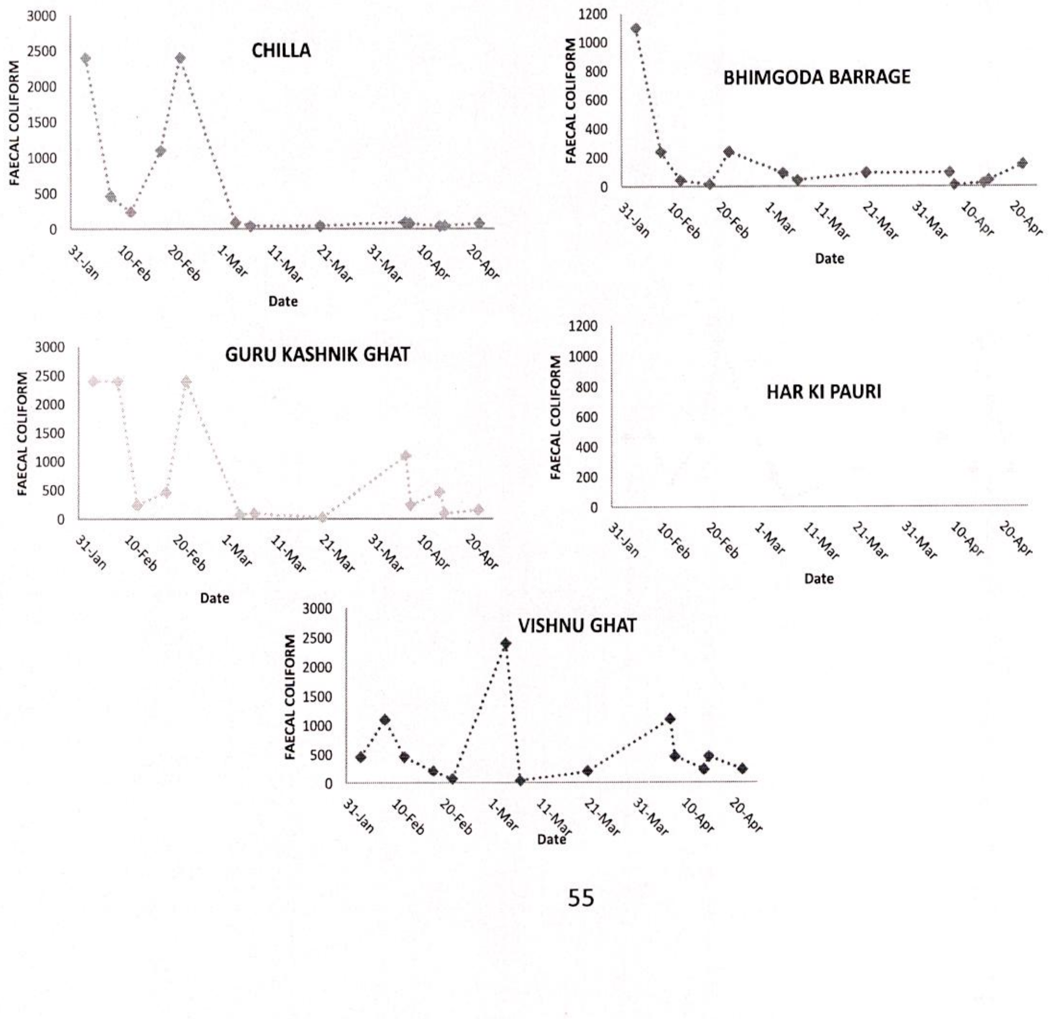
Figure 24 : Variations in TC values at different study sites

Fecal Coliform (MPN)

Fecal coliform bacteria are the most common microbiological contaminants of natural waters. Fecal coliform live in the digestive tracks of warm-blooded animals, including humans, and are excreted in the feces. Although most of these bacteria are not harmful and are part of the normal digestive system, some are pathogenic to humans. Those that are pathogenic can cause disease such as gastroenteritis, ear infections, typhoid, dysentery, hepatitis A, and cholera. A fecal coliform test is used to determine whether water has been contaminated with fecal matter. The presence of fecal coliform indicates the possible presence of organisms that can cause illness.

As represented in fig.25, fecal coliform of river Ganga was found to be maximum at Site 3, Site 4, Site 5 and minimum at Site 2. Variation in FC values may be due to water flow and sewage.

Figure 25 : Variations in FC values at different study sites



All of the graphs above show variation in all of the physicochemical parameters which may be due to change in seasons, rainfall, temperature, river flow, etc. Variations in the water discharge, water quality and elemental load can be due to changes in land use, especially reduction in forest cover in the catchments, due to irrigation projects, anthropogenic activities such as the discharge of effluents from industries, run-off from agricultural farm land and wastewater from residential areas into the river account for the observed variability in the water quality. Also, the variations in the total & faecal bacterial content is due to mass gatherings for the holy dip in river ganga, introduction of untreated sewage, offerings (such as flowers, curd, milk, ghee, etc.) of the pilgrims in the river Ganga.

5.4 Water Quality Index

A water quality index provides a convenient means of summarizing complex water quality data and facilitating its communication to a general audience. The specific variables, objectives, and time period used in the index are not specified and indeed, could vary from region to region, depending on local conditions and issues. It is recommended that at a minimum, four variables sampled at least four times be used in the calculation of index values. It is also expected that the variables and objectives chosen will provide relevant information about a particular site.

In order to assess the suitability of water for diverse uses, there is a need to devolve an index similar to the air quality model that will categorize the quality of water. This index should integrate the significant physico-chemical and biological constituents of water and present them in a simple, yet scientifically defensible manner.

The present study describes the application of the CCME Water Quality Index to monitor the changes in water quality at the following five sites in the river Ganga at Haridwar.

1. Chilla (Under the Bridge)
2. Bhimgoda Barrage
3. Guru Kashnik Ghat
4. Har ki Pauri
5. Vishnu Ghat

CCME BASED REGULATORY VALUES APPLIED ON VARIOUS WATER USES

1. Category for drinking use based on the variables: pH, ammonia, nitrate and ,turbidity, total dissolved solids (TDS), chlorides, sulphate, Alkalinity, Total Hardness, Calcium,Magnesium, Fluoride, Total Coliform, Faecal Coliform.
2. Category for bathing use based on the variables: pH, Dissolved Oxygen (DO), Biological Oxygen Demand(BOD), Faecal Coliform.

Table 5.4: Chilla (Under The bridge)

DATA SUMMARY	Drinking	Bathing
CWQI	41	85
RATING	Poor	Good
F1(SCOPE)	21.42	25
F2(FREQUENCY)	19.78	5.76
F3(AMPLITUDE)	98.72	4.6
No. of Parameters tested	14	4
No. of Parameters failed	3	1

Table 5.5: Bhimgoda Barrage

DATA SUMMARY	Drinking	Bathing
CWQI	40	71
RATING	Poor	Fair
F1(SCOPE)	35.71	50
F2(FREQUENCY)	21.42	03.84
F3(AMPLITUDE)	96.04	0.68
No. of Parameters tested	14	4
No. of Parameters failed	5	2

Table 5.6: Guru Kashnik Ghat

DATA SUMMARY	Drinking	Bathing
CWQI	40	56
RATING	Poor	Marginal
F1(SCOPE)	28.57	7.5
F2(FREQUENCY)	19.78	11.53
F3(AMPLITUDE)	3.84	6.50
No. of Parameters tested	14	4
No. of Parameters failed	4	3

Table 5.7: Har ki Pauri

DATA SUMMARY	Drinking	Bathing
CWQI	38	85
RATING	Poor	Good
F1(SCOPE)	35.71	25
F2(FREQUENCY)	19.78	3.84
F3(AMPLITUDE)	98.72	1.30
No. of Parameters tested	14	4
No. of Parameters failed	5	1

Table 5.8: Vishnu Ghat

DATA SUMMARY	Drinking	Bathing
CWQI	40	85
RATING	Poor	Good
F1(SCOPE)	21.42	25
F2(FREQUENCY)	20.87	3.8
F3(AMPLITUDE)	98.76	1.3
No. of Parameters tested	14	4
No. of Parameters failed	3	1

It was observed that the overall quality in terms of drinking water for River Ganga at all the study sites falls under poor category throughout the research period. The parameters responsible for the ***Poor*** water quality were turbidity and coliforms. Presence of coliforms may be attributed to discharge of untreated sewage and mass bathing. The water quality at all sites is ranked ***Good*** for Bathing purposes.

CONCLUSION

The water is getting dirtied step by step by the expanding convergences of various poisons. The River Ganga is a sacrosanct waterway however getting to be dirtied at this old journey, perhaps because of rising anthropogenic impact. There are a few components which are in charge of debased state of waterway water quality. Release of sizable measure of untreated residential waste and keep running off from agribusiness ranches give comprehensive wellspring of contaminations expansion to Ganges basin. There are some different reasons unchecked like transfer of dead bodies and creature cadavers in the waterway, the washing of fabrics and showering of creatures on the stream banks, other than crap and different exercises.

Based on this study, following conclusions can be drawn for river water of Ganga At Haridwar

- The pH value of river Ganga samples in the study area were in the range 6.06 to 8.47. Most of the time, the samples were conforming the limits prescribed by BIS (2012) for drinking water except few occasions.

- Conductivity of collected samples varies between 131 μS/cm to 221 μS/cm and TDS in the river Ganga of study area varies from 84 mg/l to 141 mg/L. It can be concluded that all the analyzed river water 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).

- Turbidity in the analyzed river ganga samples of study area varies from 0.3 NTU to 11.8 NTU.Turbidity of only 15% samples was well within the acceptable limit prescribed by BIS (2012) and turbidity of 50% 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.

- Total Hardness was found to be within 50-108 mg/l as $CaCO_3$.Total hardness in 100% 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 magnesium in groundwater samples of the study area ranges between 0.98 to 13.66 mg/l, .Magnesium content in all samples was well within the acceptable limit (30 mg/l) and the permissible limit (100 mg/l) prescribed by BIS (2012).

- The concentration of sodium in river water samples of the study area ranges between 2.2 to 5.1 mg/l during study period. The potassium content in the groundwater samples of the study area ranges between 1.1 to 15 mg/l.

- The concentration of ammonium in river water samples of the study area ranges between ND to 0.54 mg/l during study period . BIS has prescribed 0.5 mg/l as the acceptable limit with no relaxation. Ammonium content in the 5% samples found exceeding the limiting value.

- The alkalinity values were found to be significant at the Ganges and at different study sites. Total Alkalinity ranged from 42mg/l to 98.4mg/l as $CaCO_3$ which was well within the permissible limits of BIS standards (200-600mg/l).

- Chloride content in the collected samples were in the range of 0.8 to 3.11 mg/l and was well within the acceptable limit.

- 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.

- 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 river

Ganga water samples of the study area ranges between 0 to 3.94 mg/l (Figure 19). which were well within the BIS guidelines of acceptable limit.

- The fluoride concentration in the river Ganga water samples of the study area were in the range 0.06 to 0.1 mg/l and fluoride content in all the samples were within the acceptable limit prescribed by BIS (2012).
- Application of CCME WQI to the water flowing in River Ganga at Haridwar indicates poor in terms of drinking water application. The rating was poor due to non conformity of water to BIS standards in terms of turbidity and coliforms. These contaminats should be removed from the water before supplying it for human consumption. The water was found good for bathing.
- It was observed that the Coliform population in the river water increases during mass bathing and hence, the flow of the river during this type of gatherings or people taking bath should be optimized.
- There's a great need of intercepting the sewage originating from the habitation of Haridwar and nearby area and routing it to treatment plant before discharging in river.

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