POLLUTION ASSESSMENT OF RIVER GANGA SEGMENT IN UTTARAKHAND

Thesis

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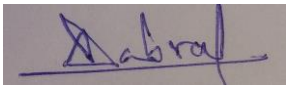
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CERTIFICATE

This is to certify that the thesis entitled **"Pollution Assessment of river Ganga Segment in Uttarakhand"** submitted in partial fulfillment of the requirements for the degree of **Masters of Technology** in **Agricultural Engineering** with major in **Soil And Water Conservation Engineering** of the College of Post Graduate Studies, G.B. Pant University of Agriculture & Technology, Pantnagar, is a record of bona-fide research carried out by **Mr. Ashish Dabral,** Id. No. **49668,** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.



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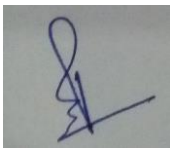
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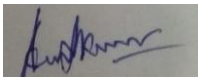
We**,** the undersigned, members of the Advisory Committee of **Mr. Ashish Dabral,** Id. No. **49668**, a candidate for the degree of **Master of Technology** in **Agricultural Engineering** with major in **Soil and Water Conservation Engineering,** agree that the thesis entitled **"Pollution Assessment of river Ganga Segment in Uttarakhand"** may be submitted in the partial fulfillment of the requirements for the degree.



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LIST OF ABBREVIATIONS

A	Volume of titrant used
$AgNO_3$	Silver nitrate
APHA	American Public Health Association
AWWA	American Water Work Association
BIS	Bureau of Indian Standards
c	Intercept
C	Volume of sample used
Ca	Calcium
$CaCl_2$	Calcium chloride
$CaCO_3$	Calcium carbonate
CaH	Calcium hardness
Cl	Chloride
CO_2 or CO2	Carbon dioxide
e	Exponential
E	East
EC	Electrical conductivity
EDTA	Ethylene diamine tetra acetic acid
etc.	Et cetera
f ( )	Function of
FCO_2 or FCO2	Free carbon dioxide
Feb	February
Fig	Figure
g	Gram
HCL	Hydrochloric acid
i.e.	Id est
IS	Indian Standards
ISI	Indian Standards Institution
Jun	June
KCl	Potassium chloride
km	Kilometer
m	Coefficient of independent parameter
Max	Maximum
Mg	Magnesium
MgH	Magnesium hardness
ml	Milliliter
MS	Microsoft
n	Number of data points
N	North

NaCl	Sodium chloride
NaOH	Sodium hydroxide
P	Level of significance
pH	Potential of Hydrogen
ppm	Parts per million
R or r	Coefficient of correlation
R^2	Coefficient of determination
S. No.	Serial number
TAc	Total acidity
TAl	Total alkalinity
TDS	Total dissolved solids
TH	Total hardness
WHO	World Health Organization
WPCF	Water Pollution Control Federation
x	Independent parameter
X	Parameter for calculating coefficient of correlation
y	Dependent parameter
Y	Parameter for calculating coefficient of correlation
&	And
µS/cm	Micro-Siemens per centimeter
<	Less than
>	Greater than
%	Per cent
’	Minute
^{0}	Degree
/	Divide
×	Multiply

1. INTRODUCTION

It is a lucid fact that water is essential for all forms of life. Water, due to its rapidly depleting sources and increasing demands has become a crisis commodity in today's world. India is comparatively richer in terms of natural water resources like river systems, glaciers, freshwater lakes, etc. But keeping in view the haphazard urbanization, industrialization, commercialization and lack of policy level measures towards the distribution and sustainable management of water in the country, it seems really inevitable that these existing water sources will fail to suffice our requirements in coming time leading to a critical situation. Water is a prime natural resource and it is a basic human need this cum natural asset.

The Ganga basin accounts for a little more than one-fourth (26.3%) of the country's total geographical area and is the largest river basin in India, covering the entire states like Uttarakhand, Uttar Pradesh, Bihar, Delhi, and parts of Punjab, Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh and West Bengal. The Ganga basin is bound in the north by the Himalayas and in the South by the Vindhyas. The main river stream originates in the Garhwal Himalaya ($30^0$55'N, $79^0$7'E) under the name of the Bhagirathi. The ice-cave of Gaumukh at the snout of the Gangotri glacier, 4100 meters above sea level, is recognized as the traditional source of river Ganga. The river cuts its path through the Himalayas and flows a distance of about 205 km from Gaumukh and transverses through two districts of Uttarakhand state i.e. Uttarkashi and Tehri to reach Devprayag where another head stream, the Alaknanda, joins it to form Holy Ganga.

The river Alaknanda is a major tributary of the river Ganga at Uttarakhand that begins at the confluence of the Satopanth and Bhagirath Kharak glaciers in Uttarakhand. The river Alaknanda meets Dhauli Ganga at Vishnuprayag, Nadakini at Nandaprayag, Pindar Ganga at Karnaprayag, Mandakini at Rudraprayag, traveling approximately a total length of 190 km before meeting Bhagirathi at Devprayag. These five confluences are called the Panch Prayag.

After flowing through the northern-most part of Uttarakhand, the river flows through Uttar Pradesh, Bihar, Jharkhand and West Bengal, and finally drains into the Bay of Bengal. The river traverses a length of 1450 km in Uttarakhand and Uttar Pradesh while touching the boundary between UP and Bihar for a stretch of 110 km. It then flows through Bihar, more or

less covering a distance of 405 km. The length of the river measured along the Bhagirathi and Hugli rivers during its course in West Bengal is about 520 km. The River Ganga has a large number of tributaries, namely, Kali, Ramganga, Yamuna, Gomti, Ghaghara, Gandak and Kosi. The River Yamuna, although a tributary of Ganga, is a river basin in itself. Its major tributaries are: Chambal, Sind, Betwa, and Ken. The main plateau tributaries of the Ganga river are Tons, Son, Damodar, and Kangsabati-Haldi.

Total Length is 2,525 kms, length in Uttarakhand is 450 kms, length in Uttar Pradesh is 1,000 kms, sharing length between Uttar Pradesh & Bihar is 110 kms, length in Bihar is 405 kms, length in Jharkhand is 40 kms and length in West Bengal 520 kms. Catchment area of Ganga basin is 861,404 square km (26.4%) of India, average annual discharge is 493,400 million cubic meter. Main tributaries are Yamuna, Ramganga, Gomti, Ghaghara, Gandak, Damodar, Kosi & Kali-East. Main sub tributaries are Chambal, Sindh, Betwa, Ken, Tons (beyond Five States), Sone & Kasia-Haldi. Major Cities located on the bank Srinagar, Rishikesh, Haridwar, Roorkee (in Uttarakhand), Bijnor, Narora, Kanauj, Kanpur, Allahabad, Varanasi, Mirzapur (In Uttar Pradesh), Patna, Bhagalpur (In Bihar) and Bahrampur, Serampore, Hawarah and Kolkata (in West Bengal).

Groundwater is believed to be comparatively cleaner and freer from pollution than surface water. Drinking water may come from surface water or Groundwater. Surface Water is found in lakes, rivers and reservoirs. Surface water is more vulnerable to contamination and requires extensive testing and treatment to assure that it is safe to drink. Groundwater and surface water are both part of the “hydrologic cycle”. Water rises from the earth’s surface as evaporation and falls to the earth as precipitation, in the form of snow or rain. Surface water becomes groundwater, when it infiltrates downward to the saturated zone.

About ten percent of the rural and urban populations do not have access to regular safe drinking water and much more are vulnerable. Most of them depend on unsafe water sources to fulfill their daily desires. Moreover, water shortages in cities and villages result in massive volumes of water being collected and transported over great distances by tankers and pipelines.

Water pollution is one of the undesirable effects of industrialization and urbanization. Water, the most vital resource on the Earth, has the distinctive property of dissolving and carrying in

the suspension an enormous style of chemicals and therefore water can simply become contaminated. Available water resources are very restricted. As the population of the earth increases tremendously, the water demand also increases simultaneously for domestic, agricultural and industrial use. Therefore groundwater level is going to deplete in coming days.

Water quality parameters are very important to use water for various purposes i.e. industrial, domestic etc. Water quality parameters can be divided into three categories: physical, chemical and biological water quality parameters. In the present study, only physical and chemical water quality parameters were studied by collecting water samples of flowing wells.

Water can be polluted chemically in following three ways:

1. Atmospheric input, which includes the pollution from climatic change, precipitation, etc.
2. Interaction of water with soil and rock, which occurs when there is a weathering or erosion of the material and that eroded material mixed with water.
3. Anthropogenic activity, which is due to the industrial and agriculture pollution increase consumption which makes water unsuitable for drinking, industrial and agriculture purpose **(Simeonov *et al.*, 2003)**.

Global needs of water are around five billion cubic meter just for drinking purpose, agriculture is additionally one of the major consumers of water resources. The quality of ground and surface water is affected by several factors, like discharge of agriculture, domestic and industrial wastes. Improper management of water systems could cause serious problems and inconvenience. The quick and continuous development of commercial enterprises and also unregulated release of mechanical waste and metropolitan waste item have quickened the debasement of water quality in streams, lakes, tanks and estuaries. Water becomes unsuitable for human consumption or for irrigation of agricultural land as a result of such deterioration of water quality.

Keeping the above factors in view, the specific objectives of the study are:

1. To analyze physico-chemical water quality of river Ganga segment in Uttarakhand.
2. To assess the suitability of water quality for drinking, agricultural and other purposes.
3. Statistical analysis and modeling of water quality parameter.

2. REVIEW OF LITERATURE

The present study involves the study of river water quality analysis. The brief review of earlier works relevant to the study on topics such as water quality assessment, Statistical analysis of water quality parameters and have been presented in this chapter.

2.1 Studies on Flowing Artesian Well

The water in artesian aquifer presents in between layers of permeable rock, like clay or sedimentary rock. If such a confined aquifer is tapped by a well, water will rise above the top of the aquifer and may even flow from the well onto the land surface. The word artesian comes from the town of Artois in France, the old Roman city of Artesium.

Liu *et al*. (2003) carried out factor analysis on the groundwater samples collected from 28 different wells in the coastal Blackfoot disease area of Yun-Lin, Taiwan. The correlation was examined among 13 hydro-chemical parameters. The two-factor model was suggested which explain the variation of 77.8% in quality of Groundwater. The factor 1 (sea water salinization) includes concentration of different parameter like electric conductivity, total dissolved solid, chloride, sodium, potassium, magnesium, sulfate etc. Maps are drawn to show the geographical distribution of the factors. These maps delineate high salinity and arsenic concentrations. It was found that land subsidence and gradual salinization of local area of sea water was due to over pumping of local Groundwater. Over pumping increases the dissolved oxygen, which oxidizes the mineral and releases arsenic by this solution of arsenic-rich iron Oxy-hydroxide and increases the concentration of arsenic in water.

Ogbu and Echebiri (2010) studied water sample from 20 artesian wells collected from 5 zones in Enugu, Southeast Nigeria area. The water was collected by multistage sampling procedure and analyzed by the di-sulfonic acid method for the presence nitrate and nitrite. The sum of nitrate and nitrite values when $P > 0.05$ shows uniform nitrate content of that zone when there is no significance different between mean values. It was observed from this study that the mean value of nitrate was below the guideline set by the World Health Organization (WHO) but the nitrite value was much higher than what is considered for human safety.

2.2 Studies on Groundwater Quality

Groundwater is the main source of potable water supply in Indian rural and urban habitats, like several areas of the world. The major drawback related to groundwater is that once contaminated, then it is very difficult to restore Groundwater quality. Hence, it is needed to protect and manage the groundwater quality. Groundwater is considered as pure compared to surface water. It is purified due to the geological formation within the soil column through anaerobic decomposition, filtration and natural process.

Kaushik (1963) carried out a survey to analyze the water quality parameters by taking water from 100 wells located in Delhi. It was observed that total alkalinity was varied between 130 to 740 ppm and also the concentration of nitrate, Sulfate and chloride were found between 23 to 457 ppm, 3.5 to 760 ppm and 12 to 1280 ppm.

Singh and Sekhon (1976) analyzed 57 water samples located near a village in Ludhiana and Hoshiarpur district of Punjab in June and September month. The water sample was analyzed for nitrate concentration and was found that 90% of the water samples have nitrate concentration less than 45 ppm. The concentration of nitrate in the good water near village varied with the depth and it was assumed that excessive use of nitrogen fertilizer was responsible for increased nitrate content. Rather than water sample soil samples were also analyzed for nitrate content. It was found that during a rainy season, nitrate concentration in water was more than non-rainy season.

Kumar (1983) performed a survey of several wells located in some parts of Uttar Pradesh for nitrate concentration. From the study, it was analyzed that the wells located in Badshapur, Mirzapur, Bangarmau, Birrdha have nitrate value more than 200 ppm. The higher value of nitrate was due to excessive use of nitrogen fertilizer.

Srivastava *et al.* (1988) conducted a study by taking the sample of Sone River and checked collected samples. Sone River was highly polluted by effluents from the Orient Paper Mills, Amelia, Madhya Pradesh, and India. Further, downstream improvement water quality was observed due to self-recovery and dilution. Between the Orient Paper Mills site and at the effluent mixing points greatest variability between the water sample was observed and

maximum similarity was found between 2 and 2.1 km; 2.3 and 2.5 km; and 2.7 and 3 km downstream.

Mondal *et al.* (2005) conducted their studies on untreated industrial effluent which when discharged to the surface, will cause groundwater pollution to very large extent in the rural part of the country. The polluted groundwater poses problems to supply the water for drinking purpose. Tamil Nadu has more than 50 percent of tanneries. In the Din Digul town near Kodaganar river basin Tamil Nadu, about 80 tanneries are operating. These tanneries release untreated influenced that affect the quality of groundwater in this area. The Groundwater quality was deteriorated excessively due to overuse of chemical like NaCl in the leather industry.

Aghazadeh and Mogaddam (2010) performed their studies in Oshnavieh plain part of west Azerbaijan. They took 31 groundwater samples and analyzed various physical and chemical parameters such as electrical conductivity, pH, total dissolved solids, sodium, potassium, Ca, Mg, Cl, bicarbonate, carbonate, phosphate, iron, fluorine, sulfate, nitrate, and ammonia. It was found from the result that water of the area was generally fresh but very hard. Major constituents of water were Ca-bicarbonate and Ca-Mg-bicarbonate in Ca-Mg-carbonate were the dominant hydro-chemical parameters. Result Calculations were carried out by using computer software and it was found that all water samples have carbonate minerals, but less sulfate minerals and water was suitable for drinking and agriculture purpose.

Choudhary *et al.* (2011) conducted their studies by taking samples from Kerwa dam, Kolar dam and Kaliasote dam of Bhopal. They analyzed samples for physico-chemical parameters pH, EC, total hardness, calcium hardness, magnesium hardness, sulfate, fluoride and chemical oxygen demand and they found that all water quality parameters except hardness and chemical oxygen demand of all the samples were within the permissible limit as described in water quality guidelines of WHO. The range of chemical oxygen demand was found 18 ppm to 30 ppm while a range of total hardness was found from 118 ppm to 170 ppm which were much higher than the described maximum permissible value by WHO.

Khalid *et al.* (2011) collected 15 water samples in different areas of Abbottabad carried out quantitative and qualitative analysis to determine the concentration of pollutants present in water. They analyzed physicochemical parameter pH, hardness, alkalinity, iron, calcium,

nitrates etc. and the results indicated the water is polluted and which cause water borne diseases to the people of a particular area.

Rao *et al.* (2011) collected sample from different locations near Tirupati Andhra Pradesh, they analyzed physicochemical parameters like pH, hardness, alkalinity, iron, calcium, nitrates, total solids, TDS, total suspended solids, dissolved oxygen, chemical oxygen demand and biochemical oxygen demand. They compared values with the standards of WHO on comparison and found that drinking water of some area was polluted and not suitable for drinking purposes.

2.3 Statistical Analysis of Water Quality

Gajendran and Thamarai (2008) did the statistical investigation on groundwater quality parameter in Nambiyar river basin with the help of correlation coefficient. This correlation coefficient is the excellent tool to predict the water quality parameters accurately. Statistical analysis is done by taking mean, mode, median, min, max and standard deviation of pollution parameter. The data was taken for statistical analysis for the years 1998, 1999, 2002, 2003. Average of water quality parameters were obtained with the confidence limit of 95%.

Bajpayee *et al.* (2012) carried out their study by taking 58 samples during pre and post monsoon season from Bankura District, west Bengal, India. They used Pearson correlation matrix and multiple linear regression analysis in their study. The collected water sample was analyzed for pH, TH), TDS, EC, nitrate, sodium, calcium, chlorine, etc. It was seen from this study, the total dissolved solids and electric conductivity are physiochemical water quality parameters. During the pre-monsoon season, there is a strong positive relationship between Ca-TH, chlorine-Mg, Mg-TH and chlorine-Ca and for post monsoon season relationship was found between chlorine-Ca.

Khawaja and Aggarwal (2014) collected 40 water samples from well in Aligarh city 20 water quality parameters. They used statistical analysis to determine physicochemical parameter statistical analysis with Pearson correlation. From the analysis, it was observed that there was strong correlation exists between total hardness and Mg ion (0.99), TDS and total hardness (0.88), TDS and chloride (0.87). In samples, alkalinity and Mg concentration were higher than a maximum permissible limit. They used limit described by BIS and from the result, it was found the water is not suitable for domestic uses.

3. MATERIALS AND METHODS

This chapter deals with the materials and methods used for the analysis of the physico-chemical properties of the samples. The methodology adopted for sampling, quality analysis are presented in the following sub headings:

3.1 Study Area

The study was carried out on river Ganga (Fig 3.1). A segment of river Ganga was selected for the study which has been presented in Fig 3.2 and Fig 3.3. The river originates from Gangotri bearing the name of the river as Bhagirathi and after reaching Devprayag, the name of the river becomes Ganga (Fig 3.4). The water samples were collected at twelve locations from Devprayag (30.14^0N, 78.59^0E) to Balawali (29.64^0N, 78.10^0E). The location of the study area is presented in Fig 3.1. Table 3.1 shows the latitude and longitude of the locations from where the samples were collected.

3.2 Water Sampling and Testing

Clean plastic bottles of one liter capacity were used to collect samples by grab sampling method from selected locations at either of banks. Grab or catch samples are single collected at a specific spot at a site over a short period of time (typically seconds or minutes). Thus, they represent a "snapshot" in both space and time of a sampling area. Three replications of the water samples from each location were taken. The samples were wrapped in insulated Water quality testing laboratory of the Department of Irrigation and Drainage Engineerings at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar and were analyzed for various physicochemical parameters, namely Potential of Hydrogen (pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS), hardness, calcium, acidity, alkalinity, chloride, carbon dioxide (CO_2) using standard methods (APHA, 1980).

Table 3.1 Latitude and longitude of the locations of the study area

S. No.	Location	Distance from Devprayag (km)	Latitude, longitude
1	Bhagirathi	-	30.14^0N, 78.59^0E
2	Alaknanda	-	30.14^0N, 78.59^0E
3	Ghuret	0	30.13^0N, 78.59^0E
4	Kauriyala	28.70	30.07^0N, 78.50^0E
5	Atali	40.30	30.08^0N, 78.43^0E
6	Shivpuri	53	30.13^0N, 78.39^0E
7	Patna	59.60	30.12^0N, 78.35^0E
8	Triveni ghat	68.40	30.10^0N, 78.29^0E
9	Veerbhadra	73.10	30.06^0N, 78.28^0E
10	Harki Pauri	92.50	29.95^0N 78.17^0E
11	Rampur Raighati Ahat	126	29.71^0N, 78.18^0E
12	Balawali	135	29.64^0N, 78.10^0E



Fig 3.1 The river course of the Ganga

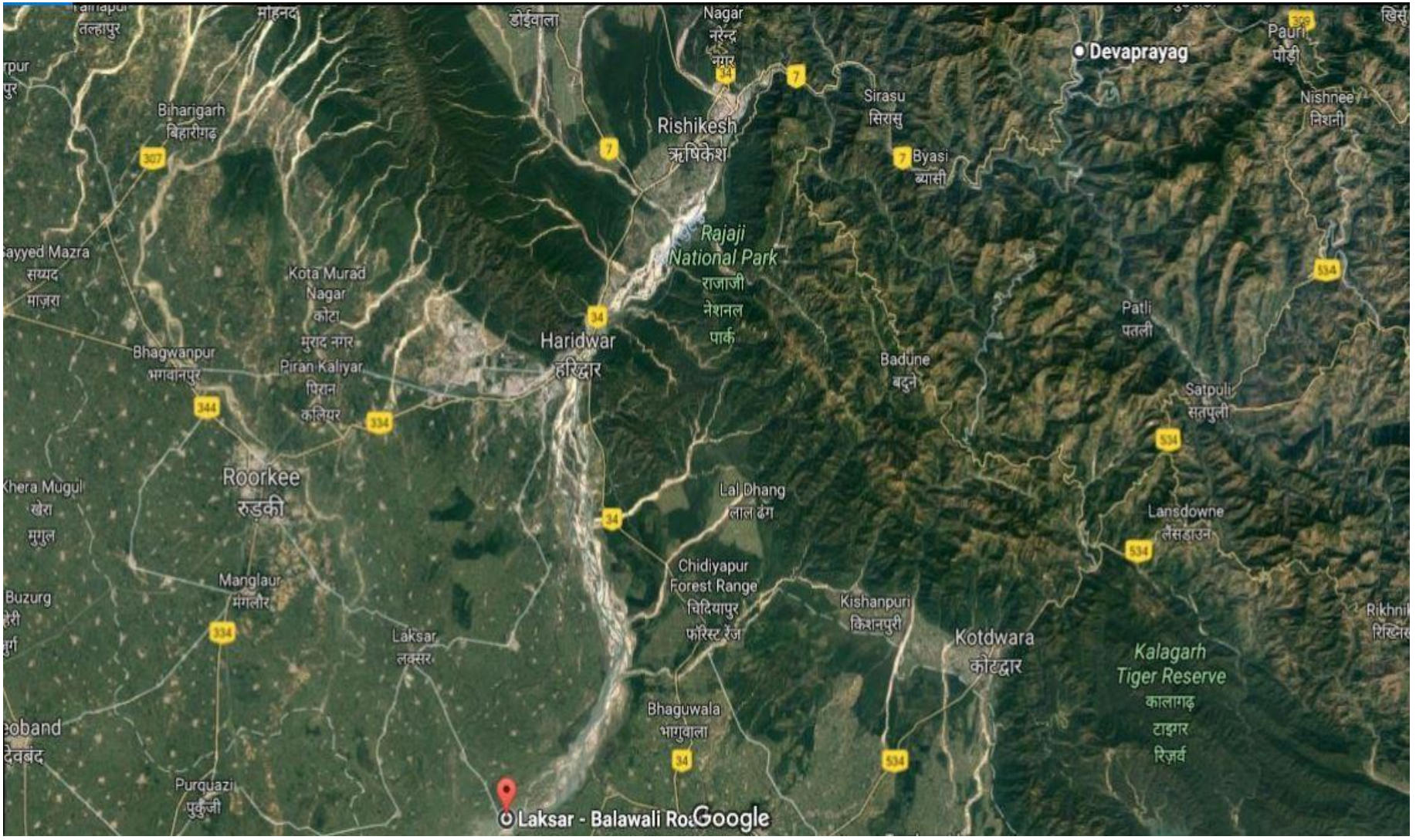


Fig 3.2 Satellite map of the study area

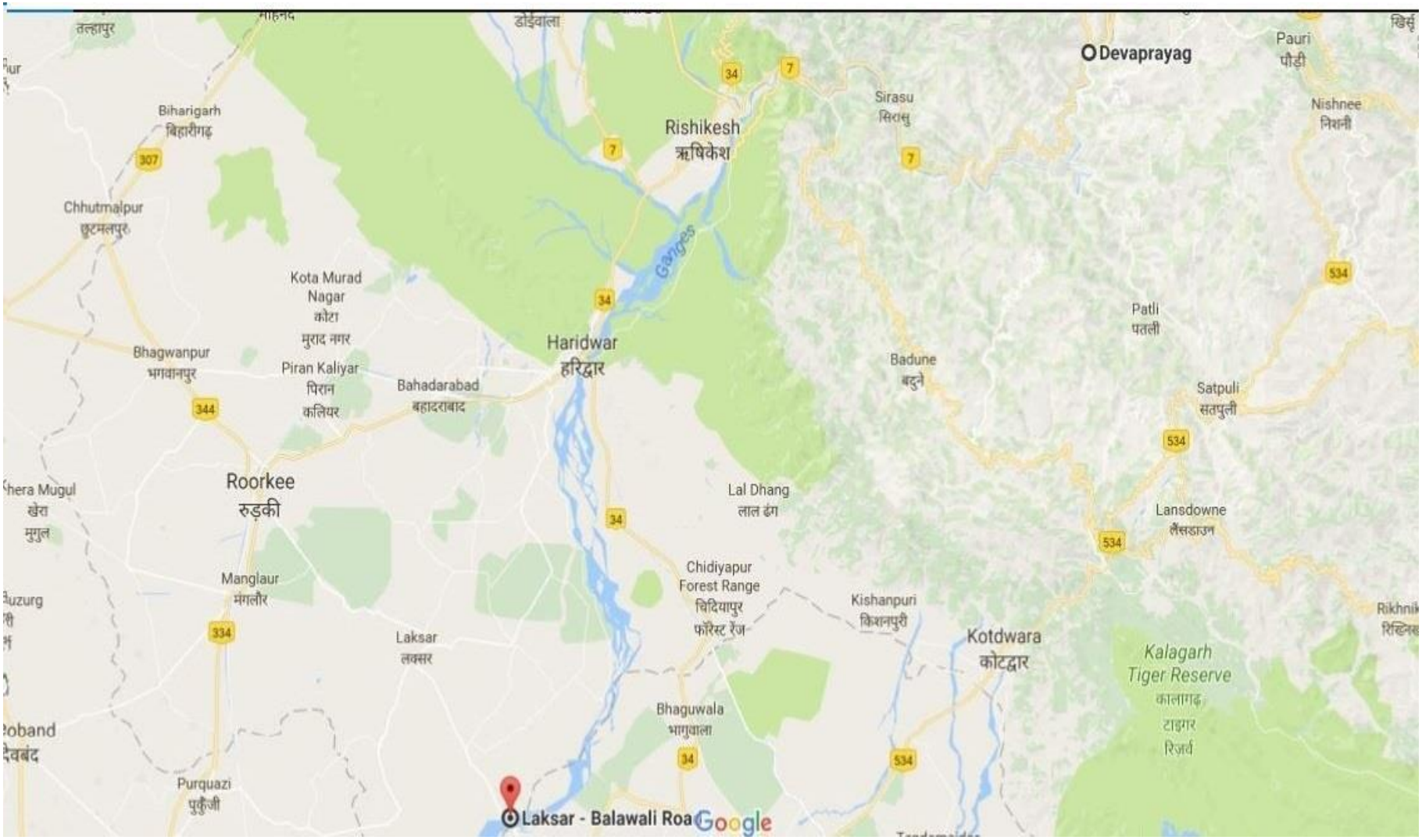


Fig 3.3 Google map of the study area



Fig 3.4 The origin and tributaries of river Ganga

3.2.1 Physical properties of the samples

Taste, Color, Odor were determined on the spot while collecting the samples whereas the Potential of Hydrogen (pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS) of water samples were determined in laboratory directly with the help of pH meter, EC meter and TDS meter respectively.

3.2.1.1 Taste

The taste of the samples collected in both the months was determined by drinking.

3.2.1.2 Color

The observation of the color of the samples collected in both the months was done visually.

3.2.1.3 Odor

The odor of the samples collected in both the months was interpreted by inhaling.

3.2.1.4 Total dissolved solids (TDS)

Total dissolved solids is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular (colloidal sol) suspended form. For estimating Total dissolved solids, 100 ml of the sample was taken. The digital TDS tester was used and before dipping the tester sensor in the vessel containing the sample, it was ensured that the reading on the scale is zero. Once the reading of the tester got stabilized, it was noted down.

3.2.1.5 Electrical conductivity (EC)

Electrical conductivity is the reciprocal of electrical resistivity, and measures a material's ability to conduct an electric current. For estimating the electrical conductivity, sample of 100 ml was taken. The digital EC tester was used and before dipping the tester sensor in the vessel containing the sample, it was ensured that the reading on the scale is zero. Once the reading of the tester got stabilized, it was noted down.

3.2.1.6 Potential of hydrogen ion (pH)

Potential of hydrogen is a numeric scale used to specify the acidity or basicity of an aqueous solution. For estimating the pH, 100 ml sample was taken. The digital pH tester was used and before dipping the tester sensor in the vessel containing the sample, it was ensured that the reading on the scale is zero. Once the reading of the tester got stabilized, it was noted down.

3.2.2 Chemical properties

The chemical analysis of collected samples were performed to estimate total alkalinity, total acidity, total hardness, calcium, magnesium, calcium hardness, magnesium hardness, chloride, free carbon dioxide (CO_2). The parameters were determined as per standard methods of water analysis specified by American Public Health Association (APHA), American Water Work Association (AWWA) and Water Pollution Control Federation (WPCF) as described below.

3.2.2.1 Total acidity (TAc)

Total acidity is a measure of the amount of acid present in a solution. To determine the concentration of total acidity, a sample of 100 ml was taken and 3 drops of methyl orange indicator were added to it. Titration was done with 0.05 normality sodium hydroxide (NaOH) until the color changed to faint pink at the end point and further titration was continued after adding 3 drops of phenolphthalein indicator to the same sample until content turned pink. If sample changed color to yellow after addition of methyl orange indicator, 3 drops of phenolphthalein indicator were added to it and titrated against 0.05 normality NaOH until the content turned pink. Total acidity was determined using the following relationships,

$$\text{Total acidity as } CaCO_3, \text{ ppm} = A \times B \times 50 \times 1000 / C \quad \text{... (3.1)}$$

Where, A = Volume of titrant (NaOH) used, ml

B = Normality of titrant

C = Volume of sample used, ml

3.2.2.2 Total alkalinity (TAl)

Total alkalinity is the equivalent sum of the bases that are titratable with strong acid (Stumm and Morgan, 1981). To find out the concentration of total alkalinity, a 100 ml sample was taken and 2 drops of phenolphthalein indicator were added to it. If the color changed color to pink, titration was done with 0.1 normality hydrochloric acid (HCl) until the color disappeared at the end point. Then 3 drops of methyl orange indicator were added to the same sample and titration was continued until the yellow color changed to pink at the end point. If sample did not change color after addition of phenolphthalein indicator, 3 drops of methyl orange indicator were added to it and titrated with 0.1 normality HCl until the yellow color changed to pink at the end point. Total alkalinity was estimated as,

$$\text{Total alkalinity as } CaCO_3, \text{ ppm} = A \times B \times 50 \times 1000 / C \quad \ldots (3.2)$$

Where, A = Volume of titrant (HCl) used, ml

B = Normality of titrant

C = Volume of sample used, ml

3.2.2.3 Total hardness (TH)

Total hardness is hardness (mineral content) that cannot be removed by boiling. To determine the concentration of total hardness, a 10 ml of water sample was taken and diluted to 50 ml using distilled water, 1 ml of buffer solution and 0.2 g of Eriochrome Black T indicator were added to it. The content was titrated against 0.01 normality ethylene diamine tetra acetic acid (EDTA) solution until the wine red color changed to blue at the end point. The total hardness was found as,

$$\text{Total hardness as } CaCO_3, \text{ ppm} = A \times 1000 / C \quad \ldots (3.3)$$

Where A = Volume of titrant (EDTA) used, ml

C = Volume of sample used, ml

3.2.2.4 Calcium hardness (CaH)

Calcium hardness is presence of calcium ions in water, from dissolved carbonates and bicarbonates. To determine the concentration of calcium, a 10 ml of water sample was taken and diluted to 50 ml, 2 ml of 0.01 normality NaOH solution and 0.2 gm of Murexide indicator were added to the sample and the content was titrated against EDTA solution until the

pink color changed to purple. The concentration of calcium was found as,

Calcium, ppm = A × 400.8/C … (3.4)

Calcium hardness, ppm = Calcium, ppm × 2.497 … (3.5)

Where A = Volume of titrant (EDTA) used, ml

C = Volume of sample used, ml

3.2.2.5 Magnesium (MgH)

Magnesium hardness is presence of calcium ions in water, from dissolved carbonates and bicarbonates. Magnesium concentration was determined using formula,

Magnesium hardness, ppm = Total hardness - Calcium hardness … (3.6)

Magnesium, ppm = Magnesium hardness × 0.244 … (3.7)

3.2.2.6 Chloride (Cl)

Chloride ion is the anion widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$). To determine the concentration of chloride content, a 50 ml of sample was taken and 2 ml of potassium chromate solution was added to it. Then the content was titrated against 0.02 normality silver nitrite ($AgNO_3$) until the persistent red tinge appeared. The chloride concentration was obtained as follows,

Chloride, ppm = A × B × 35.5 × 1000 / C … (3.8)

Where, A = Volume of titrant ($AgNO_3$) used, ml

B = Normality of titrant

C = Volume of sample used, ml

3.2.2.6 Free carbon dioxide (FCO_2)

Free carbon dioxide is carbon dioxide that exists in the environment. To determine the free carbon dioxide, a 100 ml sample was titrated against 0.05 normality NaOH solution using phenolphthalein as an indicator. The end point was marked by appearance of pink color at a pH of 8.3. The quantity of free CO_2 was calculated using the formula,

Free CO_2, ppm = A × N × 44 × 1000 / C … (3.9)

Where, A = Volume of titrant (NaOH) used, ml

B = Normality of titrant

C = Volume of sample used, ml

3.3 Statistical Analysis

Statistical analysis of different water quality parameters was carried out as,

3.3.1 Coefficient of correlation

Coefficient of correlation (r) is commonly used to measure and establish the strength of a linear relationship between two variables or two sets of data. It is a simplified statistical tool to show the degree of dependency of one variable to the other variable (**Belkhiri et al., 2010**). The coefficient of correlation (r) is computed by using the formula given by **Kumar and Sinha (2010)**. It is considered to be not significant when the value of the level of significance (P) is greater than 0.05. The inter dependence of different water quality parameters on each other was evaluated on the basic of r from Equation 3.10.

$$r = n \sum (X_i Y_i) - (\sum X_i) (\sum Y_i) / [\sqrt{ \{ n \sum X_i^2 - (\sum X_i)^2 \} \{ n \sum Y_i^2 - (\sum Y_i)^2 \} }] \quad \ldots (3.10)$$

Where, the variables X and Y represents two different parameters

n = number of data points

3.3.2 Simple linear regression

Simple linear regression approach is to develop a linear relationship between an independent variable and a dependent variable. This method provides equation linking a dependent variable to the independent variable using the following form,

$$y = mx + c \quad \ldots (3.11)$$

The intercept (c) and the regression coefficient of the independent parameter (m) for various regression equations were determined only on the basis of the P-values less than or equals 0.05 which were found out using regression function in the MS Excel 2013.

After the equations were formed, the observed values of the independent parameters were put in the regression equations along with their corresponding coefficients and intercepts to get the estimated values of the dependent variables.

Once the values of the dependent variables are estimated, tables were formed showing the estimated and observed values and their corresponding R, R^2 and P-values. Graphs were then plotted between all the estimated values for a particular dependent parameter and its observed values.

4. RESULTS AND DISCUSSION

4.1 General

This chapter deals with the results and discussion of physico-chemical analysis of the samples of the Ganga river segment in Uttarakhand taken in February and June. The samples of February and June are analyzed for their physico-chemical properties. Results of the samples collected in February and June are presented in Table 4.1 and 4.2 respectively. The minimum, maximum and mean of different parameters of the samples of both the months are shown in Table 4.3. Classification of the samples of both the months for irrigation purpose are shown in Table 4.4. Classification of the samples of February and June at different locations are presented in Table 4.5 and 4.6 respectively.

4.2 Physico-chemical Properties

The water samples from twelve locations namely, Bhagrathi (Devprayag), Alaknanda (Devprayag), Ghuret, Kauriyala, Atali, Shivpuri, Patna, Triveni Ghat, Veerbhadra, Harki Pauri, Rampur Raighati Ahat, Balawali were collected from a segment of river Ganga in Uttarakhand in February 2017 and June 2017.

4.2.1 Taste

The taste of the samples of both the months was found to be agreeable.

4.2.2 Odor

The odor of the samples of both the months was found to be unobjectionable.

4.2.3 Color

The color of the sampled water was found to be clear in February, whereas the color of the sampled water was found to be brown in June.

Table 4.1 Physico-chemical quality of river water in February 2017

S. No.	Location	EC	pH	TDS	TAc	FCO_2	Ca	TH	CaH	MgH	Mg	Cl	TAl
1	Bhagrathi (Devprayag)	102	7.6	61	36	2.8	15.61	67	38.98	28.02	6.84	5.5	59
2	Alaknanda (Devprayag)	108	7.6	65	25	3	18.02	80	45	35	8.54	5.5	71
3	Ghuret	108	7.6	65	20	3	16.01	73	39.98	33.02	8.06	5.5	63
4	Kauriyala	108	7.5	65	25	3.2	17.02	76.5	42.49	34.01	8.3	5.5	67
5	Atali	115	7.5	69	28	3.4	16.51	74.75	41.23	33.52	8.18	5.6	65
6	Shivpuri	123	7.5	74	30	3.2	16.67	76.38	41.62	34.76	8.48	5.6	66.5
7	Patna	138	7.5	83	24	3.3	16.82	78	42	36	8.78	5	68
8	Triveni Ghat	142	7.4	85	40	4.2	17.22	77	43	34	8.3	5	68
9	Veerbhadra	143	7.5	86	13	3.6	17.62	76	44	32	7.81	5	68
10	Harki Pauri	158	7.4	95	15	4.2	17.62	83	44	39	9.52	5.5	74
11	Rampur Raighati Ahat	155	7.6	93	25	4	16.41	77	40.98	36.02	8.79	5.5	71
12	Balawali	155	7.5	93	24	4	17.02	80	42.49	37.51	9.15	5.6	72.5

All values are in ppm except EC in µS/cm, pH in number, odor and taste

Table 4.2 Physico-chemical quality of river water in June 2017

S. No.	Location	EC	pH	TDS	TAc	FCO_2	Ca	TH	CaH	MgH	Mg	Cl	TAl
1	Bhagrathi (Devprayag)	170	6.1	84	72.5	33	32.06	140	80.06	59.94	14.62	18.46	85
2	Alaknanda (Devprayag)	140	6.4	70	57.5	26.4	36.07	130	90.07	39.93	9.74	15.62	100
3	Ghuret	130	6.4	67	45	26.4	24.05	200	60.05	139.95	34.14	14.2	100
4	Kauriyala	150	6.3	74	47.5	44	64.13	140	160.13	-20.13	-4.91	17.04	100
5	Atali	130	6.4	65	50	6.6	48.1	190	120.1	69.9	17.05	35.5	100
6	Shivpuri	130	6.2	64	65	19.8	48.1	170	120.1	49.9	12.17	15.62	90
7	Patna	140	6.2	67	50	24.2	48.1	170	120.1	49.9	12.17	31.24	105
8	Triveni Ghat	180	5.9	89	87.5	61.6	48.1	130	120.1	9.9	2.41	21.3	125
9	Veerbhadra	150	6	72	25	28.6	56.11	210	140.11	69.89	17.05	25.56	95
`10	Harki Pauri	140	6.1	76	30	19.8	48.1	180	120.1	59.9	14.61	14.2	105
11	Rampur Raighati Ahat	160	5.9	77	52.5	37.4	52.1	160	130.1	29.9	7.29	17.04	95
12	Balawali	160	6.1	78	52.5	28.6	60.12	160	150.12	9.88	2.41	21.3	110

All values are in ppm except EC in µS/cm and pH in number

Table 4.3 Different physico-chemical quality parameters of river water in 2017

S. No.	Parameter	Minimum		Maximum		Mean	
		February	June	February	June	February	June
1	pH	7.4	5.9	7.6	6.4	7.52	6.17
2	EC, µS/cm	102	130	158	180	130	148.33
3	TDS, ppm	61	64	95	89	77.83	73.58
4	TH, ppm	67	130	83	210	76.55	165
5	Ca, ppm	15.61	24.05	18.02	64.13	16.88	47.1
6	CaH, ppm	38.98	60.05	45	160.13	42.14	117.6
7	Mg, ppm	6.84	-4.91	9.52	34.14	8.4	11.56
8	MgH, ppm	28.02	-20.13	39	139.95	34.41	47.41
9	TAc, ppm	13	25	40	87.5	25.42	52.92
10	TAl, ppm	59	85	74	125	67.75	100.83
11	Cl, ppm	5	14.2	5.6	35.5	5.4	20.59
12	FCO_2, ppm	2.8	6.6	4.2	61.6	3.49	29.7

Table 4.4 Classification of the samples for irrigation purpose in 2017

S. No.	Location	February		June	
		EC, µS/cm	Class	EC, µS/cm	Class
1	Bhagirathi (Devprayag)	102	C1	170	C1
2	Alaknanda (Devprayag)	108	C1	140	C1
3	Ghuret	108	C1	130	C1
4	Kauriyala	108	C1	150	C1
5	Atali	115	C1	130	C1
6	Shivpuri	123	C1	130	C1
7	Patna	138	C1	140	C1
8	Triveni Ghat	142	C1	180	C1
9	Veerbhadra	143	C1	150	C1
10	Harki Pauri	158	C1	140	C1
11	Rampur Raighati Ahat	155	C1	160	C1
12	Balawali	155	C1	160	C1

Table 4.5 Classification of the samples of February 2017 considering tolerance limit for inland surface waters

S. No.	Locations	EC, µS/cm	Class	pH	Class	TDS, ppm	Class	FCO_2, ppm	Class	CaH, ppm	Class	TH, ppm	Class	MgH, ppm	Class	Cl, ppm	Class
1	Bhagirathi (Devprayag)	102	D	7.6	A	61	A	2.8	D	38.97	A	67	A	28.02	A	18.46	A
2	Alaknanda (Devprayag)	108	D	7.6	A	65	A	3	D	45	A	80	A	35	A	15.62	A
3	Ghuret	108	D	7.6	A	65	A	3	D	39.97	A	73	A	33.02	A	14.2	A
4	Kauriyala	108	D	7.5	A	65	A	3.2	D	42.48	A	76.5	A	34.01	A	17.04	A
5	Atali	115	D	7.5	A	69	A	3.4	D	41.23	A	74.75	A	33.51	A	35.5	A
6	Shivpuri	123	D	7.5	A	74	A	3.2	D	41.61	A	76.38	A	34.75	A	15.62	A
7	Patna	138	D	7.5	A	83	A	3.3	D	42	A	78	A	36	A	31.24	A
8	Triveni Ghat	142	D	7.4	A	85	A	4.2	D	43	A	77	A	34	A	21.3	A
9	Veerbhadra	143	D	7.5	A	86	A	3.6	D	44	A	76	A	32	A	25.56	A
10	Harki Pauri	158	D	7.4	A	95	A	4.2	D	44	A	83	A	39	A	14.2	A
11	Rampur Raighati Ahat	155	D	7.6	A	93	A	4	D	40.97	A	77	A	36.02	A	17.04	A
12	Balawali	155	D	7.5	A	93	A	4	D	42.48	A	80	A	37.51	A	21.3	A

Table 4.6 Classification of the samples of June 2017 considering tolerance limit for inland surface waters

S. No.	Locations	EC, µS/cm	Class	pH	Class	TDS, ppm	Class	FCO_2, Ppm	Class	CaH, Ppm	Class	TH, ppm	Class	MgH, ppm	Class	Cl, ppm	Class
1	Bhagirathi (Devprayag)	170	D	6.1	E	84	A	33	Below E	80.06	A	140	A	59.94	A	18.5	A
2	Alaknanda (Devprayag)	140	D	6.4	E	70	A	26.4	Below E	90.07	A	130	A	39.93	A	15.6	A
3	Ghuret	130	D	6.4	E	67	A	26.4	Below E	60.05	A	200	A	139.95	Below E	14.2	A
4	Kauriyala	150	D	6.3	E	74	A	44	Below E	160.13	A	140	A	-20.13	A	17	A
5	Atali	130	D	6.4	E	65	A	6.6	Below E	120.1	A	190	A	69.9	A	35.5	A
6	Shivpuri	130	D	6.2	E	64	A	19.8	Below E	120.1	A	170	A	49.9	A	15.6	A
7	Patna	140	D	6.2	E	67	A	24.2	Below E	120.1	A	170	A	49.9	A	31.2	A
8	Triveni Ghat	180	D	5.9	Below E	89	A	61.6	Below E	120.1	A	130	A	9.9	A	21.3	A
9	Veerbhadra	150	D	6	E	72	A	28.6	Below E	140.11	A	210	A	69.89	A	25.6	A
10	Harki Pauri	140	D	6.1	E	76	A	19.8	Below E	120.1	A	180	A	59.9	A	14.2	A
11	Rampur Raighati Ahat	160	D	5.9	Below E	77	A	37.4	Below E	130.1	A	160	A	29.9	A	17	A
12	Balawali	160	D	6.1	E	78	A	28.6	Below E	150.12	A	160	A	9.88	A	21.3	A

4.2.4 Potential of hydrogen (pH)

A pH range for drinking water is 6.5 to 8.5 and normally acceptable as per guidelines suggested by BIS **(IS 10500:2012)**. Lower values below 4 produces sour taste and higher values above 8.5 produces alkaline taste. Undesirable effects outside the desirable limit are that the water will affect the mucous membrane and/or water supply system.

The pH of the samples varied from 7.4 to 7.6 in February. The minimum observed value of the pH was found to be 7.4 at Triveni ghat and Harki pauri whereas the maximum observed value was 7.6 at Bhagrathi (Devprayag), Alaknanda (Devprayag), Ghuret and Rampur Raighati Ahat. The pH of the samples was found to be within the desirable limit.

The pH of the samples varied from 5.9 to 6.4 in June. The minimum observed value of the pH was found to be 5.9 at Triveni ghat and Rampur Raighati Ahat whereas the maximum observed value was 6.4 at Alaknanda (Devprayag), Ghuret and Atali. The pH of the samples was not found to be within the desirable limit. The pH variation is shown in Fig 4.1.

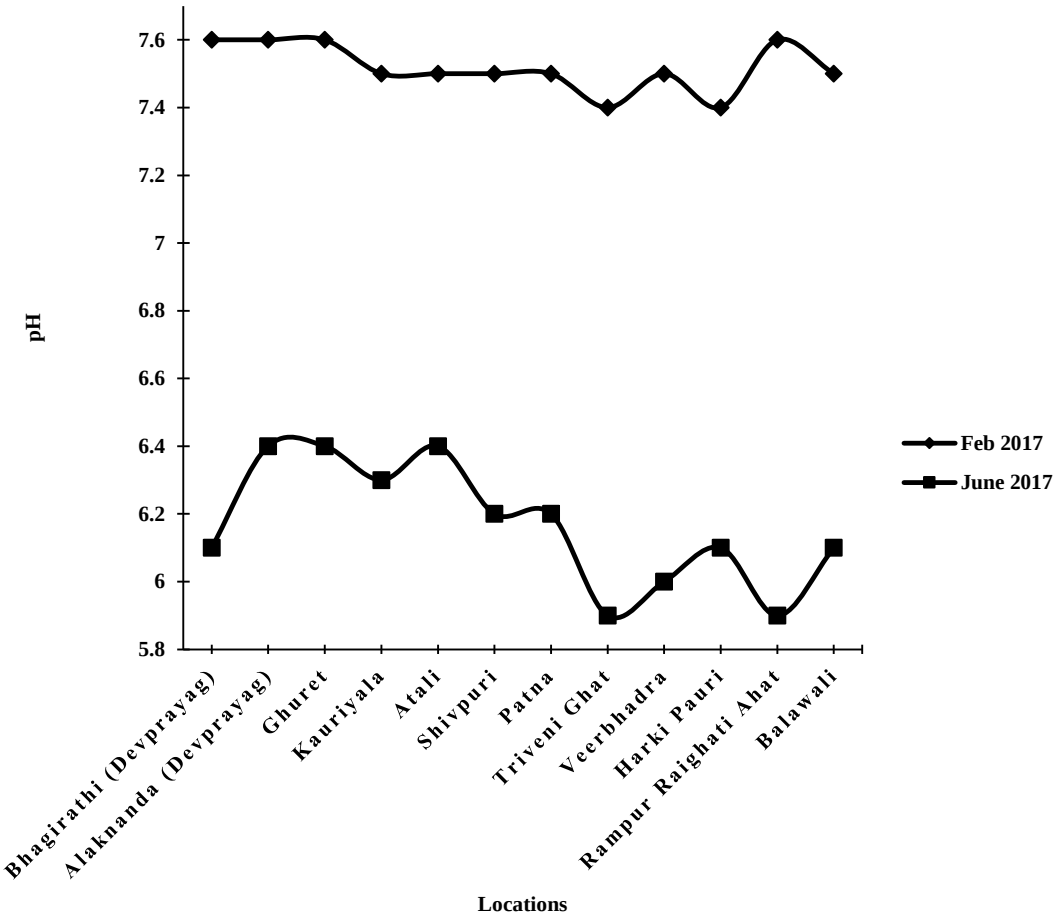


Fig 4.1 The pH of the sampled water at different locations

4.2.5 Electrical conductivity (EC)

Higher value of conductivity shows higher concentration of dissolved ions.

The EC of the samples varied from 102 µS/cm to 158 µS/cm in February. The minimum observed value of the EC was found to be 102 µS/cm at Bhagrathi (Devprayag) whereas the maximum observed value was 158 µS/cm at Harki Pauri.

The EC of the samples varied from 130 µS/cm to 180 µS/cm in June. The minimum observed value of the EC was found to be 130 µS/cm at Ghuret, Atali and Shivpuri whereas the maximum observed value was 180 µS/cm at Triveni ghat.

EC of the samples of both the months was found to be within the desirable limit as prescribed by the WHO. The variation in EC is presented in Fig 4.2.

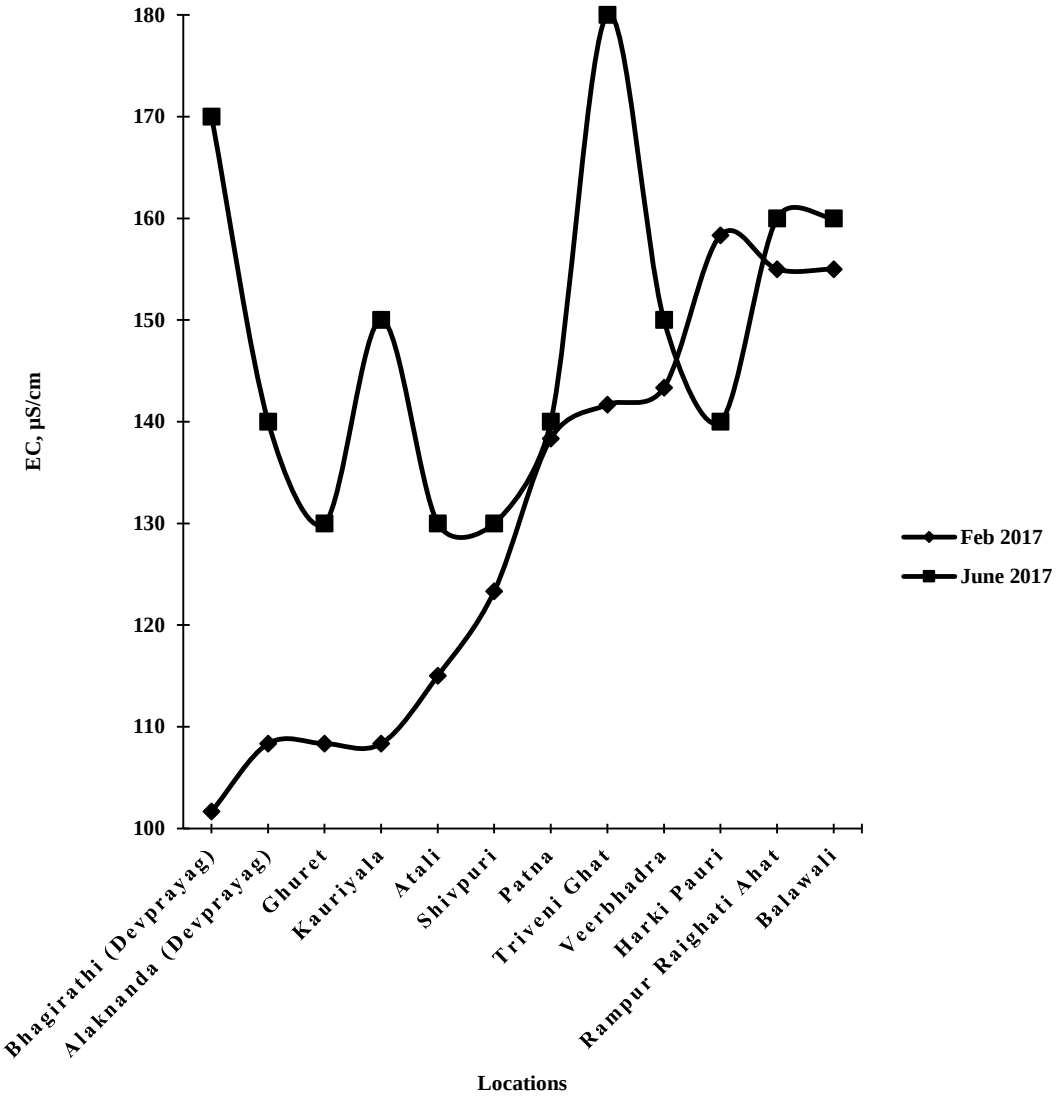


Fig 4.2 The EC of the sampled water at different locations

4.2.6 Total dissolved solids (TDS)

Dissolved minerals, gases and organic constituents may produce aesthetically displeasing color, taste and odor. The main source of the TDS in water is the flow of agricultural, industrial and domestic wastes.

The TDS of the samples varied from 61 ppm to 95 ppm in February. The minimum observed value of the TDS was found to be 61 ppm at Bhagrathi (Devprayag) whereas the maximum observed value was 95 ppm at Harki Pauri.

The TDS of the samples varied from 64 ppm to 89 ppm in June. The minimum observed value of the TDS was found to be 64 ppm at Shivpuri whereas the maximum observed value was 89 ppm at Triveni ghat.

The desirable limit of TDS in drinking water is 500 ppm as per IS 10500:2012. Undesirable effects outside the desirable limit are that palatability decreases and may cause Gastro intestinal irritation. The TDS of the samples of both the months was found to be within the desirable limit. The variation of TDS is presented in Fig 4.3.

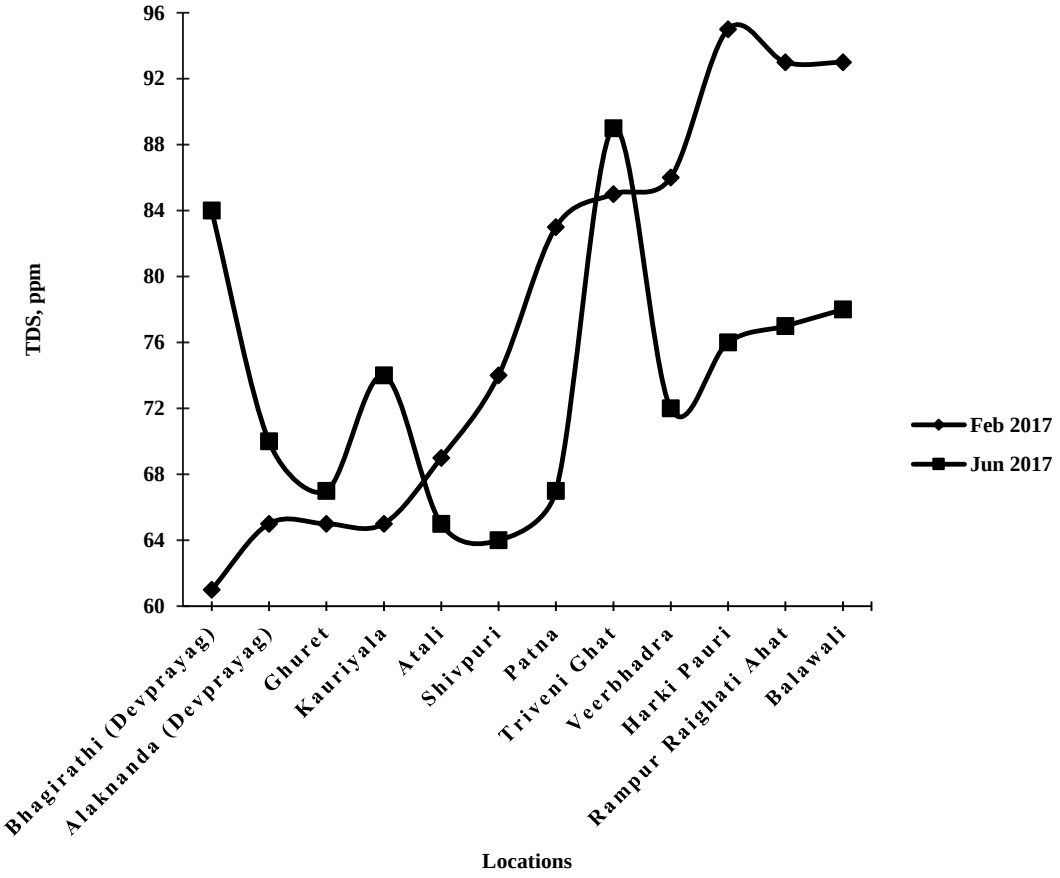


Fig 4.3 The TDS of the sampled water at different locations

4.2.7 Total hardness (TH)

The total hardness of the samples varied from 67 ppm to 83 ppm in February. The minimum observed value of the total hardness was found to be 67 ppm at Bhagrathi (Devprayag) whereas the maximum observed value was 83 ppm at Harki Pauri. The total hardness was found to be within the desirable limit.

The total hardness of the samples varied from 130 ppm to 210 ppm. The minimum observed value of the total hardness was found to be 130 ppm at Alaknanda (Devprayag) and Triveni ghat whereas the maximum observed value was 210 ppm at Veerbhadra. The total hardness of the samples was found to be within the desirable limit except for Ghuret which was just at the desirable limit and for Veerbhadra which was above the desirable limit but within the permissible limit.

The desirable limit for total hardness is 200 ppm and the permissible limit is 600 ppm as per IS 10500:2012. Undesirable effects outside the desirable limit are the encrustations in water supply structure and adverse effect on domestic use. High amount of hardness in drinking water leads to heart diseases and kidney stone formation. The variations of total hardness is presented in Fig 4.4.

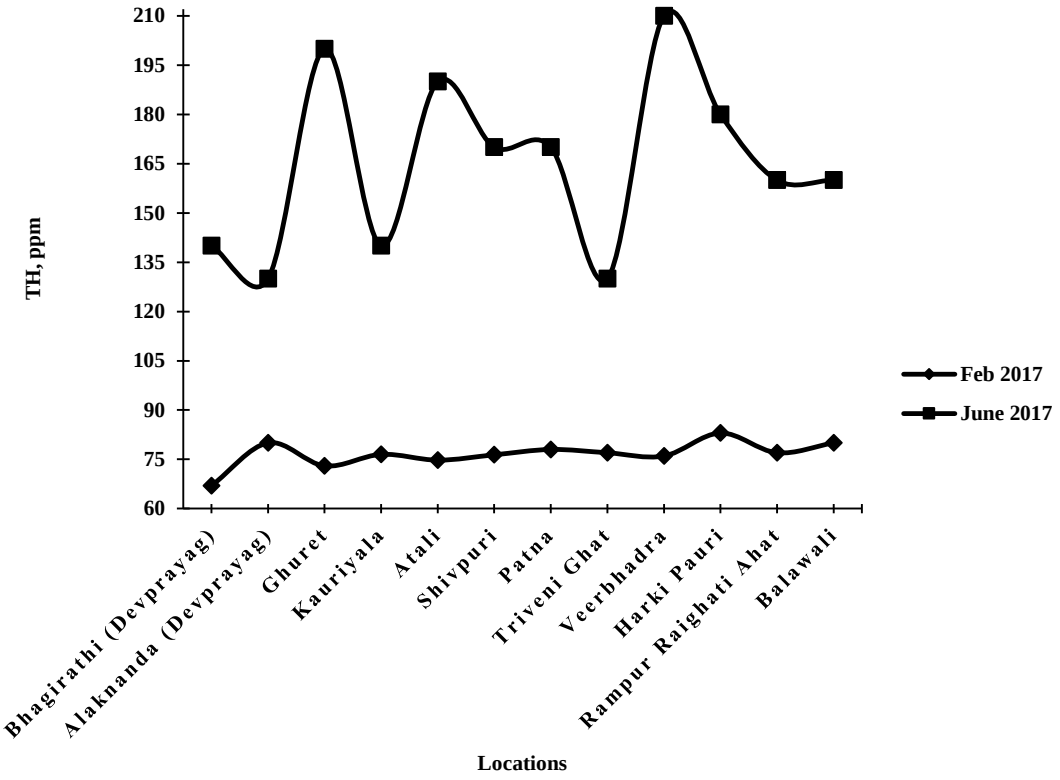


Fig 4.4 The total hardness of the sampled water at different locations

4.2.8 Calcium hardness (CaH)

The main sources of calcium in natural water are various types of rocks, industrial waste and sewage.

The calcium hardness of the samples varied from 38.98 ppm to 45 ppm in February. The minimum observed value of calcium hardness was found to be 38.98 ppm at Bhagirathi (Devprayag) whereas the maximum observed value was 45 ppm at Alaknanda (Devprayag). The calcium hardness of the samples was found to be within the desirable limit.

The calcium hardness of the samples varied from 60.05 ppm to 160.13 ppm in June. The minimum observed value of calcium hardness was found to be 60.05 ppm at Ghuret whereas the maximum observed value was 160.13 ppm at Kauriyala. The calcium hardness of Ghuret was found to be within the desirable limit and others within the permissible limit.

The desirable limit and permissible limit of calcium hardness in drinking water is 75 ppm and 200 ppm respectively as per IS 10500:2012. Undesirable effects outside the desirable limit are the encrustations in water supply structure and adverse effect on domestic use. The variation of calcium hardness is presented in Fig 4.5.

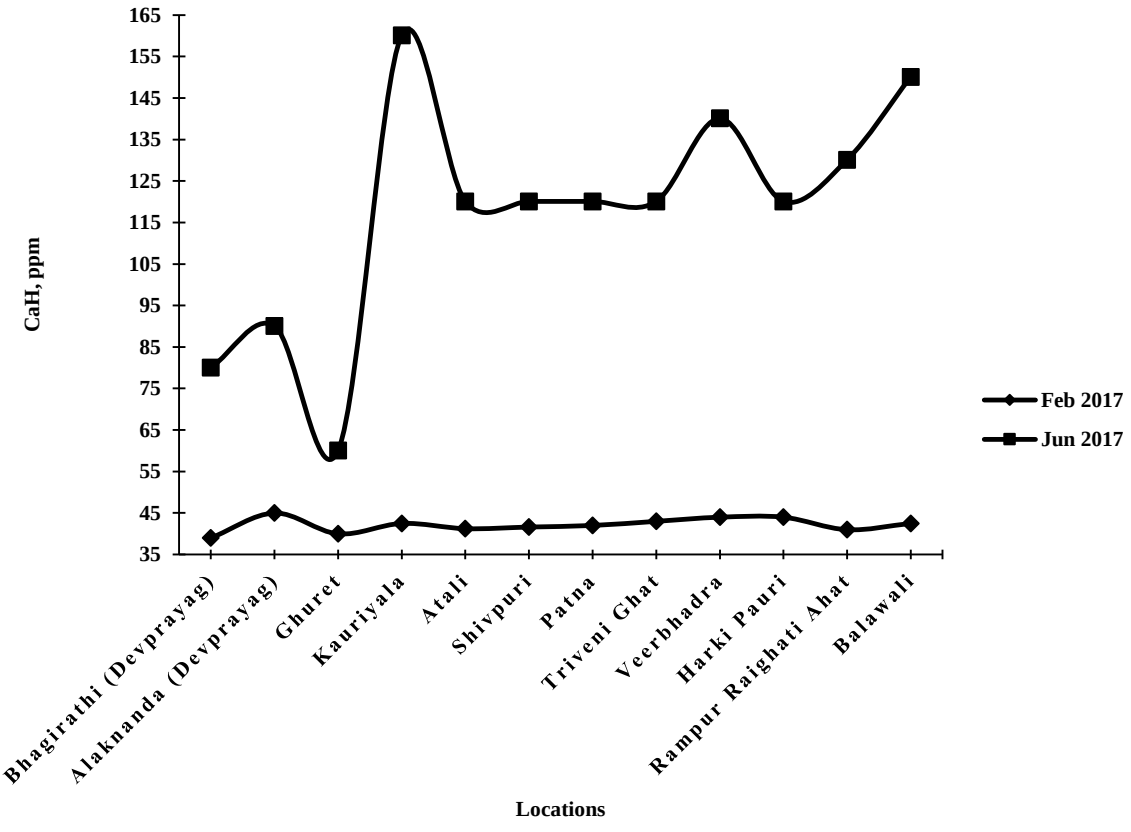


Fig 4.5 The calcium hardness of the sampled water at different locations

4.2.9 Magnesium Hardness (MgH)

The magnesium hardness of the samples varied from 28.02 ppm to 39 ppm in February. The minimum observed value of magnesium hardness was found to be 28.02 ppm at Bhagrathi (Devprayag) whereas the maximum observed value was 39 ppm at Harki Pauri. The magnesium hardness of Bhagirathi (Devprayag) was found to be within the desirable limit and all the others within the permissible limit.

The magnesium hardness of the samples varied from -20.13 ppm to 139.95 ppm in June. The minimum observed value of magnesium hardness was found to be -20.13 ppm at Kauriyala whereas the maximum observed value was 139.95 at Ghuret. The magnesium hardness of Triveni ghat, Rampur Raighati Ahat and Balawali was found to be within the desirable limit and all the others within the permissible limit except Kauriyala where magnesium hardness was negative which means that instead of the magnesium which is a divalent ion, the presence of hardness was due to monovalent ions like sodium, potassium, etc. The hardness existing due to monovalent element(s) is called pseudo hardness.

The desirable limit and the permissible limit of drinking water is 30 ppm and 100 ppm respectively as per IS 10500:2012. Undesirable effects outside the desirable limit are the encrustations in water supply structure and adverse effect on domestic use. The variation of magnesium hardness is presented in Fig 4.6.

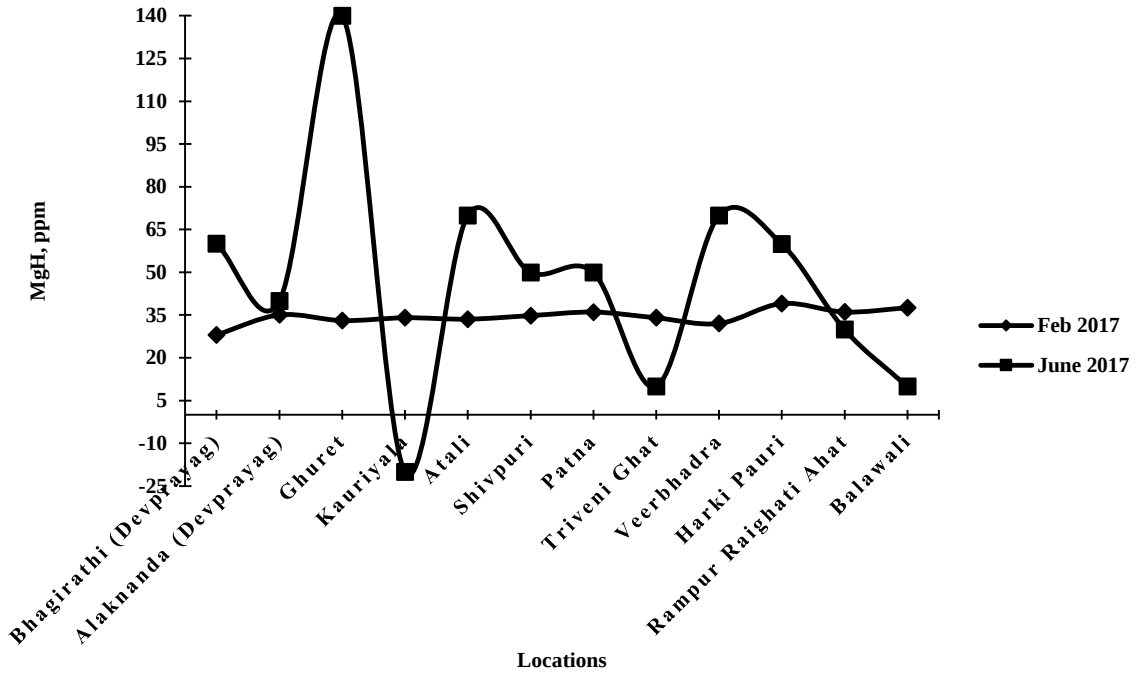


Fig. 4.6 The magnesium hardness of the sampled water at different locations

4.2.10 Total Acidity (TAc)

The total acidity of the samples varied from 13 ppm to 40 ppm in February. The minimum observed value of total acidity was found to be 13 ppm at Veerbhadra whereas the maximum observed value was 40 ppm at Triveni ghat.

The total acidity of the samples varied from 25 ppm to 87.5 ppm in June. The minimum observed value of total acidity was found to be 25 ppm at Veerbhadra whereas the maximum observed value was 87.5 ppm at Triveni ghat. The variation of total acidity is presented in Fig 4.7.

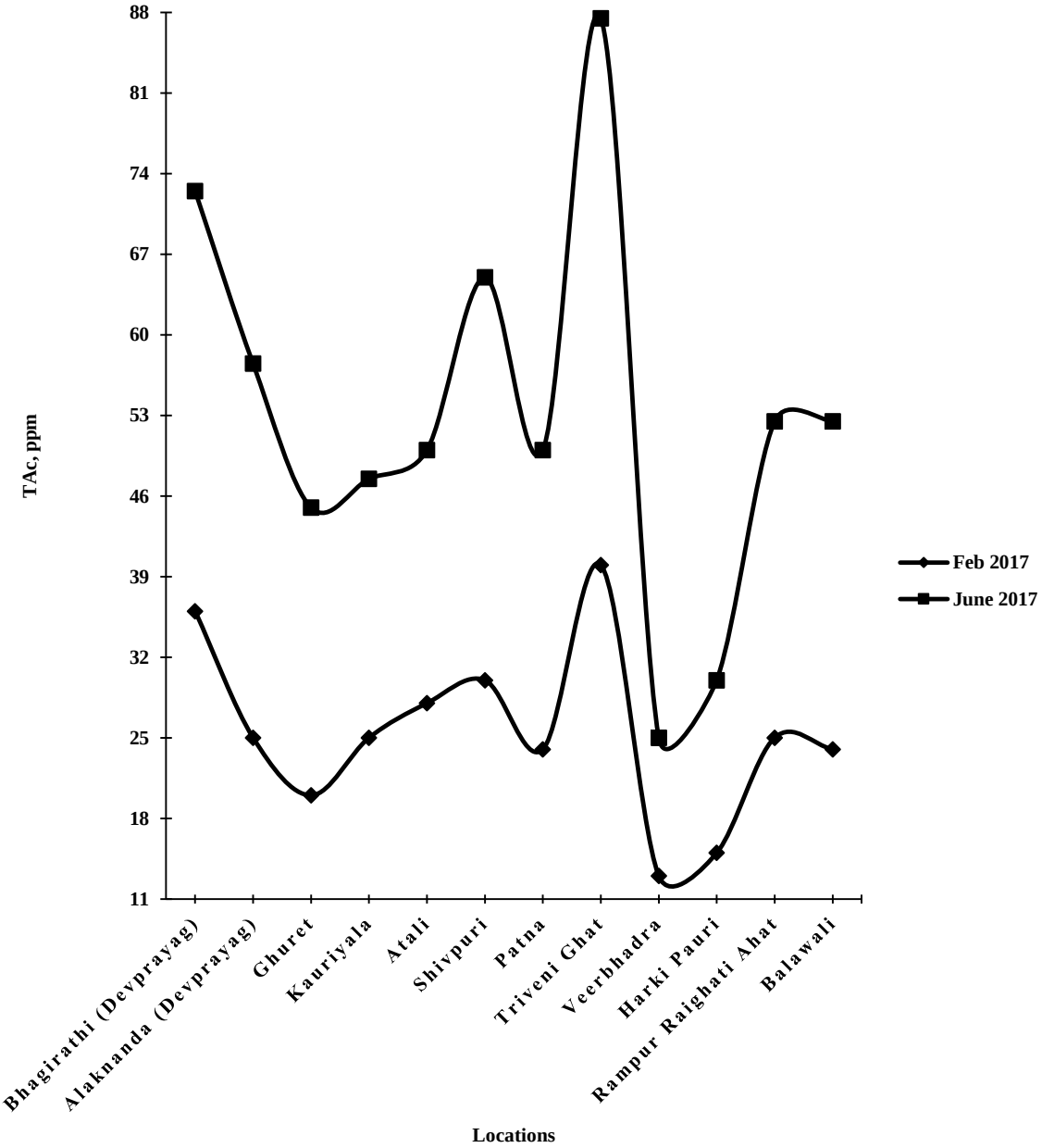


Fig. 4.7 The total acidity of the sampled water at different locations

4.2.11 Total Alkalinity (TAl)

The total alkalinity of the samples varied from 59 ppm to 74 ppm in February. The minimum observed value of total alkalinity was found to be 59 ppm at Bhagrathi (Devprayag) whereas the maximum observed value was 74 ppm at Harki Pauri.

The total alkalinity of the samples varied from 85 ppm to 125 ppm in June. The minimum observed value of total alkalinity was found to be 85 ppm Bhagrathi (Devprayag) whereas the maximum observed was 125 ppm at Triveni ghat.

The total alkalinity of the samples of both the months was found to be within the desirable limit. The desirable limit and the permissible limit of total alkalinity in drinking water is 200 ppm and 600 ppm respectively as per IS 10500:2012. Undesirable effects outside the desirable limit is that the taste becomes unpleasant. The variation of total alkalinity is presented in Fig 4.8.

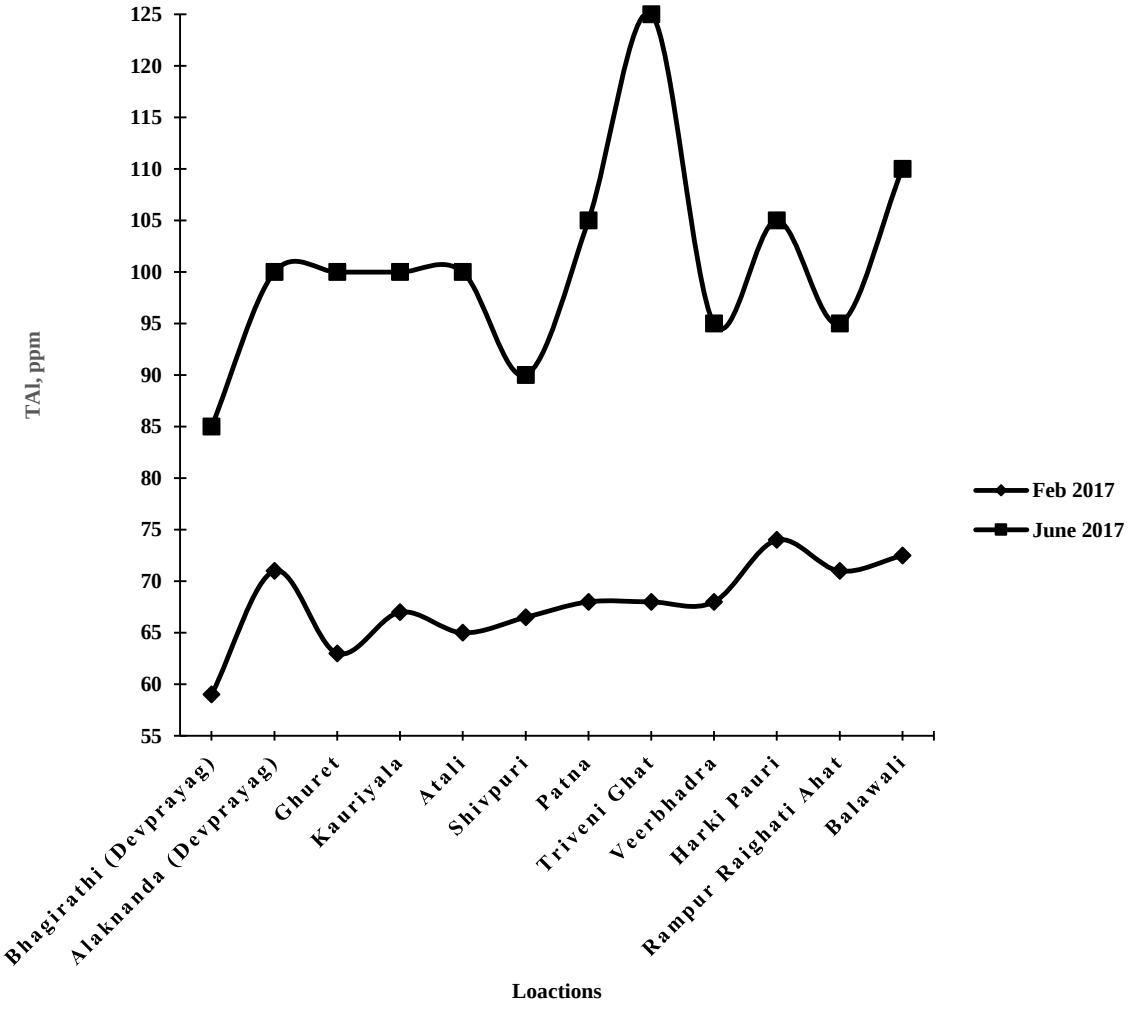


Fig. 4.8 The total alkalinity of the sampled water at different locations

4.2.12 Chloride (Cl)

The chloride content of the samples varied from 5 ppm to 5.6 ppm in February. The minimum observed value was found to be 5 ppm at Patna, Triveni ghat and Veerbhadra whereas the maximum observed value was 5.6 ppm at Atali, Shivpuri and Balawali.

The chloride content of the samples varied from 14.2 ppm to 35.5 ppm in June. The minimum observed value was found to be 14.2 ppm at Ghuret and Harki Pauri whereas the maximum observed value was 35.5 ppm at Atali.

The chloride content of the samples of both the months was found to be within permissible limit. The desirable limit and permissible limit of chloride in drinking water is 250 ppm and 1000 ppm respectively as per IS 10500:2012. Undesirable effects outside the desirable limit are that the taste, corrosion and palatability are affected. The variation of chloride content is presented in Fig 4.9.

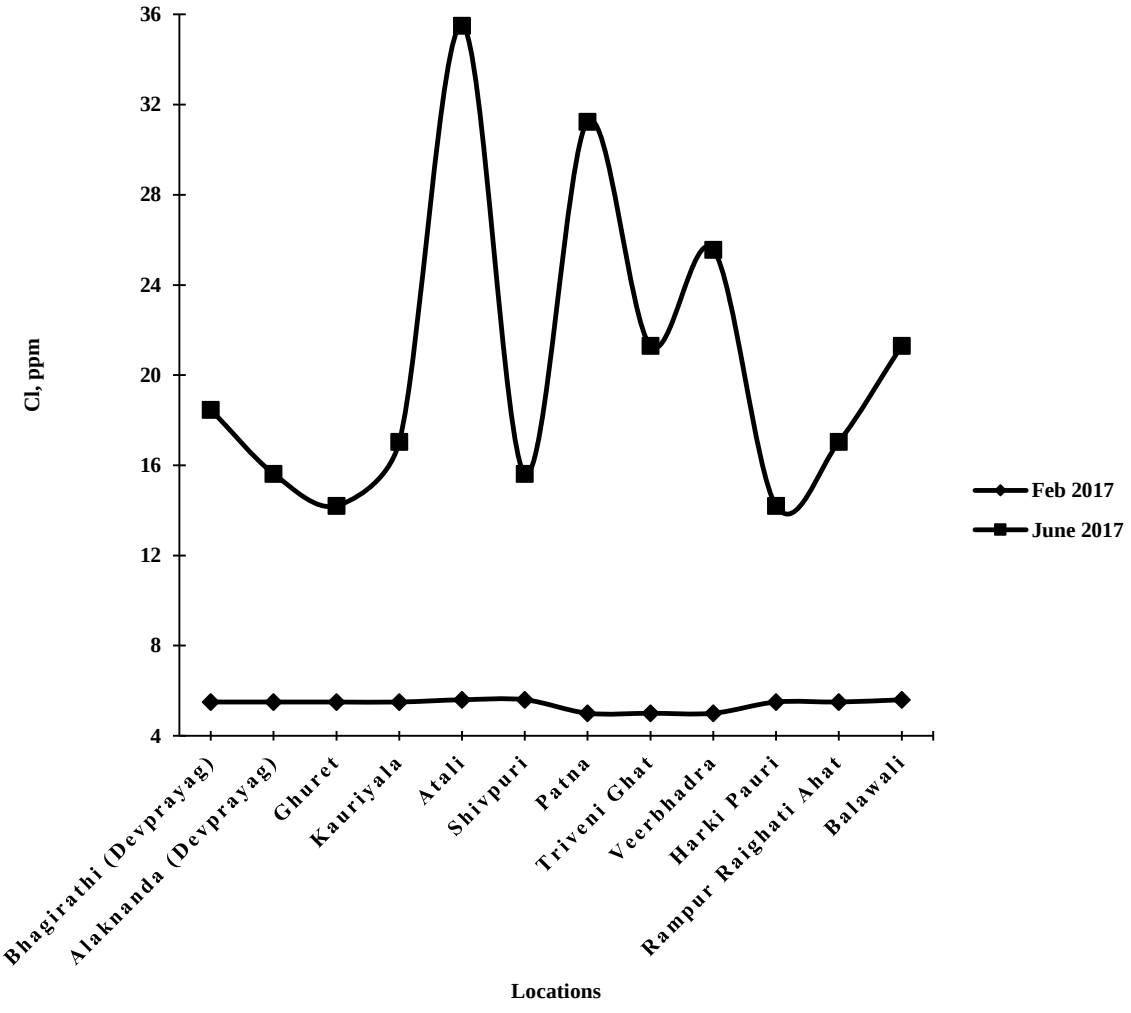


Fig. 4.9 The chloride content of the sampled water at different locations

4.2.13 Free carbon dioxide (FCO_2)

The free carbon dioxide content of the samples varied from 2.8 ppm to 4.2 ppm in February. The minimum observed value of free carbon dioxide was found to be 2.8 ppm at Bhagrathi (Devprayag) whereas the maximum observed value was 4.2 ppm at Triveni ghat and Harki Pauri. The free carbon of the samples was found to be within the permissible limit prescribed by WHO.

The free carbon dioxide content of samples varied from 6.6 ppm to 61.6 ppm in June. The minimum observed value of the free carbon dioxide was found to be 6.6 ppm at Atali whereas the maximum observed value was 61.6 ppm at Triveni ghat. Except Triveni ghat, all the other locations were within the permissible limit prescribed by WHO. The variation of free carbon dioxide content is presented in Fig 4.10.

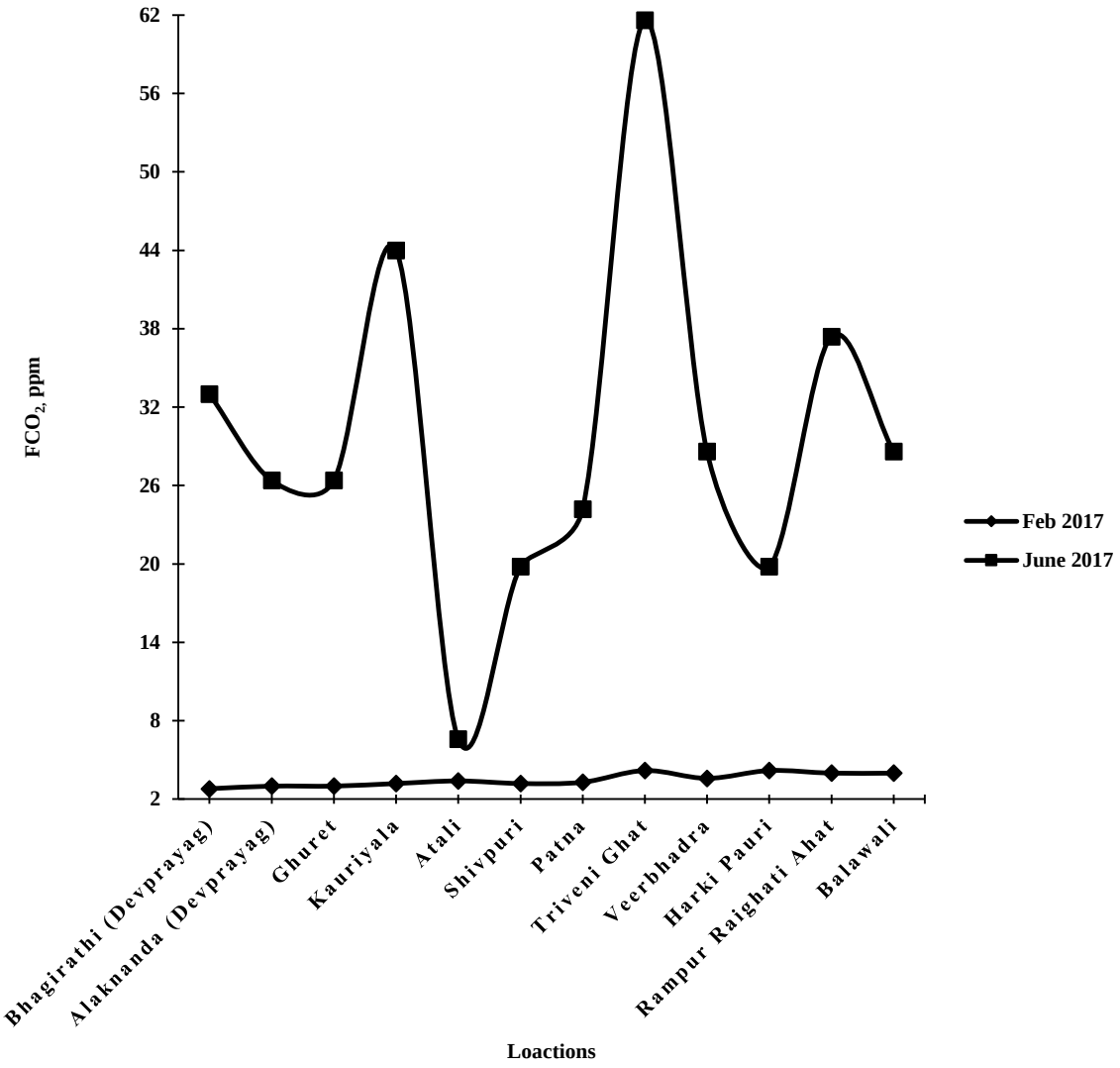


Fig. 4.10 The free CO_2 content of the sampled water at different locations

4.3 Statistical Analysis of Water Quality of the Samples

The physico-chemical properties of the samples of February and June were statistically analyzed and results were presented in Table 4.7 and 4.8 respectively. Correlation and regression analyses were carried out using Microsoft Excel 2013.

4.3.1 Correlation coefficient

Correlation analysis is useful for the measurement of the strength and statistical significance of the relation that exists between two variables, one taken as dependent variable. The correlation coefficients (R) were determined and correlation matrix was obtained. The negative sign of R value indicates that the correlation between the two parameters is of negative kind, i.e. as the value of the independent parameter increases, the value of the dependent parameter decreases or vice versa. Table 4.8 and Table 4.9 represent the correlation matrices for the 10 water quality parameters for the month of February and June respectively.

a) Very weak correlation was found between TAc & FCO_2 (-0.11), TH & Cl (-0.04), Cl & TAl (-0.02), TAc & Cl (0.01), TAc & pH (0.002) and MgH & Cl (0.11) as indicated by Table 4.7.

Weak correlation was found between EC & TAl (-0.31), EC & Cl (-0.29), TAc & CaH (-0.39), TAc & MgH (-0.39), TAc & TDS (-0.33), FCO_2 & Cl (-0.22), CaH & Cl (-0.29), CL & TDS (-0.28), EC & CaH (0.36), FCO_2 & Ca (0.39), CaH & TDS (0.36) and Cl & pH (0.36) as indicated by Table 4.7.

Moderate correlation was found between pH & EC (-0.51), TH & TAc (-0.44), TAl & TAc (-0.43), TH & pH (-0.51), CaH & pH (-0.46), MgH & pH (-0.44), TAl & pH (-0.40), pH & TDS (-0.51) and CaH & MgH (0.52) as indicated by Table 4.7.

Strong correlation was found between FCO_2 & pH (-0.65), EC & TH (0.63), EC & MgH (0.67), EC & TAl (0.74), FCO_2 & TH (0.61), FCO_2 & MgH (0.63), FCO_2 & TAl (0.71), TH & TDS (0.63), CaH & TAl (0.75), MgH & TDS (0.67) and TAl & TDS (0.74) as indicated by Table 4.7.

Very strong correlation was found between MgH & TAl (0.89), TH & CaH (0.80), TH & TAl (0.95), TH & MgH (0.92), FCO_2 & TDS (0.90), EC & FCO_2 (0.90) and EC & TDS (0.99) as indicated by Table 4.7.

b) Very weak correlation was found between EC & Cl (-0.09), pH & TAc (-0.17), Cl & TAc (-0.07), TH & CaH (-0.04), TH & pH (0.13), Cl & pH (0.07), TDS & CaH (0.09), FCO_2 & CaH (0.17), Cl & MgH (0.01) and Cl & TAl (0.15) as indicated by Table 4.8.

Weak correlation was found between CaH & pH (-0.36), TAl & pH (-0.22), Cl & TDS (-0.23), TAc & CaH (-0.23), TAc & MgH (-0.31), FCO_2 & Cl (-0.30), TH & TAl (-0.23), MgH & TAl (-0.32), CaH & EC (0.20), TAl & EC (0.33), pH & MgH (0.34), TDS & TAl (0.39), TAc & TAl (0.24), TH & Cl (0.30), CaH & Cl (0.25) and CaH & TAl (0.24) as indicated by Table 4.8.

Moderate correlation was found between TH & EC (-0.57), MgH & EC (-0.53), pH & FCO_2 (-0.55), TH & TDS (-0.56), MgH & TDS (-0.44), FCO_2 & MgH (-0.52), EC & TAc (0.52), TDS & TAc (0.47), FCO_2 & TAc (0.51) and FCO_2 & TAl (0.47) as indicated by Table 4.8.

Strong correlation was found between EC & pH (-0.74), TDS & pH (-0.69), TH & TAc (-0.72), FCO_2 & TH (-0.60), CaH & MgH (-0.74), TDS & FCO_2 (0.76) and TH & MgH (0.69) as indicated by Table 4.8.

Very strong correlation was found between EC & TDS (0.95) and EC & FCO_2 (0.80) as indicated by Table 4.8.

Table 4.7 Correlation matrix of the pre-monsoon (February 2017) water samples

	EC	TAc	FCO_2	TH	CaH	MgH	Cl	TAl	pH	TDS
EC	1									
TAc	-0.31	1								
FCO_2	0.90	-0.11	1							
TH	0.63	-0.44	0.61	1						
CaH	0.36	-0.39	0.39	0.80	1					
MgH	0.67	-0.39	0.63	0.92	0.52	1				
Cl	-0.29	0.01	-0.22	-0.04	-0.29	0.11	1			
TAl	0.74	-0.43	0.71	0.95	0.75	0.89	-0.02	1		
pH	-0.51	0.002	-0.65	-0.51	-0.46	-0.44	0.36	-0.40	1	
TDS	0.99	-0.33	0.90	0.63	0.36	0.67	-0.28	0.74	-0.51	1

Table 4.8 Correlation matrix of the post-monsoon (June 2017) water samples

	EC	pH	TDS	TAc	FCO_2	TH	CaH	MgH	Cl	TAl
EC	1									
pH	-0.74	1								
TDS	0.95	-0.69	1							
TAc	0.52	-0.17	0.47	1						
FCO_2	0.80	-0.55	0.76	0.51	1					
TH	-0.57	0.13	-0.56	-0.72	-0.60	1				
CaH	0.20	-0.36	0.09	-0.23	0.17	-0.04	1			
MgH	-0.53	0.34	-0.44	-0.31	-0.52	0.69	-0.74	1		
Cl	-0.09	0.07	-0.23	-0.07	-0.35	0.30	0.25	0.01	1	
TAl	0.33	-0.22	0.39	0.24	0.47	-0.23	0.24	-0.32	0.15	1

4.3.2 Simple linear regression model

MS Excel 2013 was used to prepare simple linear regression models relating a dependent water quality parameter to a statistically independent water quality parameter. Dependent and Independent parameters are decided on the basis of P-value while doing regression analysis. Value of R lies between $-1 \leq R \leq 1$ and R^2 lies between $0 \leq R^2 \leq 1$ indicates the strength of the linear association between the dependent and the independent variable. Simple linear regression equations showing relationships between various dependent parameters and other physico-chemical water properties, their corresponding R, R^2 and P-values for February and June are presented in Table 4.9 and 4.10 respectively.

The observed and the estimated values for February are shown in Fig. 4.11 to Fig. 4.18 and for June are shown in Fig 4.19 to Fig. 4.26. The results indicated that the relationships developed could be used somewhat satisfactorily to evaluate the water quality of various parameters.

Table 4.9 Regression equations of the samples with corresponding R, R^2 and P-values for the month of February 2017

S. No.	Equation	R	R^2	P-value
1	TDS = 0.18 + 0.59 × EC	0.99	0.99	2.68e-17
2	TDS = - 2.43 + 22.95 × FCO_2	0.90	0.81	6.62e-05
3	TDS = - 76.26 + 2.01 × TH	0.63	0.40	0.02
4	TDS = - 28.05 + 3.07 × MgH	0.67	0.46	0.01
5	TDS = - 75.97 + 2.26 × TAl	0.74	0.56	0.01
6	pH = 7.84 - 0.09 × FCO_2	0.65	0.43	0.01
7	TAl = 48.57 + 0.14 × EC	0.74	0.56	0.01
8	TAl = 46.77 + 6 × FCO_2	0.71	0.50	0.01
9	TAl = - 8.82 + TH	0.95	0.91	1.15e-06
10	TAl = - 8.74 + 1.81 × CaH	0.75	0.57	0.004
11	TAl = 21.68 + 1.33 × MgH	0.89	0.80	7.8e-05
12	TAl = 48.56 + 0.24 × TDS	0.74	0.56	0.01
13	MgH = 22.83 + 0.08 × EC	0.67	0.45	0.01
14	MgH = 21.89 + 3.58 × FCO_2	0.63	0.40	0.02
15	MgH = - 15.4 + 0.65 × TH	0.92	0.86	1.25e-05

16	MgH = - 6.27 + 0.6 × TAl	0.89	0.80	7.8e-05
17	MgH = 22.74 + 0.15 × TDS	0.67	0.46	0.01
18	CaH = 15.39 + 0.34 × TH	0.80	0.64	0.001
19	CaH = 30.91 + 1.32 × MgH	0.92	0.86	1.25e-05
20	TH = - 1.23 + 1.84 × CaH	0.80	0.64	0.001
21	TH = 61.09 + 0.11 × EC	0.63	0.39	0.02
22	TH = 59.26 + 4.95 × FCO_2	0.61	0.37	0.03
23	TH = 30.91 + 1.32 × MgH	0.92	0.86	1.25e-05
24	TH = 14.6 + 0.91 × TAl	0.95	0.91	1.15e-06
25	TH = 61 + 0.2 × TDS	0.63	0.40	0.02
26	FCO_2 = 0.73 + 0.02 × EC	0.90	0.81	5.21e-05
27	FCO_2 = - 2.36 + 0.07 × TH	0.61	0.37	0.03
28	FCO_2 = - 0.39 + 0.11 × MgH	0.63	0.40	0.02
29	FCO_2 = - 2.25 + 0.08 × TAl	0.71	0.50	0.01
30	FCO_2 = 37.75 - 4.55 × pH	0.65	0.43	0.01
31	FCO_2 = 0.74 + 0.03 × TDS	0.90	0.81	6.62e-05
32	EC = - 5.04 + 38.55 × FCO_2	0.90	0.81	5.21e-05
33	EC = - 126.7 + 3.34 × TH	0.63	0.40	0.02
34	EC = - 46.14 + 5.1 × MgH	0.67	0.45	0.01
35	EC = - 127.54 + 3.79 × TAl	0.74	0.56	0.01
36	EC = - 0.22 + 1.67 × TDS	0.99	0.99	2.68e-17

Table 4.10 Regression equations of the samples with corresponding R, R^2 and P-values for the month of June 2017

S. No.	Equation	R	R^2	P-value
1	MgH = - 124.9 + 1.04 × TH	0.69	0.48	0.01
2	MgH = 169.55 - 1.03 × CaH	0.74	0.55	0.01
3	TH = 305 - 0.94 × EC	0.57	0.33	0.04
4	TH = 310.26 - 1.97 × TDS	0.56	0.32	0.05
5	TH = 225.69 - 1.14 × TAc	0.72	0.52	0.01
6	TH = 199.93 - 1.17 × FCO_2	0.6	0.36	0.03
7	TH = 142.82 + 0.46 × MgH	0.69	0.48	0.01
8	FCO_2 = - 70.4 + 0.67 × EC	0.8	0.65	0.001
9	FCO_2 = 288.7 - 42 × pH	0.55	0.31	0.05
10	FCO_2 = - 71.39 + 1.37 × TDS	0.76	0.59	0.003
11	FCO_2 = 80.7 - 0.3 × TH	0.6	0.36	0.03
12	TDS = 7.5 + 0.44 × EC	0.95	0.9	2.02e-06
13	TDS = 254.65 - 29.36 × pH	0.69	0.48	0.01
14	TDS = 60.79 + 0.43 × FCO_2	0.76	0.59	0.003
15	TDS = 100.42 - 0.16 × TH	0.56	0.32	0.05
16	pH = 7.4 - 0.008 × EC	0.74	0.55	0.01
17	pH = 7.38 - 0.01 × TDS	0.69	0.48	0.01
18	pH = 6.38 - 0.007 × FCO_2	0.55	0.31	0.05
19	CaH = 142.82 - 0.53 × MgH	0.74	0.55	0.01
20	TAc = 128.62 - 0.45 × TH	0.72	0.52	0.01
21	EC = 563.18 - 67.27 × pH	0.74	0.55	0.01
22	EC = - 1.07 + 2.03 × TDS	0.95	0.9	2.02e-06
23	EC = 119.69 + 0.96 × FCO_2	0.8	0.65	0.001
24	EC = 206.81 - 0.35 × TH	0.57	0.33	0.04

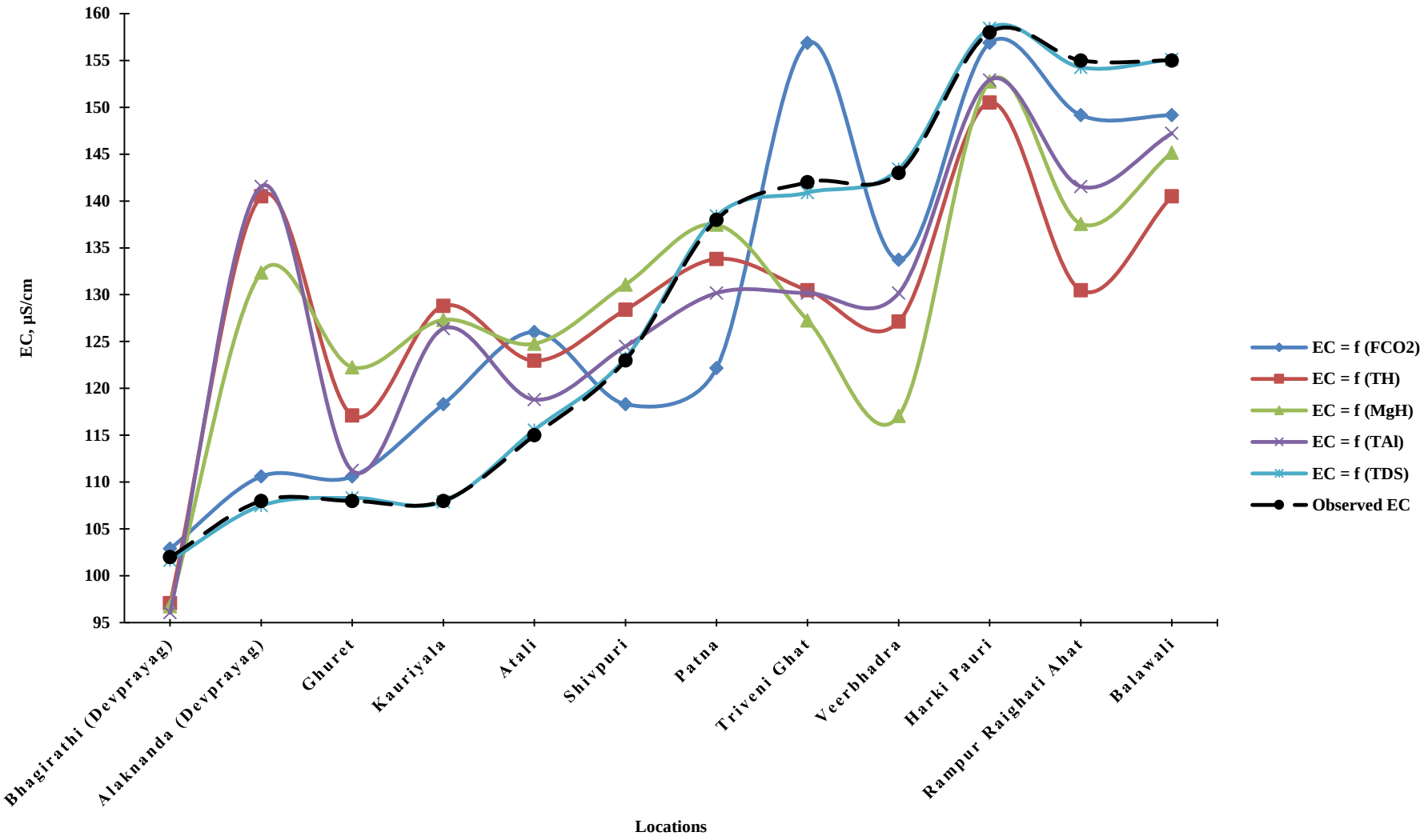


Fig 4.11 Estimated and observed values of EC in February 2017

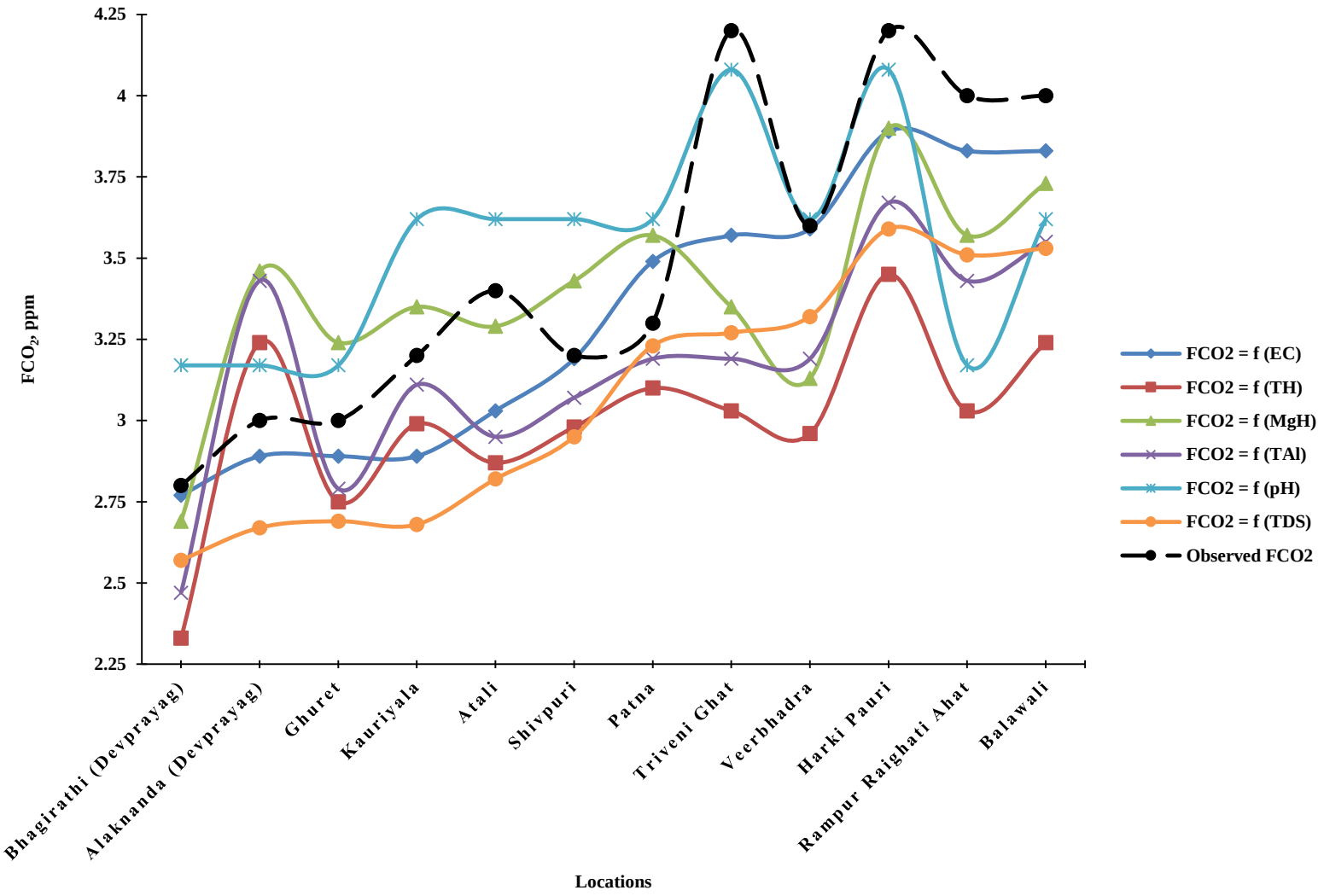


Fig 4.12 Estimated and observed values of free CO_2 in February 2017

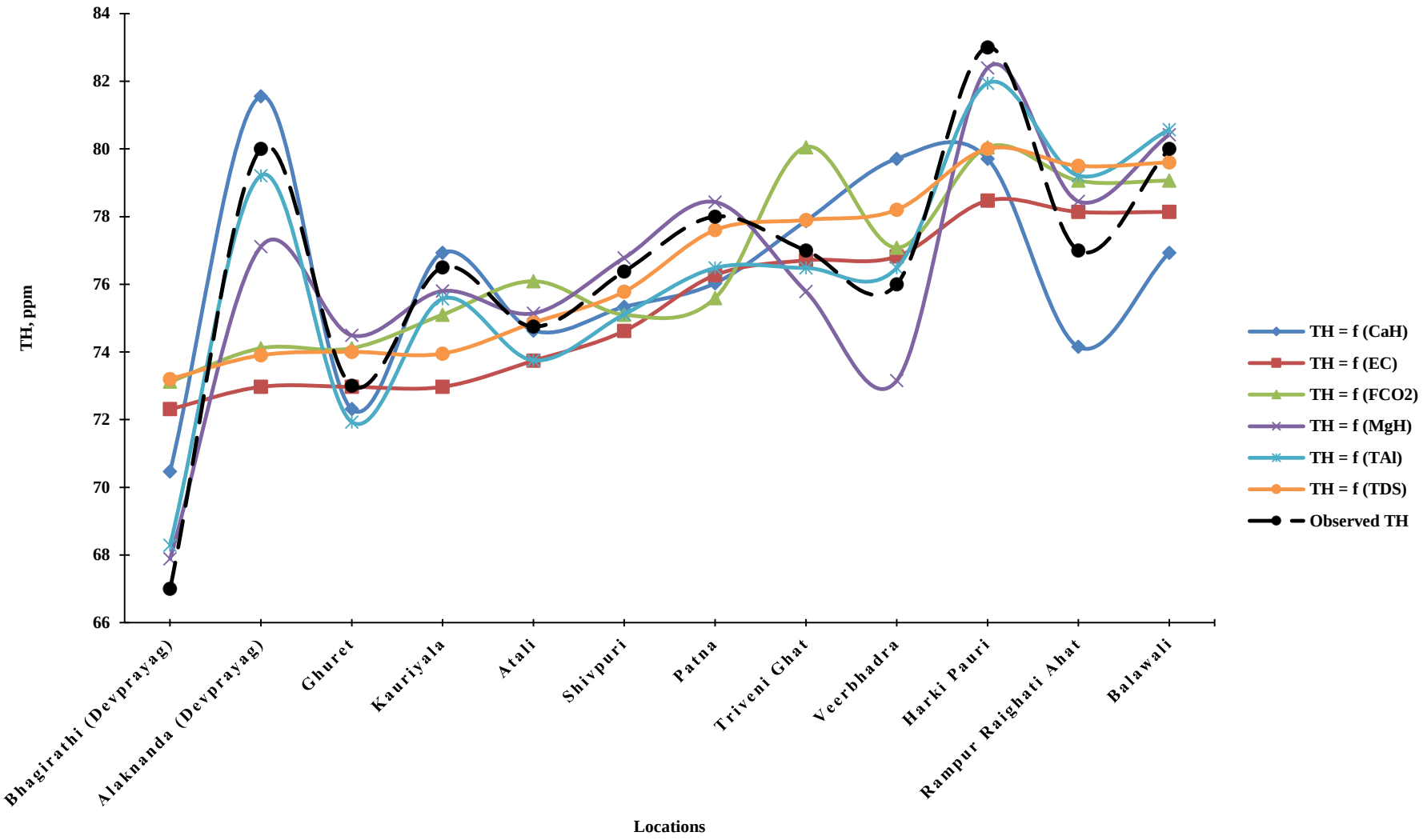


Fig 4.13 Estimated and observed values of total hardness in February 2017

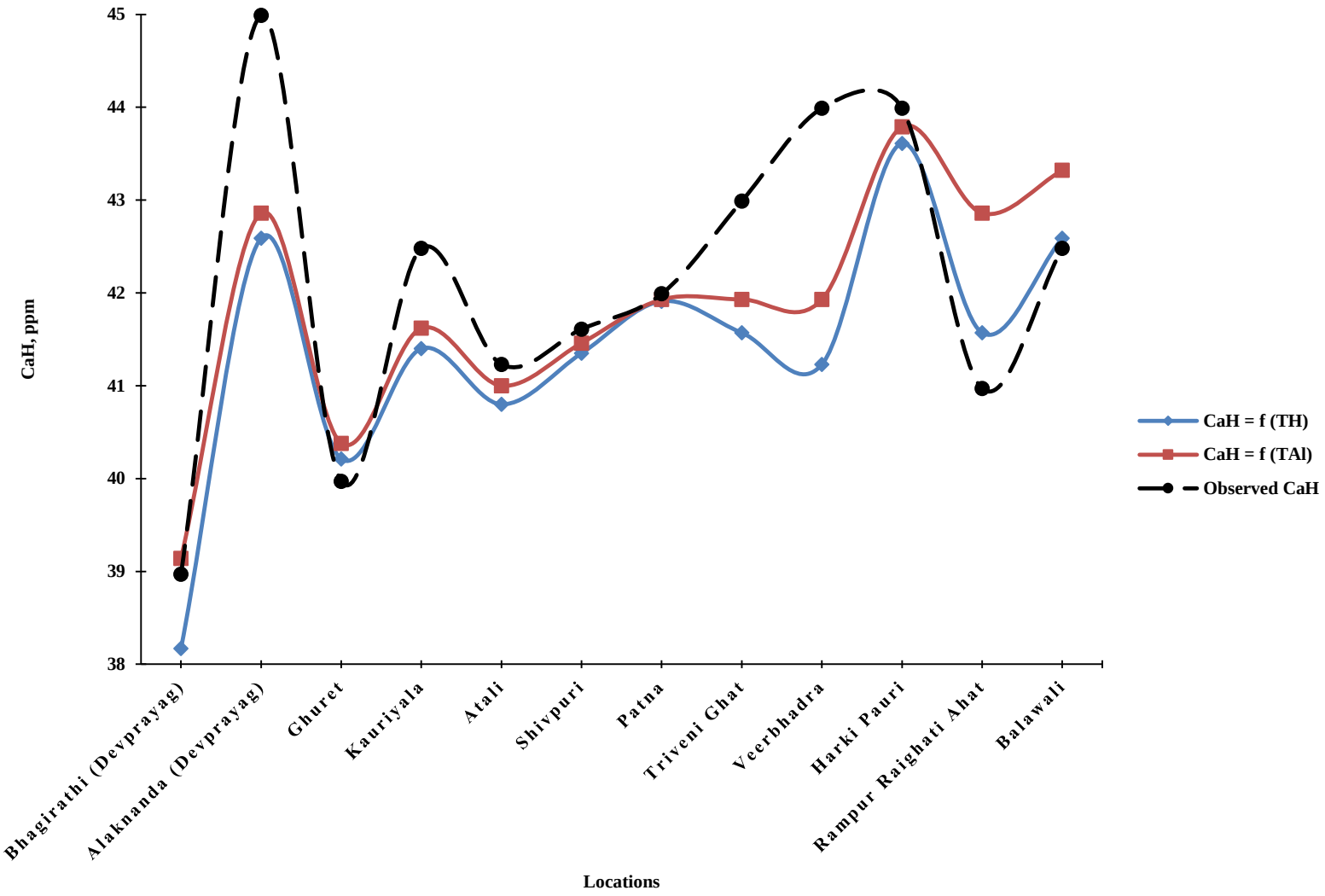


Fig 4.14 Estimated and observed values of calcium hardness in February 2017

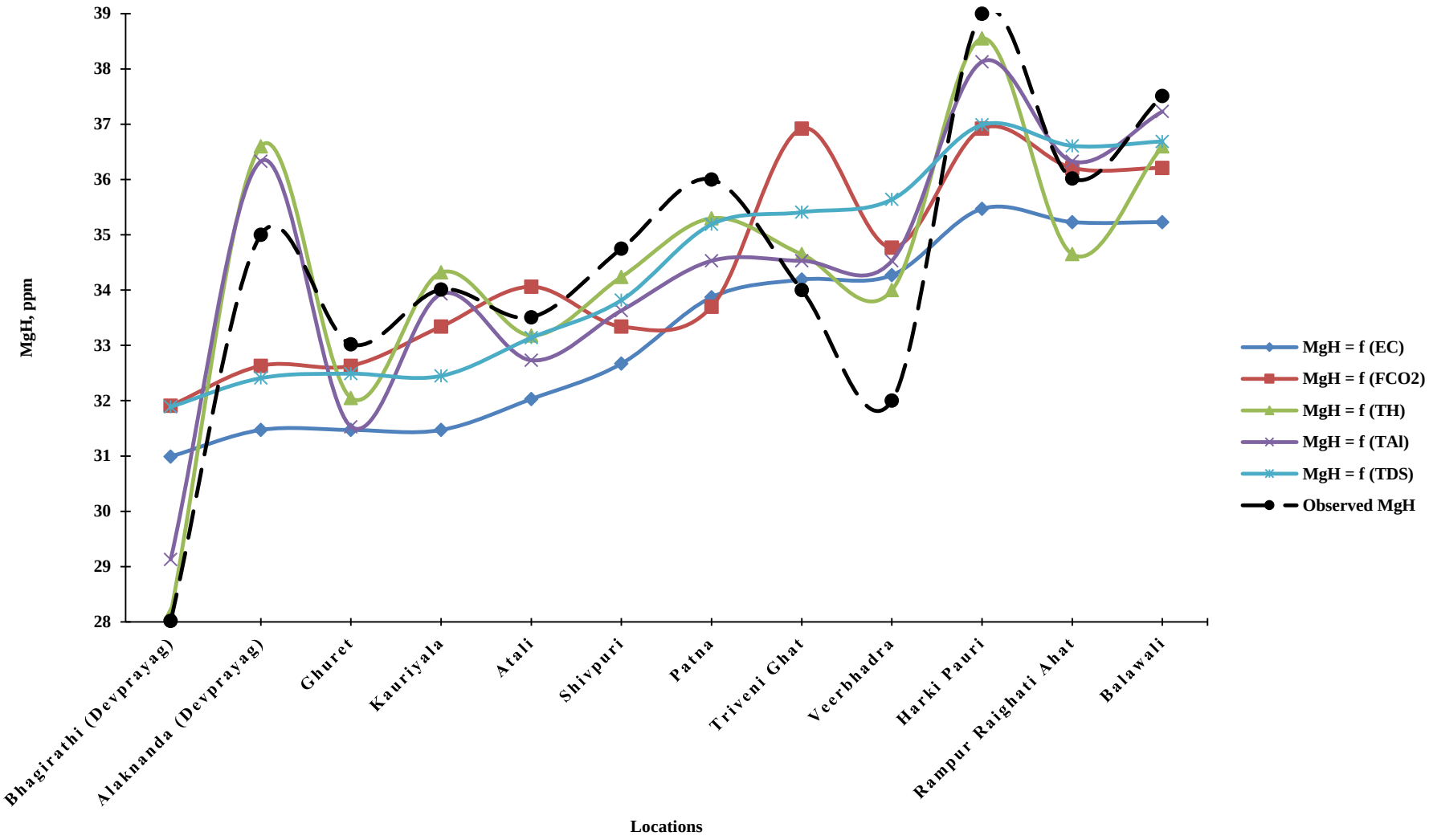


Fig 4.15 Estimated and observed values of magnesium hardness in February 2017

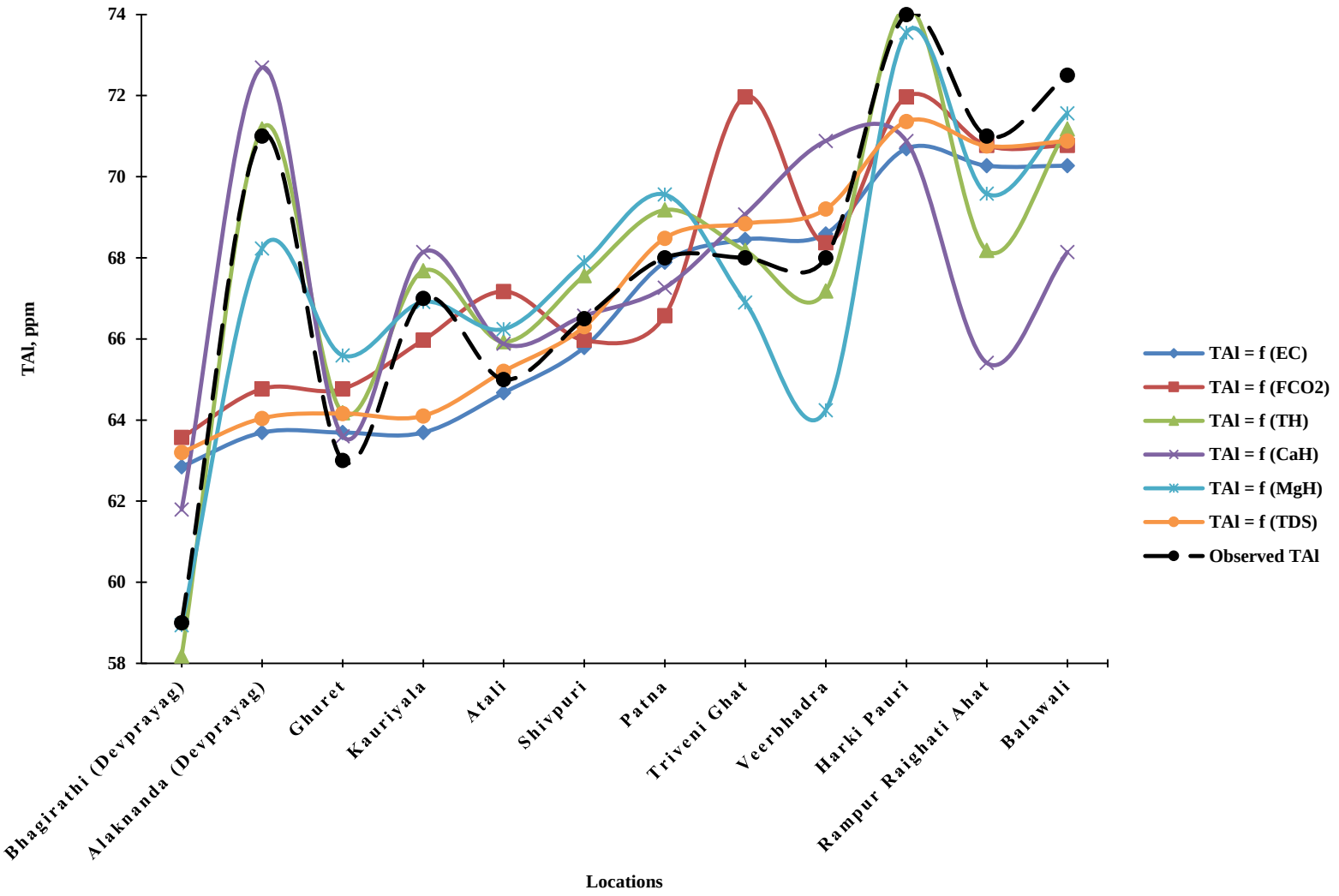


Fig 4.16 Estimated and observed values of total alkalinity in February 2017

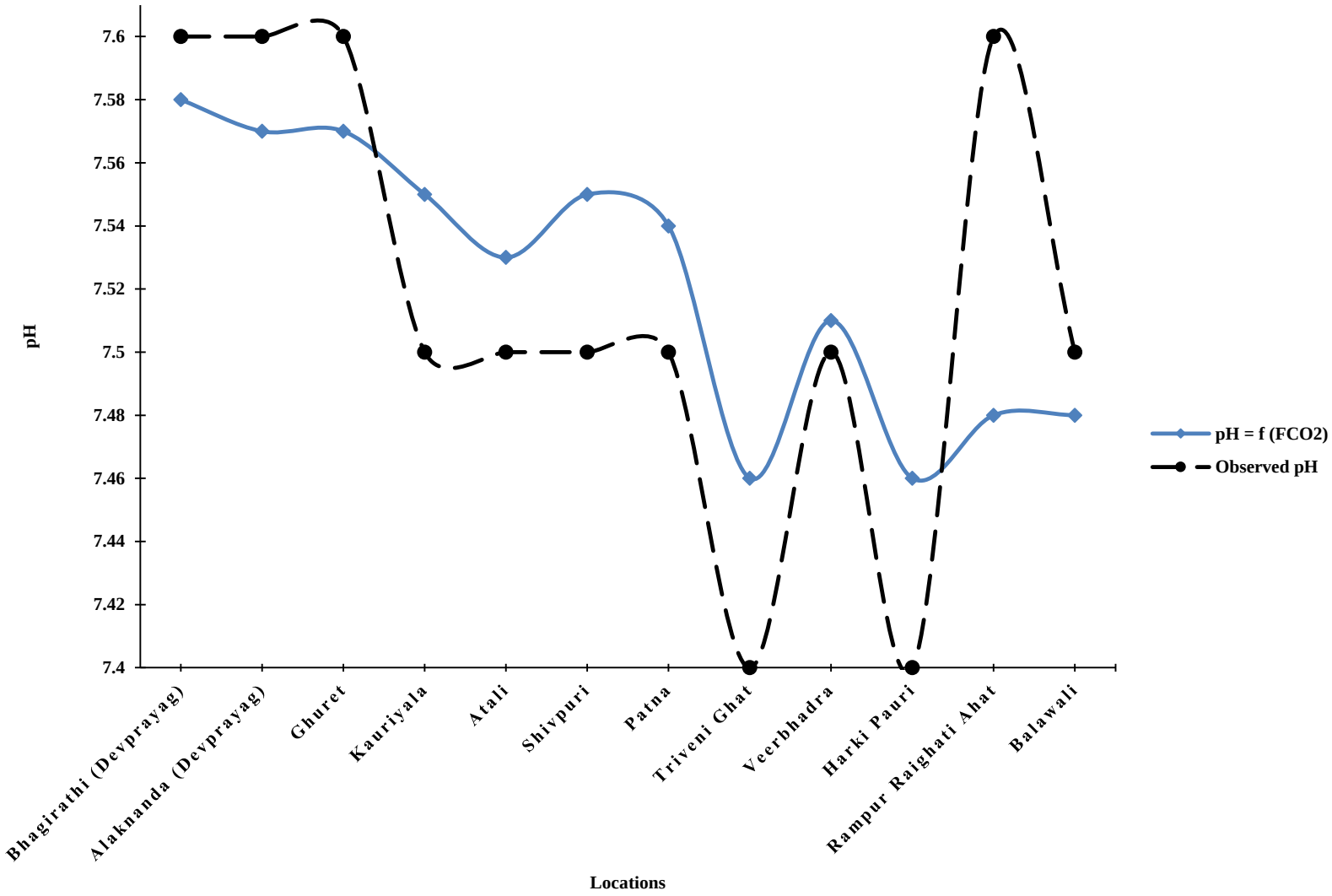


Fig 4.17 Estimated and observed values of pH in February 2017

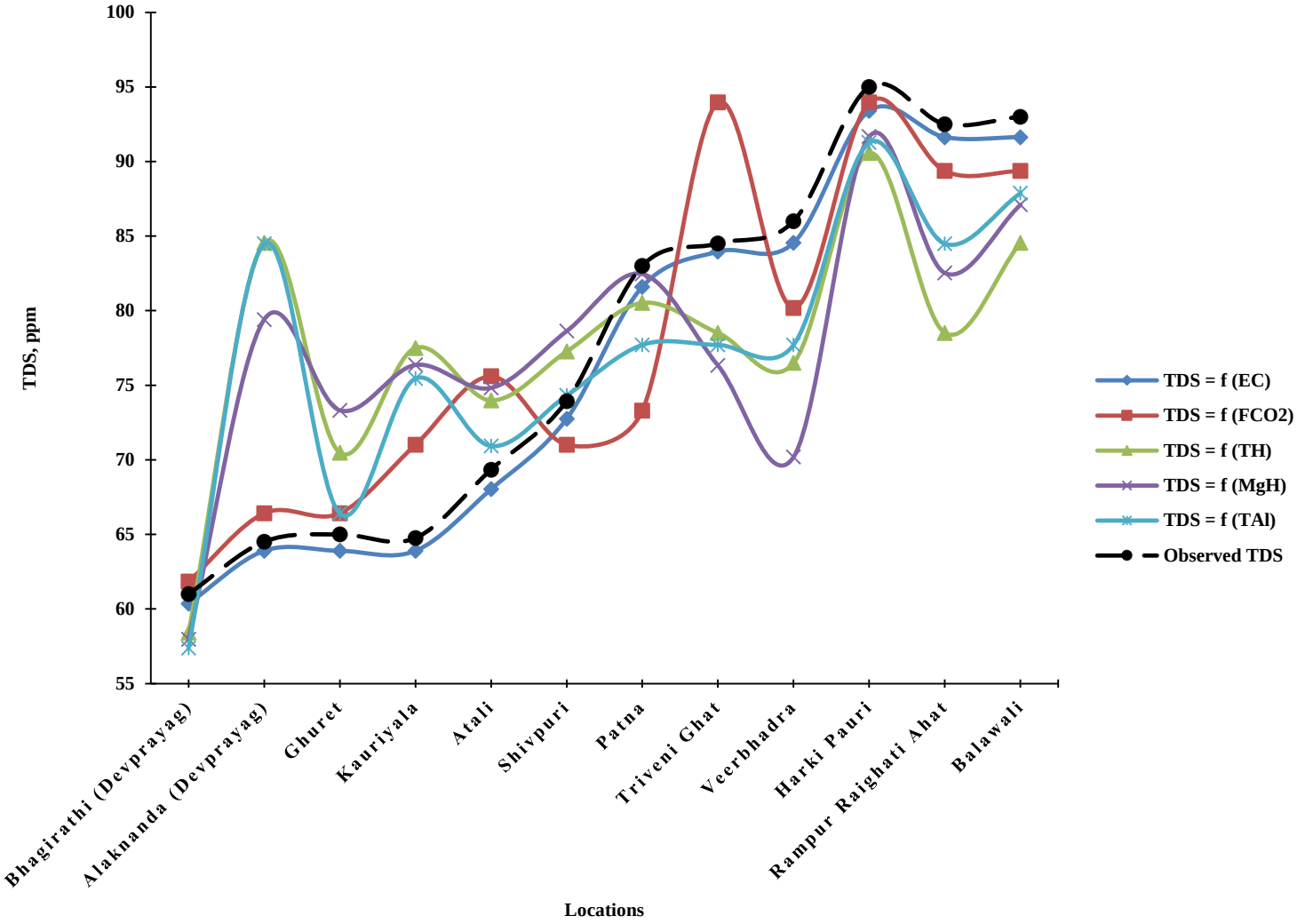


Fig 4.18 Estimated and observed values of TDS in February 2017

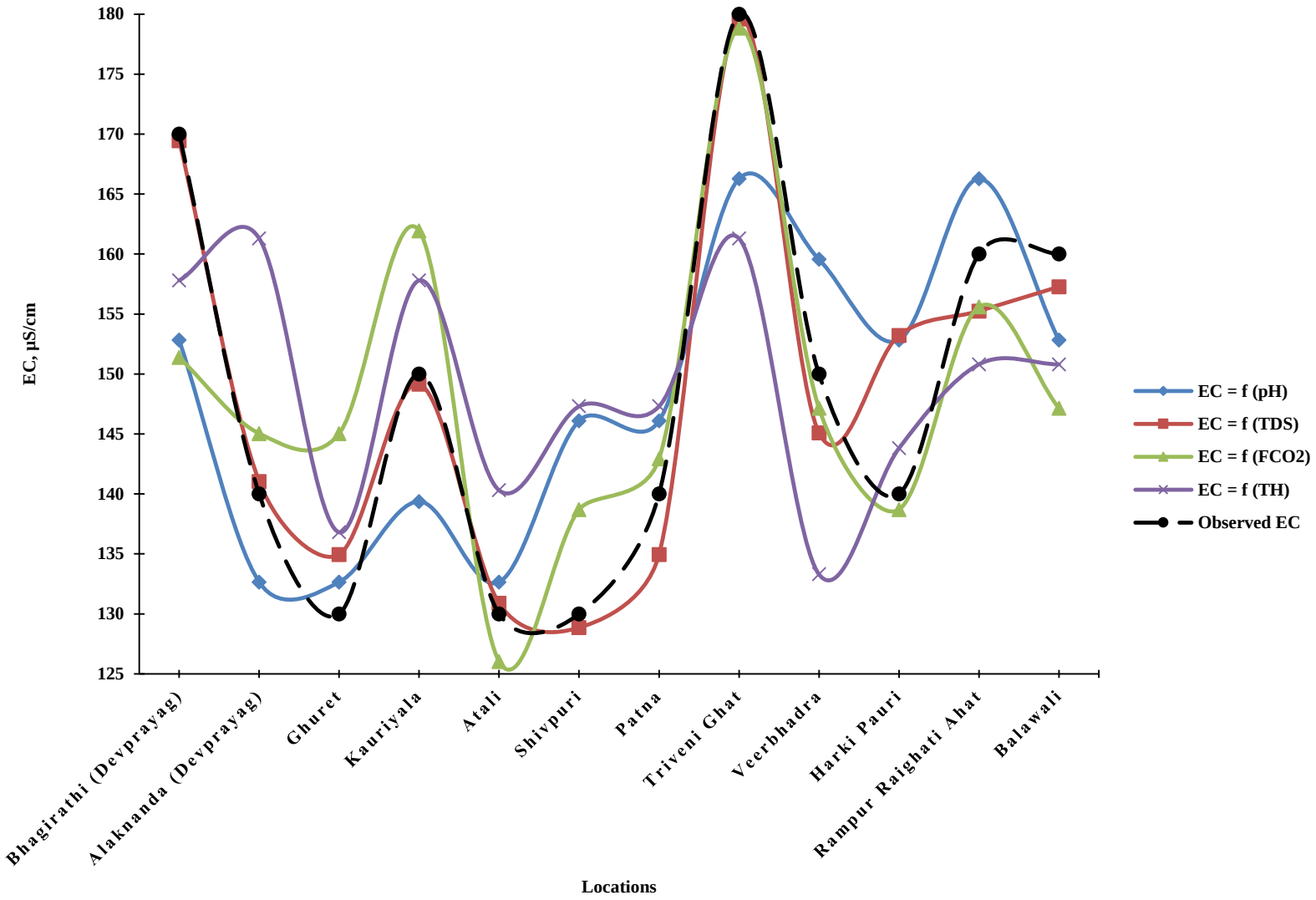


Fig 4.19 Estimated and observed values of EC in June 2017

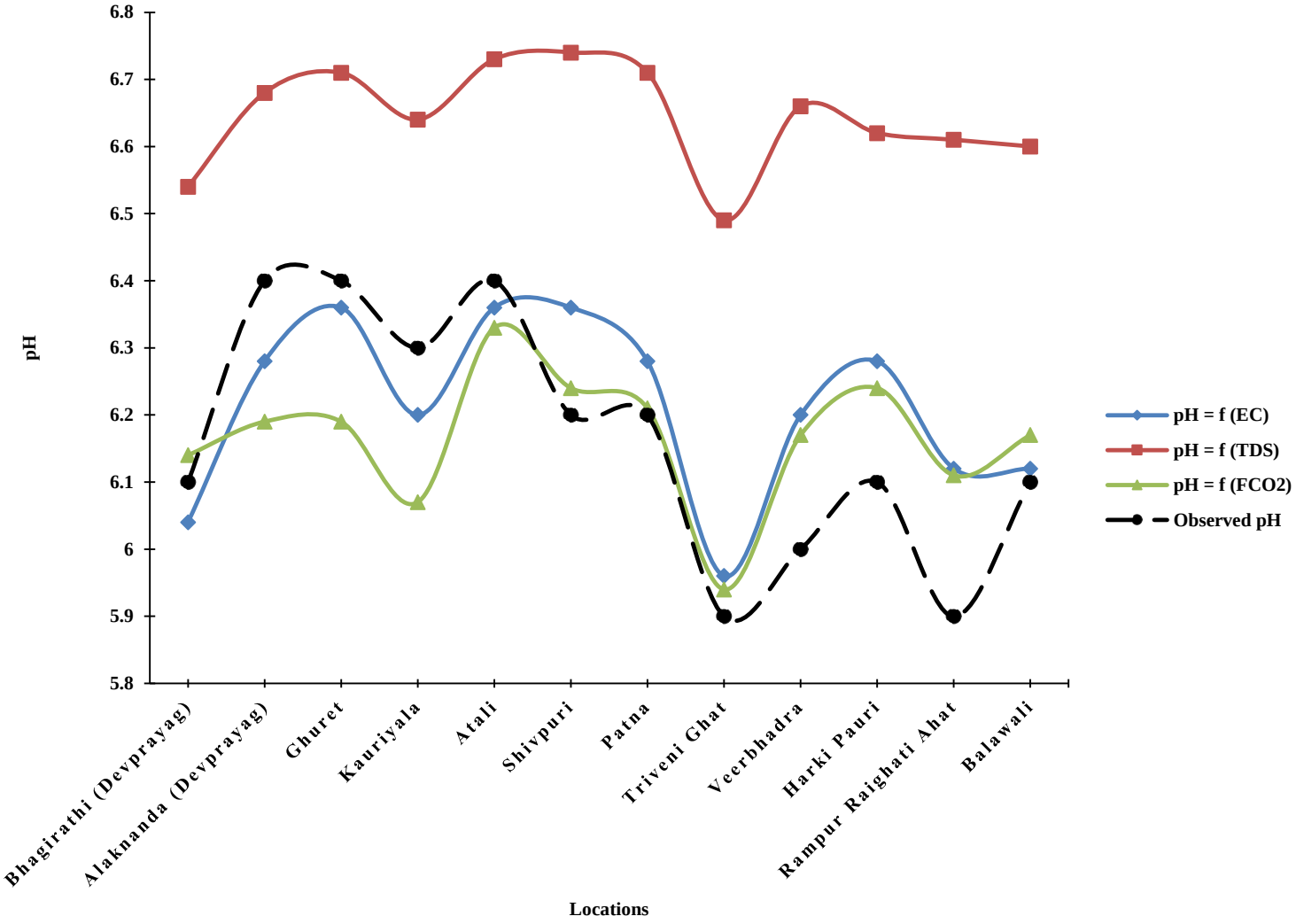


Fig. 4.20 Estimated and observed values of pH in June 2017

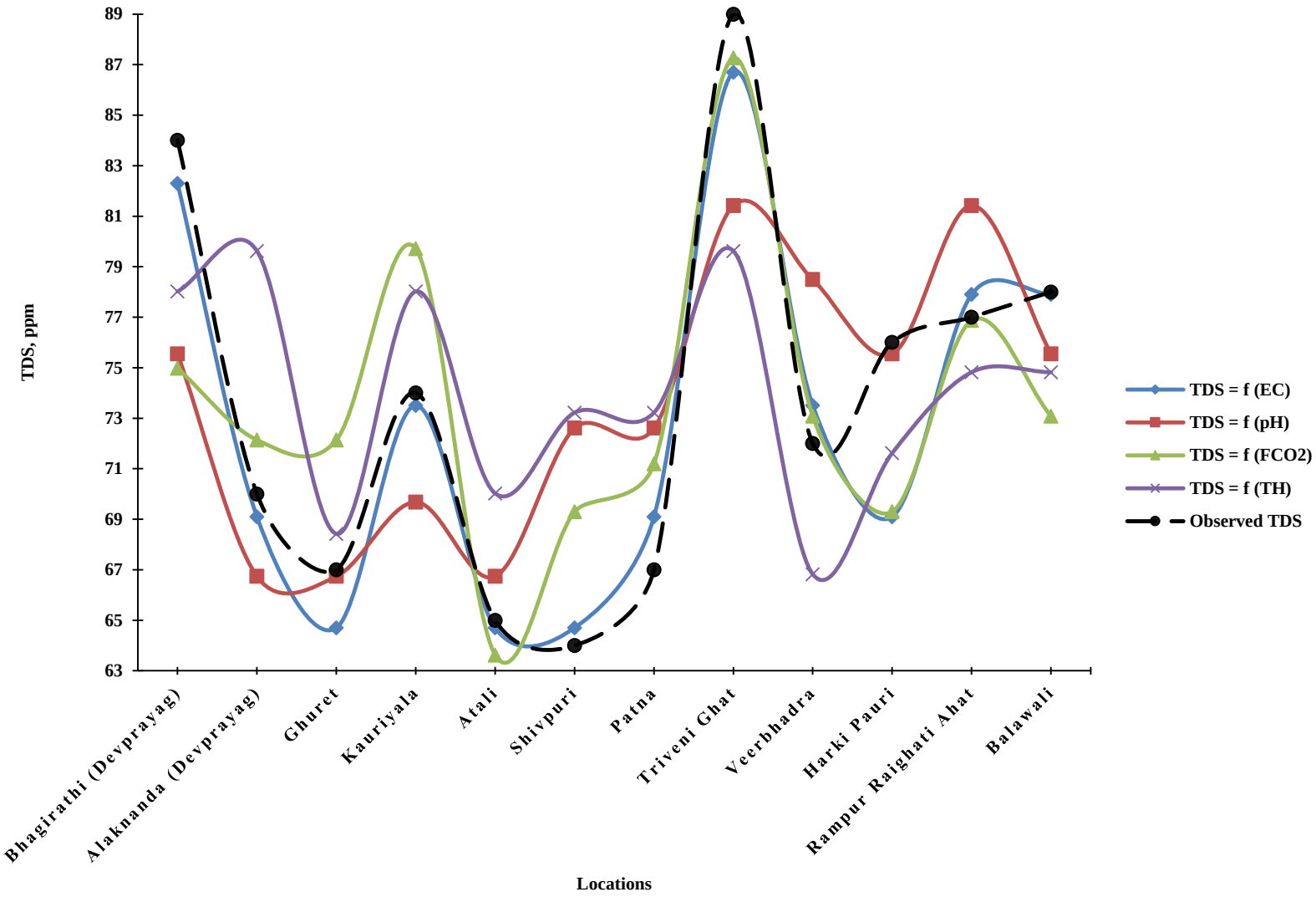


Fig 4.21 Estimated and observed values of TDS in June 2017

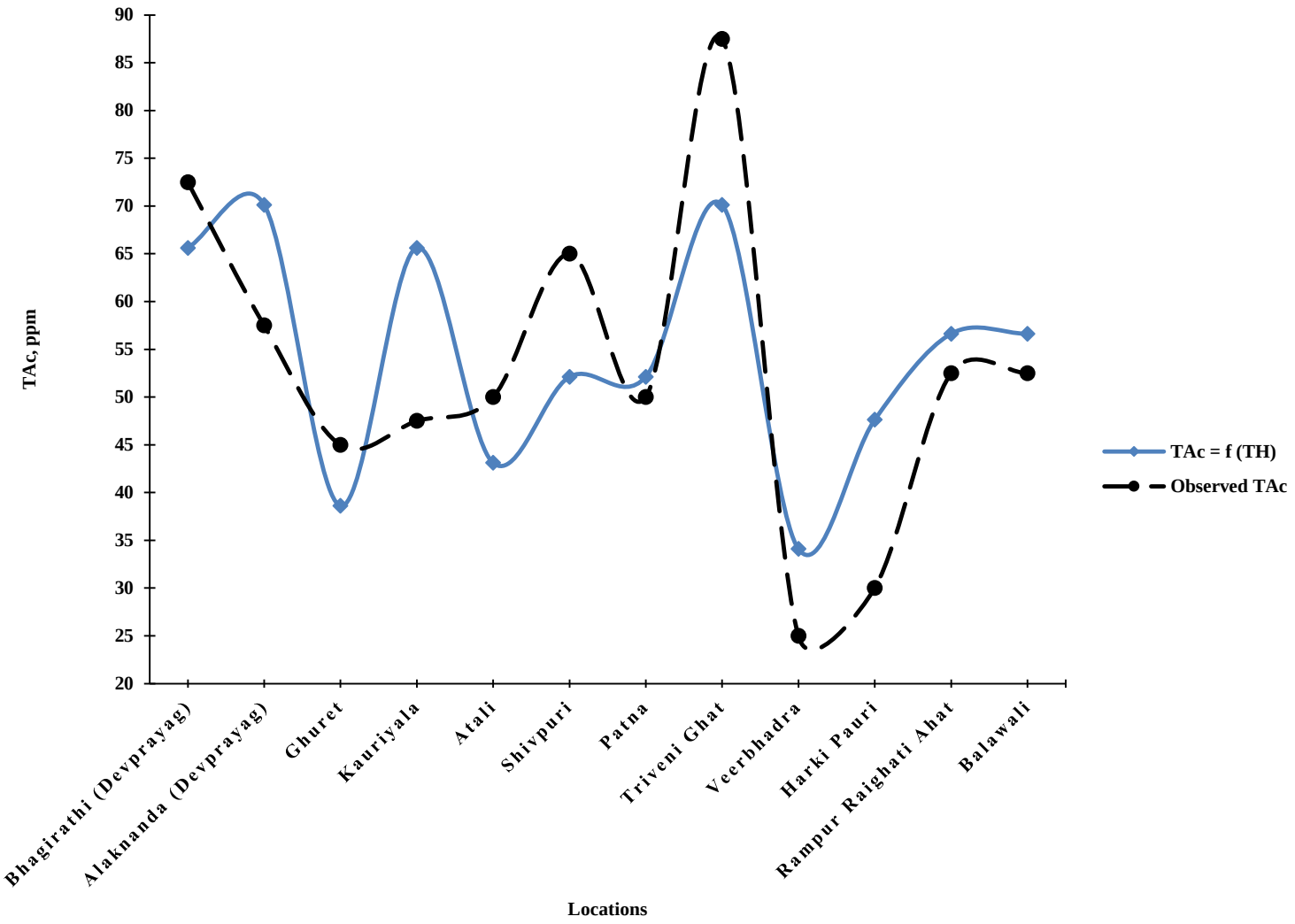


Fig. 4.22 Estimated and observed values of total acidity in June 2017

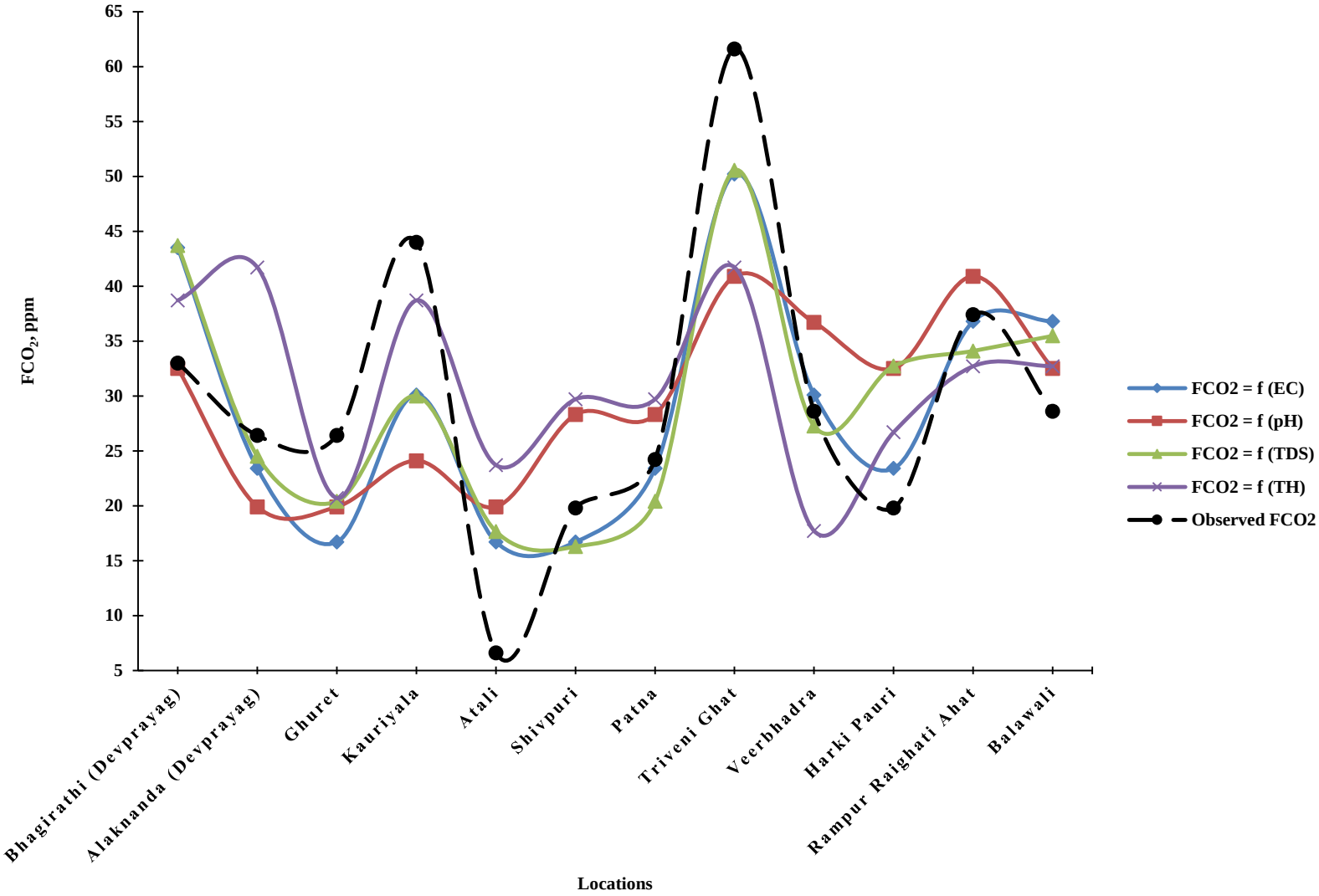


Fig. 4.23 Estimated and observed values of free CO_2 in June 2017

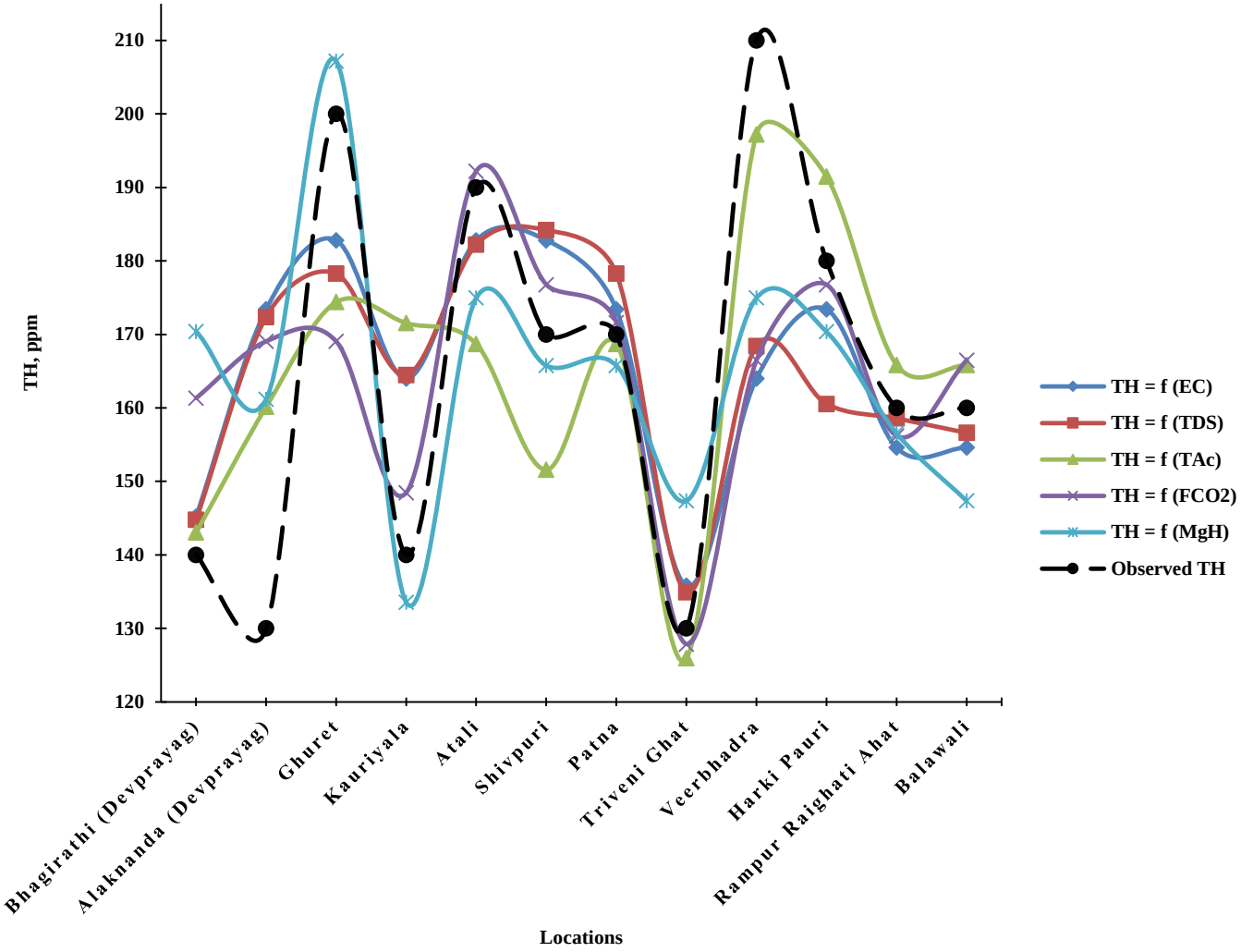


Fig. 4.24 Estimated and observed values of total hardness in June 2017

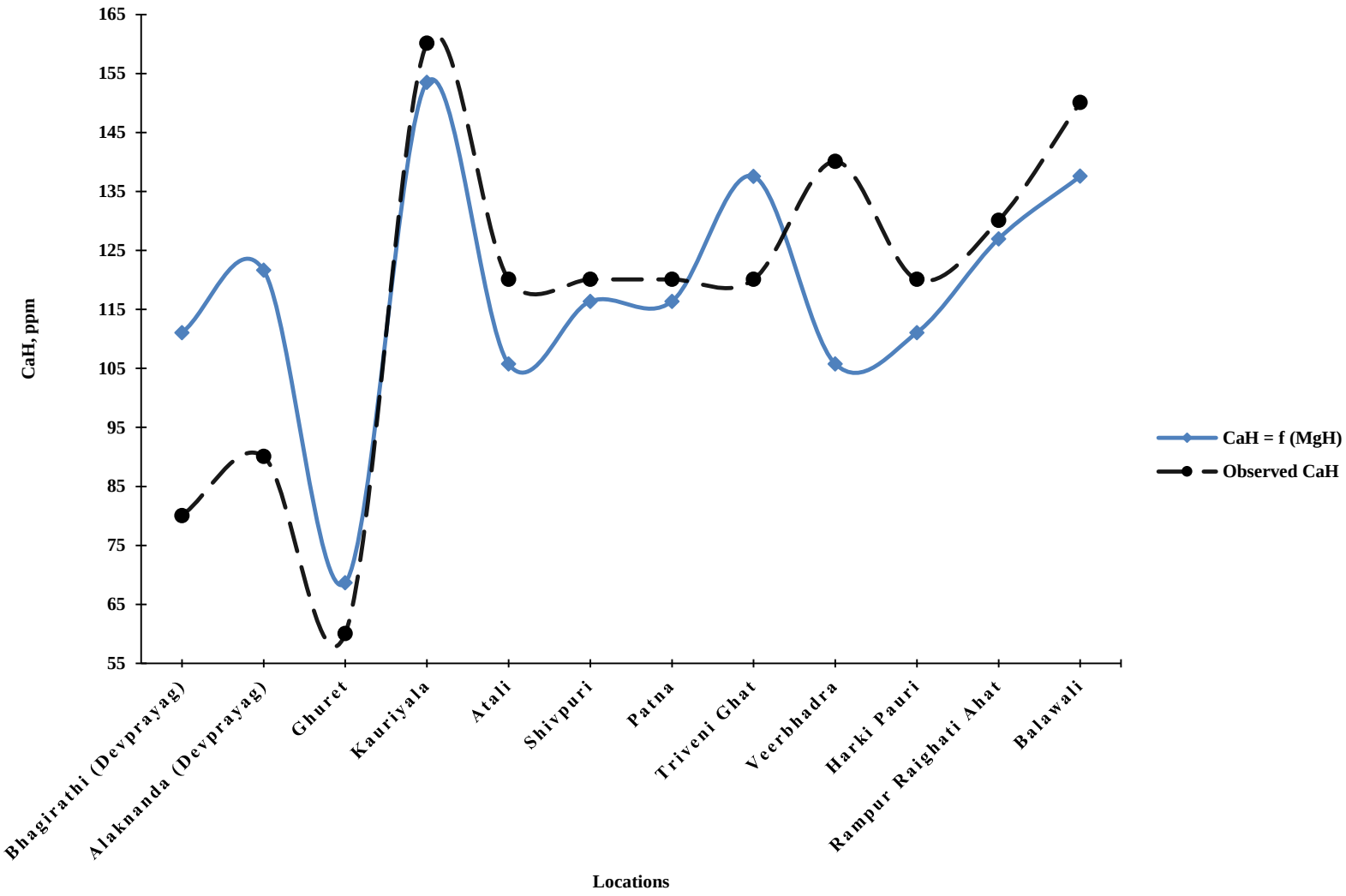


Fig. 4.25 Estimated and observed values of calcium hardness in June 2017

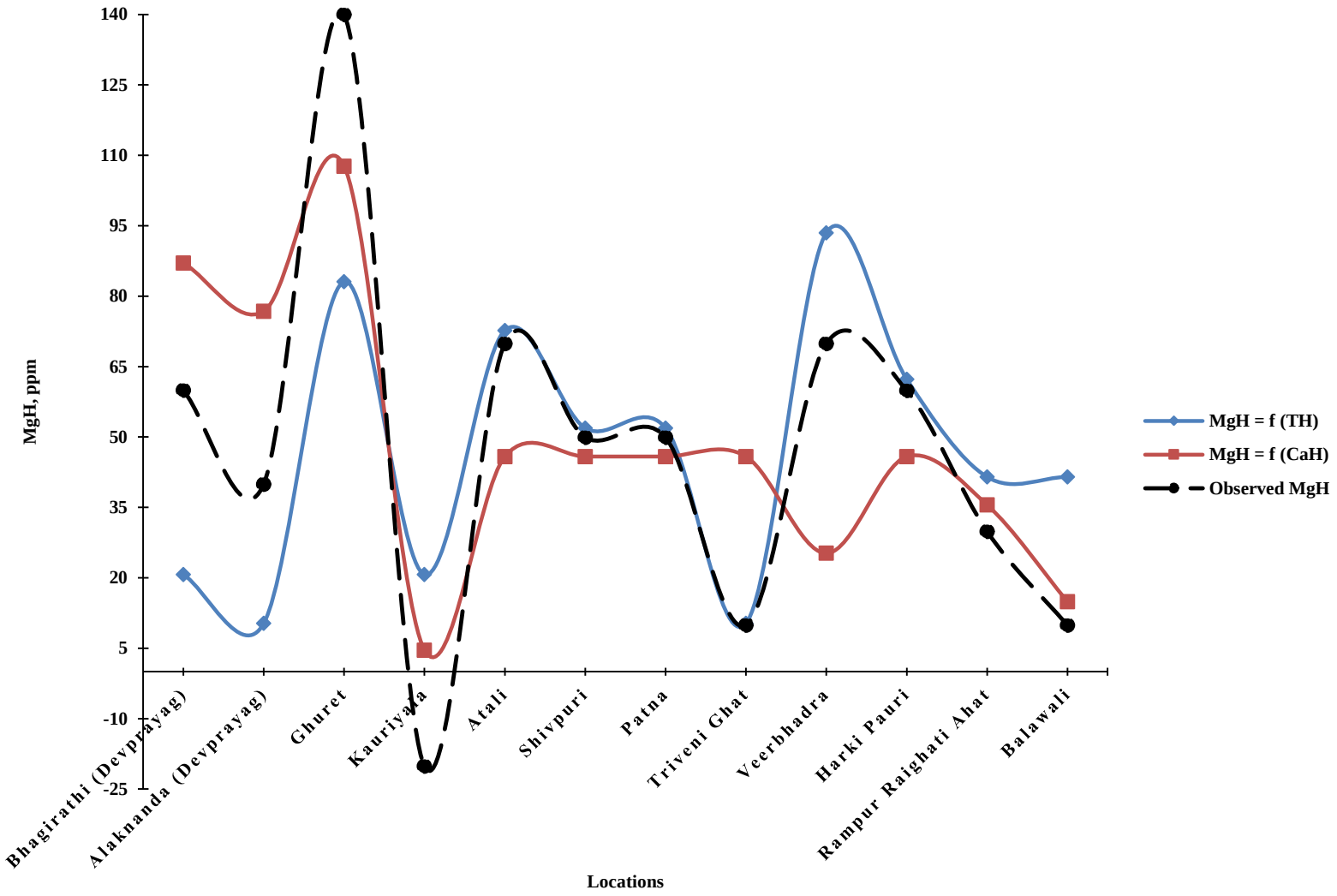


Fig. 4.26 Estimated and observed values of magnesium hardness in June 2017

5. SUMMARY AND CONCLUSIONS

5.1 Summary

Water is prime natural resource and it is a basic human need. Special efforts should be made to develop, technological capability to collect, process and disseminate data (National Water Policy, 2012). Rivers have become one of the major sources of water to meet the requirements of domestic and irrigation purposes in India due to the easy availability and reliability since a number of dams, reservoirs, etc. are built on it. Water is also used for sanitation and waste disposal and not only for domestic and commercial purposes but also for industrial and irrigation purposes. The impurities are in the form of physical, chemical and biological parameters due to rapid industrialization, overpopulation and indiscriminate use of chemicals in agriculture field.

In the present and estimated study, physical and chemical parameters of the river were observed. The river Ganga segment in Uttarakhand was taken as study area from Devprayag (30.14^0N, 78.59^0E) to Balawali (29.64^0N, 78.10^0E). From the study area, a total of 12 locations were selected and water samples were taken in February (pre-monsoon) and June (post-monsoon).

River water is being used by people throughout its length without even caring about its quality. Various attributes of the samples were observed and used to create classification charts. Water quality parameters were also analyzed for correlation and regression analysis using Microsoft Excel 2013. The simple linear regression analyses were done for various parameters for useful future predictions for planners, water quality managers and decision markers for initiating water quality development and management in the study area.

In February, the pH of the samples varied from 7.4 (Triveni ghat and Harki pauri) to 7.6 (Bhagrathi, Alaknanda, Ghuret and Rampur Raighati Ahat), the EC of the samples varied from 102 µS/cm (Bhagrathi) to 158 µS/cm (Harki Pauri), the TDS of the samples varied from 61 ppm (Bhagrathi) to 95 ppm (Harki Pauri), the total hardness of the samples varied from 67 ppm (Bhagrathi) to 83 ppm (Harki Pauri), the calcium hardness of the samples varied from 38.98 ppm (Bhagirathi) to 45 ppm (Alaknanda), the magnesium hardness of the samples varied from 28.02 ppm (Bhagrathi) to 39 ppm (Harki Pauri), the total acidity of the samples varied from 13 ppm (Veerbhadra) to 40 ppm (Triveni ghat), the total alkalinity of the samples varied from 59 ppm (Bhagrathi) to 74 ppm (Harki Pauri), the chloride content

of the samples varied from 5 ppm (Patna, Triveni ghat and Veerbhadra) to 5.6 ppm (Atali, Shivpuri and Balawali) and the free carbon dioxide of the samples varied from 2.8 ppm (Bhagrathi) to 4.2 ppm (Triveni ghat and Harki Pauri) whereas in June, the pH of the samples varied from 5.9 (Triveni ghat and Rampur Raighati Ahat) to 6.4 (Alaknanda, Ghuret and Atali), the EC of the samples varied from 130 µS/cm (Ghuret, Atali and Shivpuri) to 180 µS/cm (Triveni ghat), the TDS of the samples varied 64 ppm (Shivpuri) to 89 ppm (Triveni ghat), the total hardness of the samples varied from 130 ppm (Alaknanda and Triveni ghat) to 210 ppm (Veerbhadra), the calcium hardness of the samples varied from 60.05 ppm (Ghuret) to 160.13 ppm (Kauriyala), the magnesium hardness of the samples varied from -20.13 ppm (Kauriyala) to 139.95 ppm (Ghuret), the total acidity of the samples varied from 25 ppm (Veerbhadra) to 87.5 ppm (Triveni ghat), the total alkalinity of the samples varied from 85 ppm (Bhagrathi) to 125 ppm (Triveni ghat), the chloride content of the samples varied from 14.2 ppm (Ghuret and Harki Pauri) to 35.5 ppm (Atali) and the free carbon dioxide of the samples varied from 6.6 ppm (Atali) to 61.6 ppm (Triveni ghat).

On the basis of classification of tolerance limits for inland surface waters, in February, pH, TDS, calcium hardness, total hardness, magnesium hardness and chloride content of all the samples were falling in class - A, free carbon dioxide and EC of all the samples were falling in class - D whereas in June, pH was falling in class - E for all the samples except for Triveni ghat and Rampur Raighati Ahat, for which it was falling in class - Below E, TDS, calcium hardness, total hardness and chloride content for all the samples were falling in class - A, magnesium hardness of all the samples was falling in class - E except for Ghuret, free carbon dioxide of all the samples was falling in class - Below E, EC of all the samples was falling in class - D.

On the basis of classification of irrigation water, EC of all the samples was falling in class - C1 for February and June.

5.2 Conclusions

1) The taste of the water taken in samples of both the months was agreeable. The odor of the water samples of both the months was unobjectionable. The water samples were clear in February whereas the samples were brown colored in June.

2) The pH of the samples was found to be within the desirable limit in February whereas it was beyond the desirable limit in June. EC and TDS were within the desirable limit in both the months.
3) The total hardness was found to be within the desirable limit in February whereas it was within the desirable limit except for Ghuret which was just at the desirable limit and for Veerbhadra which was above the desirable limit but within the permissible limit in June. The calcium hardness was found to be within the desirable limit in February whereas it was within the desirable limit for Ghuret and for all others, it was within the permissible limit in June. The magnesium hardness of water sample of Bhagirathi was found to be within the desirable limit and all other places within the permissible limit in February whereas Triveni ghat, Rampur Raighati Ahat and Balawali were within the desirable limit and all the places within the permissible limit except for Kauriyala where magnesium hardness was negative in June which means that instead of the magnesium ion which is divalent, the presence of hardness was due to monovalent ions like sodium, potassium, etc.
4) The total alkalinity in both the months was found to be within the desirable limit. The chloride in both the months was within permissible limit. The free carbon dioxide was found to be within the permissible limit in February whereas except for Triveni ghat, all other locations were within the permissible limit in June.
5) On the basis of the classification of tolerance limits for pre-monsoon inland surface waters if we consider the pH, TDS, calcium hardness, total hardness, magnesium hardness and chloride, all the locations could be utilized for drinking water source without conventional treatment but after disinfection. Considering free CO_2 and EC, the water of all the locations could be utilized for fish culture and wild life propagation. On the basis of classification of irrigation water considering EC, the water of all the locations could be utilized for irrigation.

On the basis of the classification of tolerance limits for post-monsoon inland surface waters if we consider the pH, the water of all the locations could be used for irrigation, industrial cooling or controlled waste disposal except for Triveni ghat and Rampur Raighati Ahat where water was not fit for use. Considering TDS, calcium hardness, total hardness and chloride, all the locations could be utilized for drinking water source without conventional treatment but after disinfection. Considering magnesium hardness, all the

locations could be utilized for drinking water source without conventional treatment but after disinfection except for Ghuret where water was not fit for any use. Considering free CO_2, no location was fit for any use. On the basis of classification of irrigation water considering EC, the water of all the locations could be utilized for irrigation.

5.3 Scope for further study

The following points are suggested for further studies.

1) Biological properties shall be tested in the study area.

2) The studies on heavy metal shall be done in the study area.

3) Longer duration studies need to be taken up for detailed evaluation.

4) Quantity variation studies should also be undertaken to know the quality characteristic variation.

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APPENDIX

Table A_1 Drinking water standard of BIS (IS 10500:2012)

S. No.	Parameter	Drinking water quality standard (IS 10500:2012)	
		Desirable limits	Permissible limits
1	Odor	Unobjectionable	-
2	Taste	Agreeable	-
3	pH	6.5 - 8.5	No relaxation
4	EC	600*	-
5	TDS	500	2000
6	TH	200	600
7	CaH	75	200
8	MgH	30	100
9	TAl	200	600
10	Cl	250	1000
11	FCO_2	-	<50*

All values are in ppm except EC in µS/cm, pH in number, odor and taste

*World Health Organization (WHO) guidelines for drinking water quality 1993

Table A_2 Classification of irrigation water (ISI-IS: 2296-1982)

S. No.	Electrical conductivity of water, µS/cm at 25^0C	Class
1	100-250	C1
2	250-750	C2
3	750-2250	C3
4	2250-5000	C4
5	5000-20,000	C5

Table A_3 Tolerance limits for inland surface waters (ISI-IS: 2296-1982)

S. No.	Characteristic	Tolerance	Class
1	pH	6.5 - 8.5	A, B, C and D
		6 - 8.5	E
2	Odor	Unobjectionable	A
3	Taste	Agreeable	A
4	Total Dissolved Solids, max	500	A
5	Total hardness (as $CaCO_3$), max	300	A
6	Calcium hardness (as $CaCO_3$), max	200	A
7	Magnesium (as $CaCO_3$), max	100	A
8	Chlorides (as Cl), max	250	A
9	Electrical conductance at 25^0C, max	1000	D
10	Free carbon dioxide (as CO_2), max	6	D

All values are in ppm except EC in µS/cm, pH in number, odor and taste

Table A_4 Class of water (ISI-IS: 2296-1982)

S. No.	Classification	Type of use
1	Class A	Drinking water source without conventional treatment but after disinfection
2	Class B	Outdoor bathing
3	Class C	Drinking water source with conventional treatment followed by disinfection
4	Class D	Fish culture and wild life propagation
5	Class E	Irrigation, industrial cooling or controlled waste disposal

VITA

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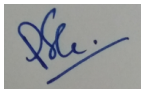
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C/O	:	Mr. Jaman Singh Kharola
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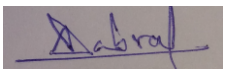
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ABSTRACT

Soil erosion due to rain and wind action is a serious problem in India. Its negative impacts include reduction in soil productivity, silting of dams and reservoirs, deficits in water availability, pollution of water courses, serious damages to properties by soil-laden runoff, and desertification of natural environments. In the present study, chemical and physical parameters of the river were observed. The river Ganga segment in Uttarakhand was taken as study area from Devprayag (30.14^0N, 78.59^0E) to Balawali (29.64^0N, 78.1^0E). From the study area, a total of twelve locations were selected and water samples were taken in February and June.

The classification of the locations of the samples of both the months for the utilization of water for various purposes like drinking water source without conventional treatment but after disinfection, fish culture and wild life propagation and irrigation and industrial cooling or controlled waste disposal was done for useful interpretation of which water could be used for what purposes according to desirable and permissible limits of pH, EC, TDS, free CO_2, chloride, total acidity, calcium hardness, total hardness and magnesium hardness.





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मुख्य विषय : मृदा एवं जल संरक्षण अभियांत्रिकी

विभाग : मृदा एवं जल संरक्षण अभियांत्रिकी

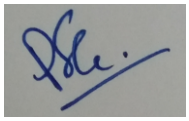
शोध का शीर्षक : **उत्तराखंड में गंगा नदी के खंड का प्रदूषण आकलन**

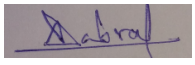
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सारांश

बारिश और हवा की वजह से मृदा क्षरण भारत में एक गंभीर समस्या है। इसके नकारात्मक प्रभावों में मिट्टी द्वारा उत्पादकता में कमी, बांधों और जलाशयों में कमी, पानी की उपलब्धता में कमी, जलमार्ग के प्रदूषण, मिट्टी के बहाव से संपत्ति को गंभीर क्षति, प्राकृतिक परिवेश का मरुस्थलीकरण। वर्तमान अध्ययन में, नदी के रासायनिक और भौतिक मापदंडों का परीक्षण किया गया। उत्तराखंड में गंगा नदी के खंड देवप्रयाग (30.14^0N, 78.59^0E) से बालावाली (29.64^0N, 78.1^0E) तक अध्ययन क्षेत्र के रूप में लिया गया है। अध्ययन क्षेत्र से कुल बारह स्थानों का चयन किया गया है और फरवरी और जून के महीने में पानी के नमूनों को लिया गया है।

विभिन्न प्रयोजनों के लिए पानी के इस्तेमाल के लिए परंपरागत उपचार के बिना पीने के पानी के स्रोत के लिए दोनों महीने के नमूनो का वर्गीकरण विसंक्रमण के बिना, मछली पालन और वन्य जीवन प्रसारण और सिंचाई और औद्योगिक शीतलन या नियंत्रित अपशिष्ट निराकरण, किया गया है जो कि पीएच, ईसी, टीडीएस, मुक्त कार्बन डाइआक्साइड, क्लोराइड, कुल अम्लता, कैल्शियम कठोरता, कुल कठोरता और मैग्नीशियम कठोरता की वांछनीय और स्वीकार्य सीमाओं के आधार पर किया गया है।





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