WATER QUALITY ASSESSMENT OF RIVER GANGA HEALTH HAZARD IDENTIFICATION AND CONTROL

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AT
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CERTIFICATE

This is to certify that the project entitled "**Water Quality Assessment of river Ganga Health Hazard Identification and Control**" submitted by **Satendra Singh**, Student of M.Tech Health Safety and Environmental Engineering from University of Petroleum and Energy Studies, Dehradun, was carried out under Nation Water Mission Programme (Ministry of Water Resources, River Development and Ganga Rejuvenation-Government of India) at National Institute of Hydrology, Roorkee, under my supervision and guidance.

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Table of Content

S.No.	Contents	Page No
	List of Table	v
	List of Figure	vi
	Abstract	viii
1.	INTRODUCTION	1
	1.1 OBJECTIVE OF PROJECT	2
2	LITERATURE REVIEW	3-8
3	SAMPLING & PRECAUTIONS FOR ANALYSIS	
	3.1 SAMPLING	9
	3.2 PRECAUTIONS	9
	3.3 SOURCES OF SAMPLES	10
4	MATERIAL AND METHODOLOGY	
	4.1 STUDY AREA-	13
	4.2 SOFTWARE USED	13
	4.3 PHYSICO-CHEMICAL ANALYSIS	13
	4.4 DEFINING WATER QUALITY	14
	4.5 METHODOLOGIES	14-38
5	RESULT AND DISCUSSION	
	5.1 DISCUSSION	42
	5.2 CHADDHA DIAGRAM	74
	5.3 HOT SPOT MATRIX	74
	CONCLUSION	77
	REFERENCES	78

List of Table Page No.

Table No 3.1 Sampling Sites 11

Table No 4.1 Method to Determine Water Quality Parameters 13

Table No.5.1 Physical Chemical Characterisation of River Ganga 40

Table No.4.2 Drinking Water Standard (BIS 10500) 41

Table No.4.3 Hot Spot Matrix 76

List of Figure Page No.

Fig 3.1 Sampling Location (Satellite Map) 12

Fig 5.1 pH Trend in river Ganga 42

Fig 5.2 pH Contour in river Ganga 43

Fig 5.3 EC Trend in river Ganga 44

Fig 5.4 EC Contour in river Ganga 45

Fig 5.5 Alkalinity Trend in river Ganga 46

Fig 5.6 Alkalinity Contour in river Ganga 47

Fig 5.7 Hardness Trend in River Ganga 48

Fig 5.8 Hardness Contour in river Ganga 49

Fig 5.9 Chloride Trend in River Ganga 50

Fig 5.10 Chloride Contour in river Ganga 51

Fig 5.11 Nitrate Trend in River Ganga 52

Fig 5.12 Nitrate Contour in river Ganga 53

Fig 5.13 Calcium Trend in River Ganga 54

Fig 5.14 Calcium Contour in river Ganga 56

Fig 5.15 Iron Trend in River Ganga 57

Fig 5.16 Iron Contour in river Ganga 59

Fig 5.17 Magnesium Trend in river Ganga 60

Fig 5.18 Magnesium Contour in river Ganga 62

Fig 5.19 Sodium Trend in river Ganga 63

Fig 5.20 Sodium Contour in river Ganga 64

Fig 5.21 Potassium Trend in river Ganga 65

Fig 5.22 Potassium Contour in river Ganga 68

Fig 5.23 Sulphate Trend in river Ganga 69

Fig 5.24 Sulphate Contour in river Ganga 70

Fig 5.25 TDS Trend in river Ganga 71

Fig 5.26 TDS Contour in river Ganga 73

Fig 5.27 Chaddha Diagram 74

ABSTRACT

The present project 'Water Quality Assessment of river Ganga Health Hazard Identification and control' includes tests for, pH value, Electrical Conductivity, Total Dissolve Solid, Hardness, Alkalinity, Chloride, Nitrate, Sulphate, Iron, Sodium, Potassium, Calcium and Magnesium. Result was compared with drinking water standard prescribed by BIS 10500-2012 and all parameters satisfied the prescribed limit given in BIS standard for drinking water. Water Quality of river Ganga from Gangotri to Haridwar is found Pollution free. Spatial variation in river water quality is shown by Quality Contour Map by using Surfer Software 9.0 version. Maximum water quality deviation from mean value is observed at Haridwar which shows the adverse impact of Industrialization, Urbanisation and Rapid growth of population on the river water quality.

Keywords: water quality, IS: 10500, Electrical Conductivity, Total Dissolve Solid, Hardness, Alkalinity, Chloride, Nitrate, Sulphate, Iron, Sodium, Potassium, Calcium, Magnesium, Surfer 9.0.

CHAPTER 1: INTRODUCTION

The River Ganga is a perennial river originating from the Himalayas and flowing through many states before its confluence with Bay of Bengal. The Ganga basin accounts for a little more than one-fourth (26.3%) of the country's total geographical area and is the biggest river basin in India. Ganga plain is one of the most densely populated regions of the world, due to its availability of water, fertile soil and suitable landscapes.

The Ganga has been worshipped by Indians from time immemorial and the practice still continues. The water of the Ganga was considered to be holy, having powers to rid us from all our sins it is also used for various purposes such as drinking, bathing, power generation, recreation, community water supply, irrigation etc. This water is being polluted by indiscriminate disposal of sewage, industrial waste and human activities which affect quality of river water. The increased anthropogenic activities (Praveen et al. 2012) large scale deforestation and over grazing in the watershed areas of river basins is having adverse impact on river water quality and is affecting the flora and fauna (Joshi et al. 2009). It is a fact that good water quality produces healthier humans. Freshwater scarcity ranks among the most urgent environmental challenges of this century. To water resources management and pollution mitigation plan it is essential to be have relevant information on water quality status and trend to describe overall water quality conditions. Therefore it is necessary to monitor and assess the water quality of River Ganga.

It is of utmost importance that the River Ganga be restored to its past glory. It is an urgent need to improve its water quality; this can be achieved by regular monitoring and assessment of water quality. A conscious effort towards reversing the current trends of deterioration of water quality of Ganga is the need of the hour. However, the ability to properly track progress toward minimizing impacts on natural environments and improving access of humans to safe water depends on the availability of data that document trends. As such assessing of water quality of River Ganga is a necessary activity at all governing levels: local, national. Keeping these facts in mind current study focused on assessments including approaches to their identification, analysis and resolution of current water quality status and trends of river Ganga from Gangotri to Haridwar.

Objective and possible outcomes of the Project-

- Water quality of Ganga River from Gangotri to Haridwar.
- Spatial variation in water Quality of River Ganga.
- Finding the Hot Spots in the selected river length.
- Possible Adverse Health Impact

CHAPTER 2: LITERATURE REVIEW

Abhineet et al. (2014); Water is a scarce and valuable resource for the survival of mankind. Man-made activities change the morphology of the areas the river regimes causing problems of water pollution. Fast industrialization for sustainable development is causing major concern to the pollution of surface water because most of the industries are disposing off their waste directly to the nearby stream without making any treatment and violating the provisions for standard laid out for the same.

Roy et al. (2014); River Ganga is a trans-boundary river of India and Bangladesh. It is the largest water resource available to India. As a result of the increasing anthropogenic activities in the Gangetic plain, Ganga water quality has deteriorated over years.

Seth et al. (2014); water quality of Himalayan Rivers has been steadily deteriorating over several decades due to anthropogenic activities, dumping of treated or untreated effluents, poor structured sewerage and drainage system, etc. The water of all these rivers serves as the major source for drinking and irrigation purposes in region of Uttarakhand. Therefore, to restore the vitality and water quality of all these rivers, proper water resource planning programme should be developed.

Kanchan et al. (2014); the ions i.e. Ca, Na, and HCO_3 were found to be dominant ions in surface and groundwater. The average (Ca+Mg):HCO_3 equivalent ratio of 1.4, relatively high contribution of (Ca+Mg) to the total cations (TZ+) and high (Ca+Mg):(Na+K) equivalent ratio of 9.1 indicate that carbonate weathering is the primary source of major ions to these water. Study result shows that water is slightly acidic to basic in nature. The EC were ranged from 54.2 to 1353 μS/, TDS ranged from 91 mg/l to 553 mg/l, HCO_3ranged from 21.0 mg/l to 366 mg/l and pH ranged from 6.0 to 8.7

Kumar et al. (2013); the world is facing problems with a wide variety of pollutants both inorganic and organic in nature. Healthy soil, clean water and air are the soul of life. Often soil, water and air are no longer clean and pure, but pose human health risks. Rivers receive huge quantities of untreated sewage, agricultural runoff (pesticides, fertilizeretc), street washouts (oil, asphalt, sediment and many types of heavy metals). From industrial effluents to domestic discharge, the river becomes more of a flowing dumping yard. The characterization of river water quality is a tool to understand the water quality in its catchment area.

Gorde et al. (2013); water is the most important in shaping the land and regulating the climate. It is one of the most important compounds that profoundly influence life. The quality of water usually described according to its physical, chemical and biological characteristics. Rapid industrialization and indiscriminate use of chemical fertilizers and pesticides in agriculture are causing heavy and varied pollution in aquatic environment leading to deterioration of water quality and depletion of aquatic biota. Due to the use of contaminated water, human population suffers from water borne diseases. It is therefore necessary to check the water quality at regular interval of time.

Kanchan et al. (2012); The concentration of most of the ions in surface water of Dehradun districts were high in pre monsoon as compared with post monsoon period indicating the effect of elevated temperature, increased evaporation and absence of recharge during the low water level period of the pre monsoon season. Among anions bicarbonate is the most dominant ion (65%) followed by sulphate (23.3%), chloride (6.4%) and nitrate (4.9%), fluoride (0.4%), phosphate (0.3%) in winter season. Among cations, calcium is most dominant ion, contributing about 63% followed by Mg (24%), Na (10.7%) and K (2.3%) in winter season.

Gadekar et al. (2012); Fresh water is necessary for healthy living. River water is used for various purposes such as drinking, bathing, recreation, community water supply, irrigation etc. This natural resource is being polluted by indiscriminate disposal of sewage, industrial waste and human activities which affect quality of river water. A water quality index expressed as single number is developed to describe overall water quality conditions. Therefore it is necessary for monitoring the water quality of river by analysis of various physiochemical parameters

Smita Jain (2012); water is one of the valuable natural resources and the quality of water is of vital concern for the mankind since it is directly link with human welfare. Growing population, industrial proliferation, urbanization, increasing living standards, and wide sphere of human activities exert heavy pressure on our vast but limited water resources. Since water pollution of a growing city is always in the rising trend, its effect on the environment must be studied thoroughly and regularly.

George et al. (2012); physicochemical properties play a major role in determining the density, diversity and occurrence of phytoplankton in an estuarine ecosystem. Study is conducted to assess the relationship between physicochemical parameters and phytoplankton assemblages which in turn can serve as a suitable method to assess the quality of estuarine ecosystem. Results showed an increased concentration in physicochemical parameters and phytoplankton density during post moon soon season followed by pre-monsoon and monsoon season.

Thareja et al. (2011); results reveal that Total dissolved Solids, Total Alkalinity, Total Hardness were the parameters that are most important in assessing variations of river water quality in October, November, December, January, February, March, and April. Results also revealed that turbidity and suspended solids were the parameters that are most important in assessing variations of water quality in June, July , August and September.

Yadav et al. (2011); pollution of water bodies is one of the areas of major concern to environmentalists. Water quality is an index of health and well-being of a society. Industrialization, urbanization and modern agriculture practices have direct impact on water resources. These factors influence the water resources quantitatively and qualitatively. The physico-chemical parameters like temperature, pH, turbidity, total hardness, alkalinity, BOD , COD, chloride, nitrate and phosphate and fluoride content in water of River can be studied to ascertain the drinking and domestic as well as irrigation water supply.

Bharti et al. (2011); assessment of water quality can be defined as the analysis of physical, chemical and biological characteristics of water. Water quality indices aim at giving a single value to the water quality of a source reducing great amount of parameters into a simpler expression and enabling easy interpretation of monitoring data. As different National and International Agencies involved in water quality assessment and pollution control defines water quality criteria for different uses of water considering different indicator parameters, so there are numerous WQI specific to any region or area. An attempt to cover all different water quality indices developed worldwide, their background and application area has been made here. In this context, this paper displays a comparative study of many indices and detailed out eight WQI's perceived as simple, basic and most important indices for water quality assessment. Their mathematical structure set of parameters, calculation, aggregation formula and flaws have also been detailed out.

Srivastava et al. (2011); a WQI is a single indicator of the water quality determined through summarizing multiple parameters of water test results into simple terms for management and decision makers. World Health Organization (WHO) standard were adopted for calculation of water quality index (WQI) viz temperature, pH, electrical conductivity (EC), turbidity, total solids, total dissolved solids (TDS),total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total hardness (TH), calcium, magnesium, chloride, alkalinity, acidity levels. Comparison of observed and estimated values based on physico-chemical of parameters studies and water quality indices revealed that river water quality. Water quality index provides an easy and rapid method of monitoring of water quality. It also becomes easier to compare the quality levels in different locations and to give priority for the required treatment to the location.

Bhardwaj et al. (2010); the principal components of water quality are controlled by lithology, gentle slope gradient, poor drainage, long residence of water, ion exchange, weathering of minerals, heavy use of fertilizers, and domestic wastes. At some stations water is hard with an excess alkalinity and is not suitable for drinking and irrigation purposes. The variation in the local and regional hydro geochemical processes distinguished the geogenic sources from the anthropogenic one.

Verma et al.(2010); For studying the pollution status of a river certain pollution parameters such as transparency, electrical conductivity, turbidity, total suspended solids, dissolved oxygen, nitrite-nitrogen, phosphates, ammonia, sulphide, BOD and COD should be considered. It was found that out of these parameters, transparency varies from station to station. When the physico-chemical characteristics of water at various locations were compared with those of standards (IS: 2296:1974 for Tolerance limits for inland surface waters subject to pollution), the suitability of water can be determined. After studying the water quality of river some of conservation and management plans were proposed to save river.

R.M.Bhardwaj (2005); India is rich in water resources, being endowed with a network of rivers and blessed with snow cover in the Himalayan range that can meet a variety of water requirements of the country. However, with the rapid increase in the population of the country and the need to meet the increasing demands of irrigation, human and industrial consumption, the available water resources in many parts of the country are getting depleted and the water quality has deteriorated. Indian rivers are polluted due to the discharge of untreated sewage and industrial effluents.

Jain C.K (2002); the maximum suspended sediment concentrations of 1405 and 2002 mg/L were recorded at Deoprayag and Rishikesh, respectively, during the rainy season. A large amount of sediment and nutrient load is transported from the watershed during the rainy season. Concentrations of NO_3–N and NH_3–N at Deoprayag varied from 0.30 to 0.50 and 0.02 to 0.12 mg/L, respectively, depending on season. Examination of the results showed clearly that NH_3–N was generally low as compared to NO_3–N. Depending on the pH and temperature of soils, NH_4^+ and NO_3^- ions are produced in the watershed through ammonification and nitrification of organic matter and mobilized into rivers through run-off. Dissolved N and P from fertilizer application, sewage and non-point source run-off contributes significant quantities of these nutrients in river water. The nitrate and phosphate are transported from the cropland either by being adsorbed on to soil particles that are subsequently eroded, or dissolved in runoff water from agricultural land. The data generated through the study will be useful for development and management planning of the hilly watershed.

CHAPTER 3: SAMPLING & PRECAUTIONS FOR ANALYSIS

3.1 SAMPLING

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

3.2 PRECAUTIONS

1. When the results of successive events are assembled properly, they enable one to better understand the nature, extent, and degree of water pollution.
2. Each water sample must be collected so as to ensure the reliability of analytical determinations.
3. Achieving a specified time the information period requires needs of a water sampling program over careful planning and execution of the sampling design.
4. Each field measurement and water sample collected for laboratory analysis should also be representative of the discrete sampling point within the sampling network.
5. Special care must be taken not to contaminate samples. This includes storing samples in a secure location to preclude conditions which could alter

the properties of the sample. Samples shall be custody sealed during long-term storage or shipment.

6. Always sample from the anticipated cleanest, i.e., least contaminated location, to the most contaminated location. This minimizes the opportunity for cross-contamination to occur during sampling.
7. Collected samples must remain in the custody of the sampler or sample custodian until the samples are relinquished to another party.
8. Documentation of field sampling is done in a bound logbook

3.3 SOURCES OF SAMPLES

A total number of 23 samples were collected and analysed. The samples were collected from Gangotri to Haridwar in River Ganga during winter period with their GPS coordinates during December 2014 and preserved by adding an appropriate reagent (Jain and Bhatia, 1988; APHA, 1992) River Ganga from Gangotri to Haridwar .Descriptions of River water sampling location along with their GPS coordinates are given in Table 3.1

Table-3.1 Sampling Sites-

Code	Location	Long.	Lat.	Hight (m)	Distance(Km)
G-1	Jangla Bridge	78.84065833	31.0433278	2585	0
G-2	Jhala Bridge	78.71349861	31.0159611	2378	26.490613
G-3	Dabrani Bridge	78.68833889	30.9462333	1966	34.699657
G-4	UK Laghu Vidhut Pariyojna	78.61881389	30.7853278	1430	54.332124
G-5	Nalluna Senj	78.578	30.756875	1320	54.332124
G-6	After Heena Power Station	78.50666667	30.7362603	1208	66.772303
G-7	u/s Uttarkashi	78.44674722	30.7295	1076	75.606229
G-8	d/s Uttarkashi	78.43944444	30.7258333	1106	76.264219
G-9	Badethi Chungi	78.43944444	30.7303528	1053	79.404703
G-10	Dharashu	78.31622222	30.6106639	815	99.205983
G-11	Chinyalisaur	78.332475	30.5745333	790	103.34455
G-12	Tehri Reservoir (Koti colony)	78.45367778	30.4123139	792	125.445578
G-13	Zero Bridge Tehri	78.48515	30.3527278	561.95	133.415968
G-14	Downsream of Koteswar PP	78.50085556	30.2625472	518	144.180048
G-15	Bhagirathi Devprayag	78.59858611	30.1510139	462	160.430282
G-16	Ganga Devprayag	78.59638611	30.1407139	365.48	161.979644
G-17	Lakundi Shiv Chula	78.435275	30.0858028	321	187.707604
G-18	Lakhman Chula Rishikesh	78.32709167	30.126375	312	205.295911
G-19	Saptrishi Ashram	78.19606389	29.9871056	243.308	226.962528
G-20	Bhimgowada Barrage	78.17639444	29.9698833	242.42	229.997382
G-21	Khadkhadi	78.16209167	29.947425	236.59	232.421654
G-22	Gujrawala Bhawan	78.17800833	29.9573194	234	242.092785
G-23	Bisanpur village	78.14702222	29.8577361	217.5	254.712282

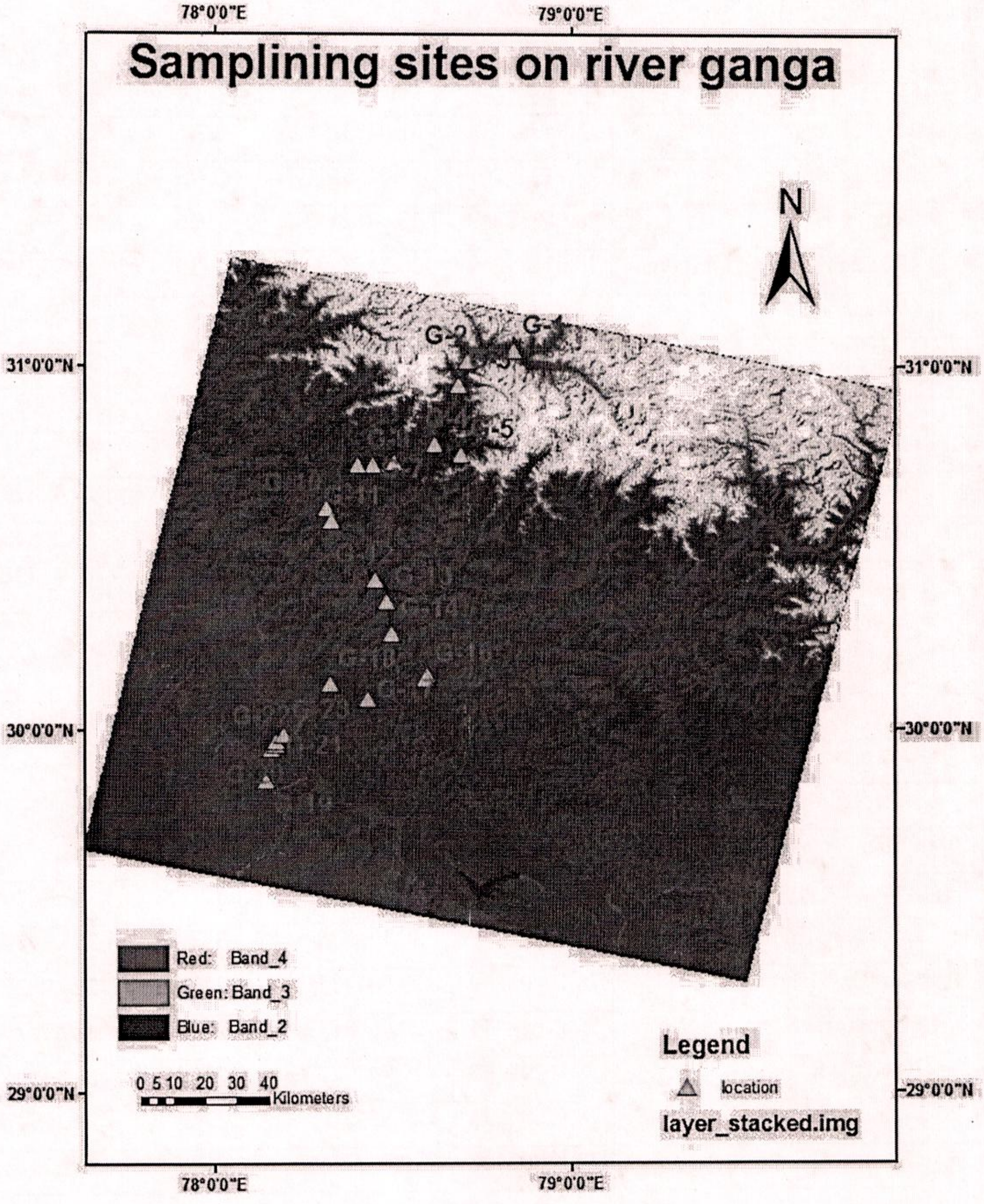

Fig 3.1 Sampling Location (Satellite Map)

CHAPTER 4: MATERIAL AND METHODOLOGY

4.1 STUDY AREA-current study area cover river Ganga from Gngotri to Haridwar of approximate length of 254 Km starting from Gangotri to Bishanpur (Haridwar).

4.2 SOFTWARE USED-Arc GIS 9.3 and Surfer 9.

4.3 PHYSICO-CHEMICAL AND BACTERIOLOGICAL ANALYSIS

Water sample analysis was performed as per standard method (Jain and Bhatia, 1988; APHA, 1992) at National Institute of Hydrology, Roorkee laboratory (An ISO 9001-2008 Certified) .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 thirteen for assessing water quality of river Ganga.

Table 4.1 Details of the analytical method and equipment used in the study

Parameter	Method	Instrumentation and Apparatus
pH	Electrometric	pH Meter
Conductivity	Electrometric	Conductivity Meter
TDS	Electrometric	Conductivity Meter/TDS Meter
Alkalinity	Titration by H_2SO_4	-
Hardness	Titration by EDTA	-
Chloride	Titration by $AgNO_3$	-
Sulphate	Turbidimetric	Turbidity Meter
Nitrate	Ultraviolet Screening	UV-VIS Spectrophotometer
Sodium	Flame Emission	Flame Photometer
Potassium	Flame Emission	Flame Photometer
Calcium	Titration by EDTA	-
Magnesium	Titration by EDTA	-
Iron	Spectrophotometric	Spectrophotometer

4.4 DEFINING WATER QUALITY

The quality of any body of surface or ground water is a function of either or both natural influences and human activities. Without human influences, water quality would be determined by the weathering of bedrock minerals, by the atmospheric processes of evapotranspiration and the deposition of dust and salt by wind, by the natural leaching of organic matter and nutrients from soil, by hydrological factors that lead to runoff, and by biological processes within the aquatic environment that can alter the physical and chemical composition of water. As a result water in the natural environment contains many dissolved substances and non-dissolved particulate matter. Dissolved salts and minerals are necessary components of good quality water as they help maintain the health and vitality of the organisms that rely on this ecosystem service (Stark *et al.*, 2000).A brief introduction of methods to determine water quality parameter are described here.

4.5 METHODOLOGIES FOR MEASUREMENT OF WATER QUALITY PARAMETERS

P^H Value

The pH value is a measure of hydrogen ion concentration and is the negative exponent of the logarithm of the hydrogen ion concentration. A low pH solution has a high hydrogen ion concentration and is therefore, acidic while high pH solution is low in hydrogen ion concentration and is alkaline (pH 7 being neutral).

The pH value of natural water is an important index of acidity or alkalinity and is the resulting value of the acidic/basic interaction of a number of its .mineral and organic components. In pure or slightly polluted water, the value of pH is determined mainly by the correlation between the concentrations of free carbon dioxide, bicarbonate and carbonate ions. This correlation, in turn depends substantially on the intensity of the process of photosynthesis and the biochemical oxidation of organic substances as well as on chemical conversions of some mineral substances.

Most natural water range from pH 4 to 9 and are often slightly basic due to the presence of carbonates and bicarbonates. A major deviation from the normal pH for given water indicates the industrial wastes. Practically every phase of water supply and wastewater treatment, e.g., acid- base neutralization, water softening, precipitation, coagulation, disinfection, and corrosion control, is pH dependent.

The pH value of water may be determined potentiometrically by a wide variety of pH meters which are battery operated or run by standard-line power. They are equipped with glass and reference electrodes which require standardizing with standard buffer solutions before each measurement in the field. Care must also be taken that the pH meters are stored in a dry place to prevent them from getting wet.

PRINCIPLE

The basic principle of pH measurement is determination of hydrogen ion activity by potentiometric measurement using a standard hydrogen electrode and a reference electrode. The hydrogen electrode consists of a platinum electrode across which hydrogen gas a bubbled at a pressure of 101 kPa. Because of difficulty in its use and the potential for poisoning the hydrogen electrode, the glass electrode is commonly used.

The sensor electrode (glass electrode) is a bulb of special glass containing a fixed concentration of HCL or a buffered chloride solution in contact with an internal reference electrode. Upon immersion of a new electrode in a solution the outer bulb surface becomes hydrated and exchanged sodium ions for hydrogen ions to build up a surface layer of hydrogen ions, This, together with the repulsion of anions by fixed, negatively charged silicate sites, produces at the glass-solution interface a potential that is a function of hydrogen ion activity in solution.

$$P^H = - \log [H^+]$$

INTERFERENCE

The glass electrode is relatively free from interference from colour, turbidity, colloidal matter, oxidants, or high salinity, except for a sodium error at pH>10. This error can be reduced by using special 'low sodium error' electrodes. Other source of interference is temperature.

REAGENTS

- **Potassium hydrogen phthalate, 0.05M:** Dissolved 10.12 g potassium hydrogen phthalate in IL of distilled water at 25°C.
- **Sodium borate deca hydrate, 0.01 M:** Dissolve 3.80g sodium borate deca hydrate in IL of distilled water at 25°C.

PROCEDURE

i) For detailed instructions, follow manufacturer's manual, Standardise the pH meter by immersing the electrode in buffer solution of known pH. Read the pH and correctly, adjust with the control until the meter indicates the correct value for pH of buffer solution.

ii) Remove electrodes from first buffer, rinse thoroughly with distilled water, blot dry with a soft tissue, and immerse in second buffer, the reading should be within 0.1 unit for the pH of the buffer. If the response shows a difference greater than 0.1 pH unit from expected value, look for trouble with the electrode or pH meter.

iii) Rinse the electrodes in distilled water and immerse them in the sample. Let the reading stabilize. Read the pH value.

CONDUCTIVITY.

Conductivity is a measurement of water's capacity for conveying electrical current and is directly related to the concentrations of ionized substance in the water. Solutions of most inorganic acids, bases and salts are relatively good conductors. Conductivity measurements are commonly used to determine the purity of demineralized water and total dissolved solids in boiler and cooling tower water.

PRINCIPLE

Specific conductance is a measure of the total concentration of ionised constituents of water. It is related to the son of anions and cations. Specific conductance is reciprocal of the resistance between 2 electrodes 1om apart and 1 Sq. on in cross section.

REAGENTS

i) Conductivity water: Pass distilled water through a mixed bed deionizer and discard first liter. Conductivity should be less than 1 µmho/cm.

ii) Standard potassium chloride solution, 0.01 N: Dissolve 745.6 mg anhydrous KC1 in conductivity water and dilute to 1000 ml at 25°C. This is the standard reference solution, which at 25°C has a conductivity of 1413 µmho/cm. It is satisfactory for most samples when the cell has a constant between 1 and 2.

PROCEDURE

(i) Determination of cell constant: Rinse conductivity cell with at least three portions of 0.01 N KCl solution, adjust temperature of a fourth portion to 25.0 ± 0.1°C. Measure resistance of this portion and note temperature. Compute cell constant, C, using following equation:

$$C = (0.001413)\ (R_{KCl}) = 1 + 0.0191\ (t\text{-}25)$$

Where,

R_{KCl} = measured resistance, ohm, and

t = observed temperature, °C

ii) Conductivity measurement: Rinse cell with one or more portions of sample. Adjust temperature of a final portion to 25.0 ± 0.1°C Measure sample conductivity and note temperature.

CALCULATION

$$\text{Conductivity at } 25^0\text{ C }\mu\text{mho/cm} = \frac{Km \times C}{1 + 0.0191(t\text{-}25)}$$

Km = measured conductivity, μ/mho at t°C

C = cell constant, cm^{-1} and

t = temperature of measurement

ALKALINITY

Alkalinity refers to the capability of water to neutralize acids. The presence of carbonates, bicarbonates and hydroxides is the most common cause of alkalinity in natural waters. Alkalinities values provide guidance in applying proper doses of chemicals in water and waste water treatment processes, particularly in coagulation, softening and operational control of anaerobic digestion.

Bicarbonates present the major form since they are formed in considerable amounts from the action of carbonate upon the basic materials in the soil.

$$CO_2 + CaCO_3 + H_20 \longrightarrow Ca\,(HCO_3)_2$$

Natural waters may also contain appreciable amounts of carbonates and hydroxide alkalinities, particularly surface waters blooming with algae. The algae take up carbonate for its photosynthesis activities and raise the pH.

PRINCIPLE

Hydroxyl ions present in a sample as a result of dissociation or hydrolysis of solutes react with additions of standard acid. Alkalinity thus depends on the end point pH used. Alkalinity can be obtained by neutralizing hydroxide, carbonate and bicarbonate with standard sulfuric acid solution. Titration to pH 8.3 or de-colouration of phenolphthalein indicator will snow complete neutralization of total hydroxide and one half the carbonate pre-sent, while to pH 4.4 or sharp change from yellow to pink colour of methyl orange indicator will indicate total alkalinity, i.e. hydroxide, carbonate and bicarbonate.

INTERFERENCE

Colour, turbidity, iron, aluminium and residual chlorine are prime sources of interference.

REAGENTS

- **Methyl orange indicator:** Dissolve 0.5 g of methyl orange in 1 L of distilled water.
- **Phenolphthalein indicator:** Dissolve 5.0 g phenolphthalein in 1 L of 5.0% ethyl alcohol. Neutralize the solution with 0.02 N NaOH solutions.

- **Sulfuric acid, 0.02 N:** Prepare stock H_2SO_4 solution (approximately 0.1N) by diluting 3 ml H_2SO_4 to 1 L of distilled water. Dilute 200 mL of the 0.1 N stock solution to 1 L with distilled water. Standardise the 0.02 N acid against 0.02 N sodium carbonate solutions.
- Sodium carbonate solution can be made by dissolving 1.06 g of Na_2CO_3 oven dried, in 1 L of distilled water. The standardisation is done by titrating exactly like an alkalinity titration using phenolphthalein or methyl orange as indicator.

PROCEDURE

i) Take 100 ml sample in a conical flask and add 2-3 drops of phenolphthalein indicator and swirl to mix.

ii) If pink colour develops titrate the sample with sulfuric acid standard solution, 0.02 N, while swirling the flask until the solution changes from pink to colourless or the pH meter reads 8.3. Note the volume of sulfuric acid required.

iii) Add 2-3 drops methyl orange indicator to the titrated solution and swirl to mix. Continue titration with sulfuric acid standard solution, 0.02 N, to a pink colour or pH comes down to 4.5. Note the volume of sulfuric acid used.

iv) In case pink colour does not appear after addition of phenolphthalein continue as in 3 above.

CALCULATION –

Total (T), phenolphthalein (P), and methyl orange (MO) alkalinity can be calculated as follows:

$$\text{P Alkalinity, mg/L as CaCO}_3 = \frac{\text{A x 1000}}{\text{Volume of sample, ml}}$$

$$\text{MO Alkalinity, mg/L as CaCO3} = \frac{\text{B x 1000}}{\text{Volume of sample, mL}}$$

$$\text{T Alkalinity, mg/L as CaCO3} = \frac{\text{(A +B) x 1000}}{\text{Volume of sample, ml}}$$

Where,

A = volume of sulfuric acid used with phenolphthalein indicator, mL, and

B = Volume of sulfuric acid solution used with methyl orange indicator, mL.

HARDNESS

The Hardness of water was originally defined in terms of its ability to precipitate soap. Calcium and magnesium ions are the principle causes although iron, aluminium, manganese, strontium, zinc and hydrogen ions are capable of producing the same effect. High concentrations of the latter ions are not commonly found in natural waters. In conformity with current practice, total hardness is defined as characteristic of water which represents the total concentration of calcium and magnesium expressed as their calcium carbonate equivalent.

Temporary hardness is caused by the presence of bicarbonates of calcium and magnesium. Permanent hardness is mostly due to sulphate.

When the total hardness has a value greater than total alkalinity, the amount of hardness equivalent to the alkalinity is called carbonate hardness and the excess amount is non-carbonate hardness. When total hardness is equal or less than the total alkalinity, there is no carbonate hardness.

PRINCIPLE

Ethylenediaminetetracetic acid and its sodium salts (abbreviated EDTA) form a chelated soluble complex when added to a solution of certain metal cations. If a small amount of dye such as Eriochrome black T is added to an aqueous solution containing calcium and magnesium ions at a pH of 10.0 ± 0.1, the solution becomes wine red. When EDTA is added as a titrant, the calcium and magnesium get complexed resulting in sharp change from wine red to blue which indicates end point of the reaction. Magnesium ion must be present to yield a satisfactory end point. To ensure this, a small amount of complexometrically neutral magnesium salt of EDTA is added to the buffer, this automatically introduces sufficient magnesium and obviates the need for a blank correction. At higher pH, i.e., about 12.0 magnesium ion precipitates and only calcium ions remain in solution. At this pH murex indicator form a pink colour with calcium ions. When EDTA is added calcium gets complexed resulting in a change from pink to purple which indicates end point of the reaction.

INTERFERENCE

Some metal ions do interfere by causing fading or indistinct end points or by stoichiometric consumption of EDTA but can be overcome by addition of inhibitors.

REAGENT

Buffer solution: Dissolve 16.9 g of ammonium chloride (NH_4C1) in 143 ml cone ammonium hydroxide (NH_4OH), add 1.25 g magnesium salt of EDTA and dilute to 250 mL with distilled water.

If the magnesium salt of EDTA is not available, dissolve 1.179 g disodium salt of ethylenediamine tetraacetic acid dihydrate and 780 mg magnesium sulphate ($MgSO_4.7H_20$) or 664 mg. magnesium chloride ($MgC1_2.6H_20$) in 50 mL distilled water. Add this solution to 16.9 g NH_4C1 and 143 mL conc. NH_4OH with mixing and dilute to 250 ml with distilled water.

Inhibitor: Dissolve 4.5 g hydroxyl amine hydrochloride in 100 ml 95% ethyl alcohol.

Eriochrome block T indicator: Mix 0.5 g dye with 100 g NaCl to prepare dry powder or dissolve 0.19 of Eriochrome black T in 20 mL of ethyl alcohol.

Murex indicator: Dry powder.

Sodium hydroxide 2N: Dissolve 80 g NaOH and dilute to 1 L.

Standard EDTA solution, 0.01 M: Dissolve 3.723g EDTA sodium salt and dilute to 1000 mL. Standardize against standard calcium solution, 1 mL=1mg $CaCO_3$.

Standard calcium solution: Weigh accurately 1.0g anhydrous $CaCO_3$ powder into a 500ml. erlanmeyer flask. Place a funnel in the flask neck and add 1 + 1 HCl till $CaCO_3$ dissolves completely. Add 200 mL distilled water and boil for a few minutes to expel CO_2. Cool and add a few drops of methyl red indicator and adjust to the intermediate orange colour by adding 3N NH_40H or 1+1 HCL. Dilute to 1000 ml to obtain 1 ml $^{-1}$ mg $CaCO_3$.

PROCEDURE

(i) Take 100 ml water sample in a conical flask and add to it 1-2 mL buffer solution followed by 1 mL inhibitor.

(ii) Add 2 drops Eriochrome black T indicator and titrate with standard EDTA solution, 0.01 M, till wine red colour changes to blue. Note the volume of EDTA used.

(iii) In another flask take 100 mL sample ad add 1 ml sodium hydroxide solution to raise the pH to 12.0 and a pinch of murex indicator.

(iv) Titrate with standard EDTA solution, 0.01M, till pink colour changes to purple. Note the volume of EDTA used.

CALCULATION

$$\text{Total hardness, mg/l} = \frac{A \times C}{\text{Volume of sample, ml}}$$

$$\text{Calcium hardness, mg/l} = \frac{B \times C}{\text{Volume of sample, ml}}$$

A = Volume of EDTA solution used with Eriochrome black T indicator.

B = Volume of EDTA solution used with murex indicator, ml, and,

C = mg $CaCO_3$ equivalent to 1.0 ml EDTA titrant

MAGNESIUM HARDNESS

Magnesium Hardness, mg/l = [Total Hardness – Calcium Hardness] × 0.243

CHLORIDE

Chloride, in the forth of chloride ion, is one of the major inorganic anions in water and waste water. Chlorides are present in all potable water supplies and in sewage, usually as a metallic salt. When sodium is present in drinking water, chloride concentrations in excess of 250 mg/L give a salty taste. If the chloride is present as calcium or magnesium salt, the taste detection level may be as high as 1000 mg/L chloride.

Chloride is essential in the diet and passes through the digestive system unchanged to become one of the' major components of raw sewage. The wide use of zeolite in water softeners also contributes a large amount of chloride to sewage and waste waters.

High chloride concentrations in water are not known to have toxic effects on man, though large amounts may act corrosively on metal pipes and be harmful to plant life. The maximum allowable chloride concentration of 250 mg/L in drinking water has been established for reasons of taste rather than as a safeguard against physical. hazard.

PRINCIPLE

In a neutral or slightly alkaline solution, potassium chromate can indicate the end point of the silver nitrate titration of chloride. Silver chloride is precipitated quantitatively before red silver chromate is formed.

INTTFERENCE

Bromide, iodide, Cyanide, Salfide, thiosulfate, sulfite, iron, phosphate are prime sources of interference.

REAGENTS

- **Potassium chromate indicator**: Dissolve 50 g of potassium chromate in a small quantity of distilled water. Add $AgNO_3$ solution to produce a light red precipitate. Allow to stand overnight and filter. Make up to 1 L.
- **N/35.5 Silver nitrate solution:** Dissolve 4.78 g of silver nitrate in 1 L of distilled water. Standardise with standard sodium chloride solution.

PROCEDURE

i) Take 100 mL sample in a conical flask. If the sample is highly coloured, add 3 ml aluminium hydroxide suspension, mix well, allow to settle and filter. If sulphide, sulphite or thiosulfate is present, add 1 mL hydrogen peroxide and stir for 1 minute.

(ii) Adjust the pH of sample between 7.0 and 10.0 if it is not in this range and add 1.0 mL potassium chromate indicator solution.

iii) Titrate with standard silver nitrate solution, N/35.5, to a pinkish yellow end point. Note the volume of silver nitrate solution used. Place the same quantity of chloride free distilled water in another flask and establish reagent blank value by the titration method outlined above.

CALCULATION

$$\text{Chloride mg/l} = \frac{(A - B) \times 1000}{\text{Volume of Sample, mL}}$$

A = Volume of $AgNO_3$, used for sample, ml, and

B Volume of $AgNO3$ used for blank, Ml

SULPHATE

Sulphate appears in natural waters in a wide range of concentrations. Mine waters and industrial effluents frequently contain large amounts of sulphate from pyrite oxidation and the use of sulfuric acid. Sodium and magnesium sulphate exert cathertic action and hence its concentration above 250 mg/L in potable water is objectionable. Sulphate causes a problem of scaling in industrial water supplies, and problem of odour and corrosion in waste water treatment due to its reduction to hydrogen sulphide.

PRINCIPLE

Sulphate ions are precipated in acetic acid solution with barium chloride so as to form a uniform suspension of barium sulphate crystals. The absorbance of the suspension is measured by a photometer and the sulphate concentration is determined by comparison of the reading with a standard curve.

INTERFERENCE

Colour and suspended mater in amounts will interfere. Some suspended matter may be removed by filtration. Silica in excess of 500 mg/l interfere.

REAGENTS

Buffer Solution: Dissolve 30 g magnesium chloride, $MgC1_2.6H_20$, 5 g sodium acetate, $CH_3COONa.3H_2O$, 1 gm. potassium nitrate, KNO_3, and 20 ml acetic acid, CH_3COOH (99%), in 500 ml distilled water and make up to 1000mL.

Barium chloride crystals: 20 to 30 mesh.

Standard sulphate solution: Dissolve 0.147 g of anhydrous Na_2S0_4 in distilled water.

PROCESSER

(i) Take 100 mL sample, or suitable portion made up to 100 ml, into a 250 ml flask. Add 20 ml buffer solution and mix in stirring apparatus. Add barium chloride crystals while stirring. Continue stirring for 1 minute after addition of barium chloride.

(ii) Measure the turbidity developed after five minutes on colorimeter at 420 mm.

(iii) Prepare standard curve by carrying standard sulphate solution through entire procedure. Space standards at 5 mg/L increment in the 0 to 40 mg/L range. Above 40 mg/L accuracy decreases and barium sulphate suspension loss stability.

(iv) Read the concentration of sulphate present in the sample from the standard curve.

CALCULATION

$$\text{Sulphate, mg/L} = \frac{\text{mg } SO_4^{2-} \times 1000}{\text{Volume of Sample}}$$

SODIUM (Na^+)

Sodium ranks sixth among the elements in order of abundance and is present in most natural water. Relatively high concentrations may be found in brines and hard water softened by the sodium exchange process. The ratio of sodium to total cations is important in agriculture and human pathology. Soil permeability can be harmed by a high sodium ratio. Persons afflicted with certain diseases require water with low sodium concentration. A limiting concentration of 2 to3 mg/L is recommended in feed water destined for high-pressure boilers. When necessary, sodium can be removed by the hydrogen-exchange process or by distillation. Sodium compounds are used in many applications, including caustic soda, sat fertilizers and water treatment chemicals.

FLAME EMISSION PHOTOMETRIC METHOD

PRINCIPLE

Trace amounts of sodium can be determined by flame emission photometry at the wavelength of 589 nm. The sample is sprayed into a gas flame and excitation is carried out under carefully controlled and reproducible conditions. The desired spectral line is isolated by the use of interference filters or by a suitable slit arrangement in light-dispersing devices such as prisms or gratings. The intensity of light is measured by a phototube potentiometer or other appropriate circuit. The intensity of light at 589 nm is approximately proportional to the concentration of the element. If alignment of the wavelength dial with the prism is not precise in the available photometer, the exact wavelength setting, which may be slightly more or less than 589 nm, can be determined from the maximum needle deflection and then used for the emission measurements. The calibration curve may be linear but has a tendency to levels off at higher concentrations.

INTERFERENCE

Flame photometers operating on the internal standard principle may require adding a standard lithium solution to each working standard and sample. The optimum lithium concentration may vary among individual instruments; therefore, ascertain it for the instrument used.

APPARATUS AND EQUIPMENT

Flame photometer (either direct-reading or internal-standard type) or atomic absorption spectrometer in the flame emission mode.

REAGENTS AND STANDARDS

To minimise sodium contamination store all solution in plastic bottles. Use small containers to reduce the amount of dry element that may be picked up from the bottle walls when the solution is poured. Shake each container thoroughly to wash accumulated salt from walls before pouring solution.

(i) Deionised distilled water: Use deionised distilled water to prepare all reagents and calibration standards and as dilution water.

(ii) Stock sodium solution: Dissolve 2.542 g NaCl dried at 140°C and dilute to 1000mL with water, 1 mL = 1 mg Na.

(iii) Intermediate sodium solution: Dilute 10 mL stock sodium solution with water to 100mL, 1 mL = 100μg Na. Use this intermediate solution to prepare calibration curve in sodium range of 1 to 10 mg/L.

(iv) Standard sodium solution: Dilute 10 mL intermediate sodium solutions with water to 100 mL; 1.00 mL = 10µg Na. Use this solution to prepare calibration curve in sodium range of 0.1 to 1 mg/L.

PROCEDURE

Pre-treatment of polluted water and wastewater samples: Filter the sample passing through 0.45µm membrane filter.

INSTRUMENT OPERATION

Because of differences between makes and models of instruments, it is impossible to formulate detailed operating instructions. Follow manufacturer's recommendation for selecting proper photocell and wavelength, adjusting slit width and sensitivity, appropriate fuel and air or oxygen pressures and the steps for warm-up, correcting for interferences and flame background, rinsing of burner, igniting sample and measuring emission intensity.

Direct-intensity measurement: Prepare a blank and sodium calibration standards in stepped amounts in any of the following applicable ranges: 0 to 1.0, 0 to 10, or 0 to 100 mg/L. Starting with the highest calibration standard and working toward the most dilute, measure emission at 589 nm. Repeat the operation with both calibration standards and samples enough times to secure a reliable average reading for each solution. Construct a calibration curve from the sodium standards. Determine sodium concentration of sample from the calibration curve. Where a large number of samples must be run routinely, the calibration curve provides sufficient accuracy.

Internal-standard measurement: To a carefully measured volume of sample (or diluted portion), each sodium calibration standard and a blank, add with a volumetric pipette, an appropriate volume of standard lithium solution. Measure the intensity directly.

Bracketing approach: From the calibration curve, select and prepare sodium standards that immediately bracket the emission intensity of the sample. Determine emission intensities of the bracketing standards (one sodium standard slightly less and the other slightly greater than the sample) and the sample as nearly simultaneously as possible. Repeat the determination on bracketing standards and sample. Calculate the sodium concentration by the equation formed by standard calibration curve.

CALCULATION

(i) For direct reference to the calibration curve: mg Na/L = (mg Na/L in portion) x D

(ii) For the bracketing approach:

$$\text{Mg Na/L} = [\{(B-A)\,(s-a) + A\,(b-a)\,/\,(b-a)\}]\,D$$

B = mg Na/L in upper bracketing standard,

A = mg Na/L in lower bracketing standard,

b = emission intensity of upper bracketing standard,

a = emission intensity of lower bracketing standard,

s = emission intensity of sample and

D = dilution ratio

D = mL sample + mL water /mL sample

POTASSIUM (K^+)

Potassium ranks seventh among the elements in order of abundance, yet its concentration in most drinking water seldom reaches 100mg/L. Potassium is an essential element in both plant and human nutrition and occurs in groundwater as a result of mineral dissolution.

Storage of samples: Do not store samples in soft-glass bottles because of the possibility of contamination from leaching of the glass. Use acid washed polyethylene or borosilicate glass bottles. Adjust sample to pH <2 with nitric acid. This will dissolve potassium salts and reduce adsorption on vessel walls.

FLAME PHOTOMETRIC METHOD

PRINCIPLE

Trace amounts of potassium can be determined in either a direct-reading of internal-standard type of flame photometer at a wavelength of 766.5 nm. Because much of the information pertaining to sodium applies equally to the potassium determination, carefully study the entire discussion dealing with the flame photometric determination of sodium before making a potassium determination.

INTERFERENCE

Interference in the internal-standard method may occur at sodium-to-potassium ratios of 5:1 or greater. Calcium may interfere if the calcium-to-potassium ratio is 10:1 or more. Magnesium begins to interfere when the magnesium-to-potassium ratio exceeds 100:1.

Minimum detectable concentration: Potassium levels of approximately 0.1 mg/L can be determined.

APPARATUS AND EQUIPMENT

Flame photometer: (either direct-reading or internal-standard type) or atomic absorption spectrometer in the flame emission mode.

REAGENTS AND STANDARDS

To minimise potassium pickup, store all solutions in plastic bottles. Shake each container thoroughly to dissolve accumulated salts from walls before pouring.

(i) Reagent water deionised distilled water: Use this water for preparing all reagents and calibration standards and as dilution water.

(ii) Stock potassium solution: Dissolve 1.907g KCl dried at 110°C and dilute to 1000mL with water; 1mL = 1mg K.

(iii) Intermediate potassium solution: Dilute 10mL stock potassium solution with water to 100mL; 1 mL = 0.1 mg K. Use this solution to prepare calibration curve in potassium of 1 to 10 mg/L.

(iv) Standard potassium solution: Dilute 10mL intermediate potassium solution with water to 100mL; 1mL = 0.01 mg K. Use this solution to prepare calibration curve in potassium range of 0.1 to 1 mg/L.

PROCEDURE

Pre-treatment of polluted water and wastewater samples:

Instrument operation: Because of differences between makes and models of instruments, it is impossible to formulate detailed operating instructions. Follow manufacturer's recommendation for selecting proper photocell and wavelength, adjusting slit width and sensitivity, appropriate fuel and oxidant gas pressures and the steps for warm-up, correcting for interference and flame background, rinsing of burner, igniting flame and measuring emission intensity.

Direct-intensity measurement: Prepare a blank and potassium calibration standards in stepped amount in any of the following applicable ranges: 0 to 1.0, 0 to 10, 0 to 100 mg/L. Determine emission intensity at 766.5 nm. Aspirate calibration standards and a samples enough time to secure a reliable average reading for each. Construct a calibration curve from the potassium standards. Determine potassium concentration of sample from the calibration curve. Where a large number of samples must be run routinely, the calibration curve provides sufficient accuracy.

CALCULATION

For direct reference to the calibration curve:

Mg K/L = (mg K/L in portion) x D

Where, D = Dilution factor.

NITRATE

PRINCIPLE

Two mole of nitrate react with one mole of chromotropic acid to form a yellow reaction pro-duct with maximum absorbance at 410 nat. The -maximum colour develops with 10 min and is stable for 24 h.

INTERFERENCES

Residual chlorine, certain oxidants and nitrite yield yellow colours with chromotropic acid. Addition of sulfite eliminates interference from residual chlorine and oxidizing agents. Addition of urea converts nitrite to nitrogen gas.

REAGENT

i) Stock nitrate solution: Dissolve 0.721 g dry potassium nitrate, KNO_3 in water and dilute to 1000 ml. Preserve with 2 mL $CHCl_3$/ L

ii) Sulfite-urea reagent: Dissolve 5 g urea and 4g anhydrous sodium sulfite. Na_2SO_3, in water and dilute to 100 ml.

iii) Chromotropic acid reagent: Dissolve 100 mg purified chromotropic acid in 100ml conc. H_2SO_4 and store in a brown bottle. A colourless reagent solution signifies the absence of NO_3^- contamination from H_2SO_4.

PROCEDURE

i) Prepare nitrate standards in the range 0.1 to 5.0 mg NIL by diluting 0,1.0,5.0,10 ,25,40 and 50 ml standard nitrate solution to 100 ml with water.

ii) Pipet 2.0 mL portions of standards, samples and a water blank into dry 10 ml. volumetric flasks. Use dilutions of standards and samples in the range 0.1 to 5.0 mg NO_3^--N/L.

iii) To each flasks add, drop sulphite-urea reagent and place flasks in a tray of cold water (10 to 20°C).

iv). After about 5 min. in the bath, add 1 ml chromotropic acid reagent, swirl, and, let stand in cooling bath for 3 min. Add conc. sulfuric acid to bring volume near the 10ml mark. Stopper flask and mix by inverting each flask four times. Let stand for 45 min at room temperature and adjust volume to 10 ml with conc. Sulfuric acid.

v) Read absorbance at 410 nm 15 – 20 min after last volume adjustment. Use double distilled water in the reference cell.

vi) Read concentration from the calibration curve.

CALCULATION

$$\text{Nitrate - Nitrogen mg/l} = \frac{\mu g NO_3^-\text{-N (in 10 ml final volume)}}{\text{Volume of sample, ml}}$$

$$\text{Nitrate, mg/l} = \text{Nitrate} - \text{Nitrogen} \times 4.4$$

TOTAL DISSOLVED SOLID

A well-mixed sample is filtered through a standard glass fiber filter, and the filtrate is evaporated to dryness in a weighed dish and dried to constant weight at 180°C. The increase in dish weight represents the total dissolved solids.

INTERFERENCE

Highly mineralized waters with a considerable calcium, magnesium, chloride, and/or sulphate content may be hygroscopic and require prolonged drying, proper desiccation, and rapid weighing. Samples high in bicarbonate require careful and prolonged drying at 180°C to ensure complete conversion of bicarbonate to carbonate.

PROCEDURE

Filter a known volume of well mixed sample through glass fiber filter, wash with three successive 10 ml volume of distilled water, and continue suction for about 3 min after filtration is complete. Transfer filtrate to a weighted evaporating dish and evaporate to dryness on a steam bath. Dry for at least one hour in an oven at 180 ±2°C, cool in a desiccator and weigh to a constant weight. Note the increase in weight.

Calculation

$$\text{Total dissolved solids, mg/L} = \frac{\text{Increase in weight, mg/l} \times 1000}{\text{Volume of Sample, ml}}$$

SULPHATE

Sulphate appears in natural waters in a wide range of concentrations. Mine waters and industrial effluents frequently contain large amounts of sulphate from pyrite oxidation and the use of sulfuric acid. Sodium and magnesium sulphate exert cathertic action and hence its concentration above 250 mg/L in potable water is objectionable. Sulphate causes a problem of scaling in industrial water supplies, and problem of odour and corrosion in waste water treatment due to its reduction to hydrogen sulphide.

PRINCIPLE

Sulphate ions are precipated in acetic acid solution with barium chloride so as to form a uniform suspension of barium sulphate crystals. The absorbance of the suspension is measured by a photometer and the sulphate concentration is determined by comparison of the reading with a standard curve.

INTERFERENCE

Colour and suspended mater in amounts will interfere. Some suspended matter may be removed by filtration. Silica in excess of 500 mg/l interfere.

REAGENTS

Buffer Solution: Dissolve 30 g magnesium chloride, $MgC1_2.6H_20$, 5 g sodium acetate, $CH_3COONa.3H_2O$, 1 gm. potassium nitrate, KNO_3, and 20 ml acetic acid, CH_3COOH (99%), in 500 ml distilled water and make up to 1000mL.

Barium chloride crystals: 20 to 30 mesh.

Standard sulphate solution: Dissolve 0.147 g of anhydrous Na_2S0_4 in distilled water.

PROCESSER

(i) Take 100 mL sample, or suitable portion made up to 100 ml, into a 250 ml flask. Add 20 ml buffer solution and mix in stirring apparatus. Add barium chloride crystals while stirring. Continue stirring for 1 minute after addition of barium chloride.

(ii) Measure the turbidity developed after five minutes on colorimeter at 420 mm.

(iii) Prepare standard curve by carrying standard sulphate solution through entire procedure. Space standards at 5 mg/L increment in the 0 to 40 mg/L range. Above 40 mg/L accuracy decreases and barium sulphate suspension loss stability.

(iv) Read the concentration of sulphate present in the sample from the standard curve.

CALCULATION

$$\text{Sulphate, mg/L} = \frac{\text{mg } SO_4^{2-} \times 1000}{\text{Volume of Sample}}$$

CHAPTER 5: RESULT AND DISCUSSION

The samples were analyzed for assessment of water quality as per standard methods (APHA, 1999). The parameters such as pH, Conductivity, TDS, Alkalinity, Hardness, Chloride, Sulphate, Nitrate, Sodium, Potassium, Calcium, Magnesium, and Iron for samples from River Ganga were analyzed and the results are given in Table 5.1.

Water quality status of River Ganga from Gangotri to Haridwar in terms of selected 13 parameters is found within specified limit as prescribed by BIS 2012 (Table 5.2). A close examination clearly indicates that all parameter are complying with the standards (BIS 10500). However the Quality of Water is spatially varying in nature from Gangotri to Haridwar. But it can be concluded that River Ganga in Uttarakhand is relatively clean and complying with the criteria.

It has been observed that at Bisanpur and Khadkhadi, deviation from mean values is more for maximum nos of parameter. After deep analysis of all possible causes it is found that the discharge from Jagjeet-Pur, Sewage treatment plant is the most probable cause of the deviation. Jagjeet-pur STP, received entire sewerage of haridwar city which is nearly 55-60 MLD but installed treatment capacity is only 45 MLD. Remaining (60-45=15) MLD sewage water directly being discharged into the river Ganga.

Results of all parameters at all the location are shown in table 5.1

Table 5.1 Physico-chemical characterization of River Ganga Samples

Sample Code	Location	pH.	EC (µs /cm)	Alkalinity (mg/L)	Hardness (mg/L)	Cl (mg/L)	NO3 (mg/L)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Fe (mg/L)	TDS (mg/l)	SO4 (mg/l)
G-1	Jangla Bridge	5.9	212	51	84	0.2	7	4.4	1.6	23	6	0.5	136	57
G-2	Jhala Bridge	5.8	175	43	85	4.2	8.8	3.9	1.6	20	9	0.17	112	44
G-3	Dabrani Bridge	6.2	171	41	75	0.8	8.4	3.9	1.7	18	7	0.16	109	37
G-4	UK Laghu Vidhut Pariyojna	6.2	174	47	71	0.8	5.3	5.1	1.9	19	6	0.21	111	40
G-5	Nalluna Senj	6.5	167	47	70	1.4	1.3	4.8	1.9	19	6	0.06	107	36
G-6	After Heena Power Station	6.4	169	45	68	0.4	4.8	5.1	1.9	18	5	0.08	108	33
G-7	u/s Uttarkashi	6.6	169	46	68	2.2	6.6	4.8	2	19	5	0.07	108	30
G-8	d/s Uttarkashi	6.7	168	47	72	1.8	6.6	4.7	2	20	6	0.06	108	32
G-9	Badethi Chungi	6.4	168	51	73	1.2	8.8	4.3	1.8	18	7	0.07	108	26
G-10	Dharashu	6.5	177	47	76	2	7	4.5	1.7	20	6	0.09	113	24
G-11	Chinyalisaur	6.6	89	33	14	0.2	18	1.7	1.1	12	2	0.15	57	14
G-12	Tehri Reservoir (Koti colony)	6.6	96	34	43	0	13	1.7	1.3	11	4	0.18	61	17
G-13	Zero Bridge Tehri	6.4	94	55	41	1.2	3.1	1.8	1.1	11	3	0.27	60	13
G-14	Downsream of Koteswar PP	6.5	100	34	43	1.4		1.7	1.1	12	3	0.06	64	12
G-15	Bhagirathi Devprayag	6.6	99	35	42	0.4	4	1.6	1	11	3	0.08	63	14
G-16	Ganga Devprayag	6.5	111	38	49	1.2	4.8	2	1	14	3	0.1	71	17
G-17	Lakundi Shiv Chula	6.6	139	52	61	2.4	5.7	1.6	0.8	17	5	0.1	106	21
G-18	Lakhman Chula Rishikesh	6.9	166	61	75	2.4	11	1.7	0.8	20	6	0.07	139	25
G-19	Saptrishi Ashram	6.7	182	69	79	2.4	12	1.6	0.7	21	6	0.19	311	43
G-20	Bhimgowada Barrage	6.5	135	52	57	0	4.8	1.7	0.9	16	4	0.1	88	20
G-21	Khadkhadi	7.5	485	401	224	7.4	5.3	5	0.5	53	22	0.02	116	20
G-22	Gujrawala Bhawan	7	160	47	72	2	9.7	1.2	0.7	21	5	0.08	102	20
G-23	Bisanpur village	6.9	217	93	108	2.2	9.2	1.4	0.5	30	8	0.02	86	17

Table-5.2 Compliance of River Water Quality with BIS Standard

Parameters	Acceptable Limit	Allowable Limit	Water Quality of River Ganga
pH	6.5-8.5	No Relaxation	Within Limit
Conductivity	-	1,500 µs/cm (WHO)	Within Limit
TDS	500	2000	Within Limit
Alkalinity	200	600	Within Limit
Hardness	200	600	Within Limit
Chloride	250	1000	Within Limit
Sulphate	200	400	Within Limit
Nitrate	45	No Relaxation	Within Limit
Sodium	200 (WHO)	-	Within Limit
Potassium	10 (WHO)	-	Within Limit
Calcium	75	200	Within Limit
Magnesium	30	100	Within Limit
Iron	0.3	No Relaxation	Within Limit

It is clear from the result of water quality parameters and prescribed BIS 10500 Standard for drinking water that parameters are within prescribed limit hence River Ganga water is free from pollution.

5.1 DISCUSSION

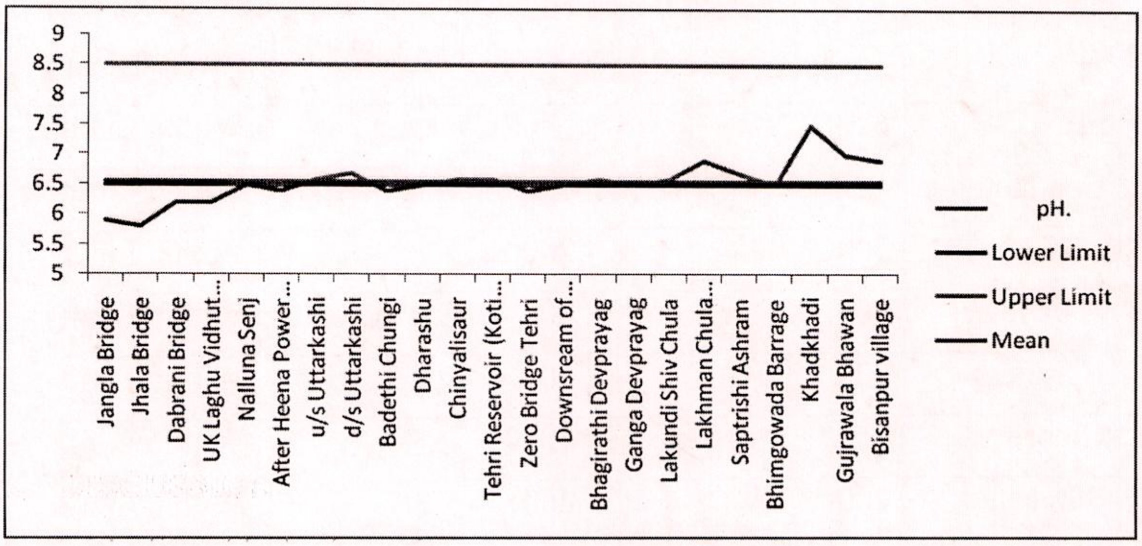

Fig-5.1 pH Trend in River Ganga

pH - The pH of a sample of water is a measure of the concentration of hydrogen ions. The term pH was derived from the manner in which the hydrogen ion concentration is calculated. It is the negative logarithm of the hydrogen ion (H+) concentration. pH in rivers is affected by the geology of the water source, atmospheric inputs and a range of other chemical contaminants. pH is only likely to become an issue on very poorly buffered upland rivers where atmospheric sulphur and nitrogen oxides may vary significantly depress the pH as low as pH 4 or in eutrophic alkaline rivers where photosynthetic bi-carbonate ion production in photosynthesis may drive the pH up above pH 10.

As it is clear from the above graph that pH Values at the entire length of river are within specified limit (The pH of most natural waters ranges between 6.5 and 8.5). However it has been observed (see graph) that pH values at Jangla Bridge, Jhala Bridge, Debrani Bridge, UK Laghuvidut pariyojna and at Naluna Senj are less than 6.5 due to dissolution of carbon dioxide and low alkalinity. On the other hand pH at Khadkhadi is maximum (but within the limit).For better understanding of spatial variation in pH concentration pH contiur map is given here-

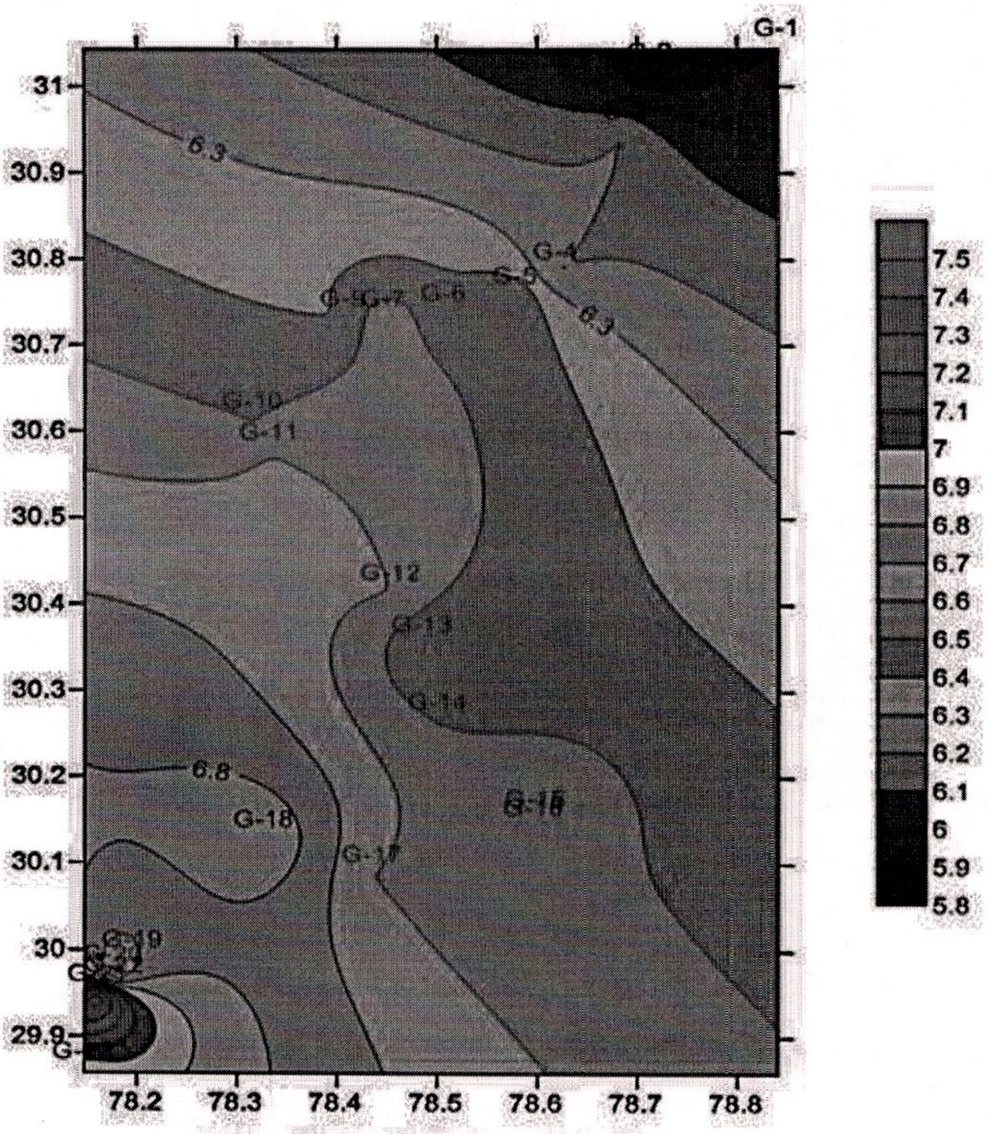

Fig 5.2 pH Contour in river Ganga

Explanation-It is clearly shown in contour map that pH Values is increasing as we moves downstream from Gangotri. Highest pH is shown near Haridwar.

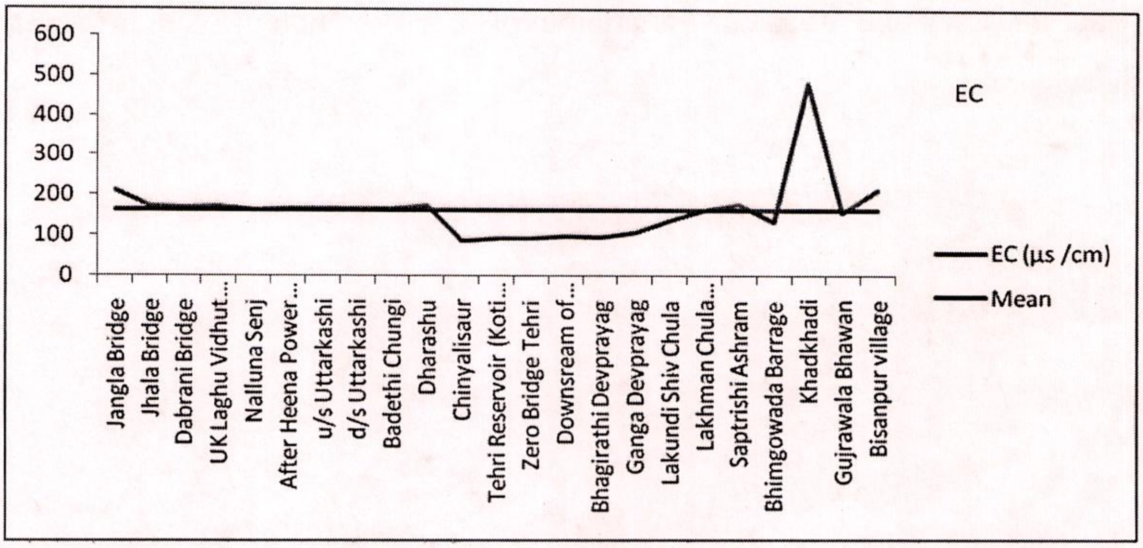

Fig 5.3 EC Trend in River Ganga

Electrical Conductivity- Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminium cations (ions that carry a positive charge). Why is it important? Most streams have a fairly constant range of conductivity under normal circumstances. Therefore, significant changes in conductivity can be an indicator that a discharge or some other source of pollution has entered the water. The composition of the water can be critical for aquatic organisms as well, as many critters have very specific ranges that they can tolerate.

Electrical Conductivity is within limit in entire course of river however its values are spatially varies (shown in fig 4.2).Electrical conductivity at Khadkhadi is found maximum but within limit.However from Chinyalisur to Lakhundi Shiv-Chula electrical conductivity are observed below mean values.

But overall Electrical Conductivity is within limit and showing good health of

river.Conductivity is within limit and showing good health of river.Conductivity is within limit and showing good health of river.

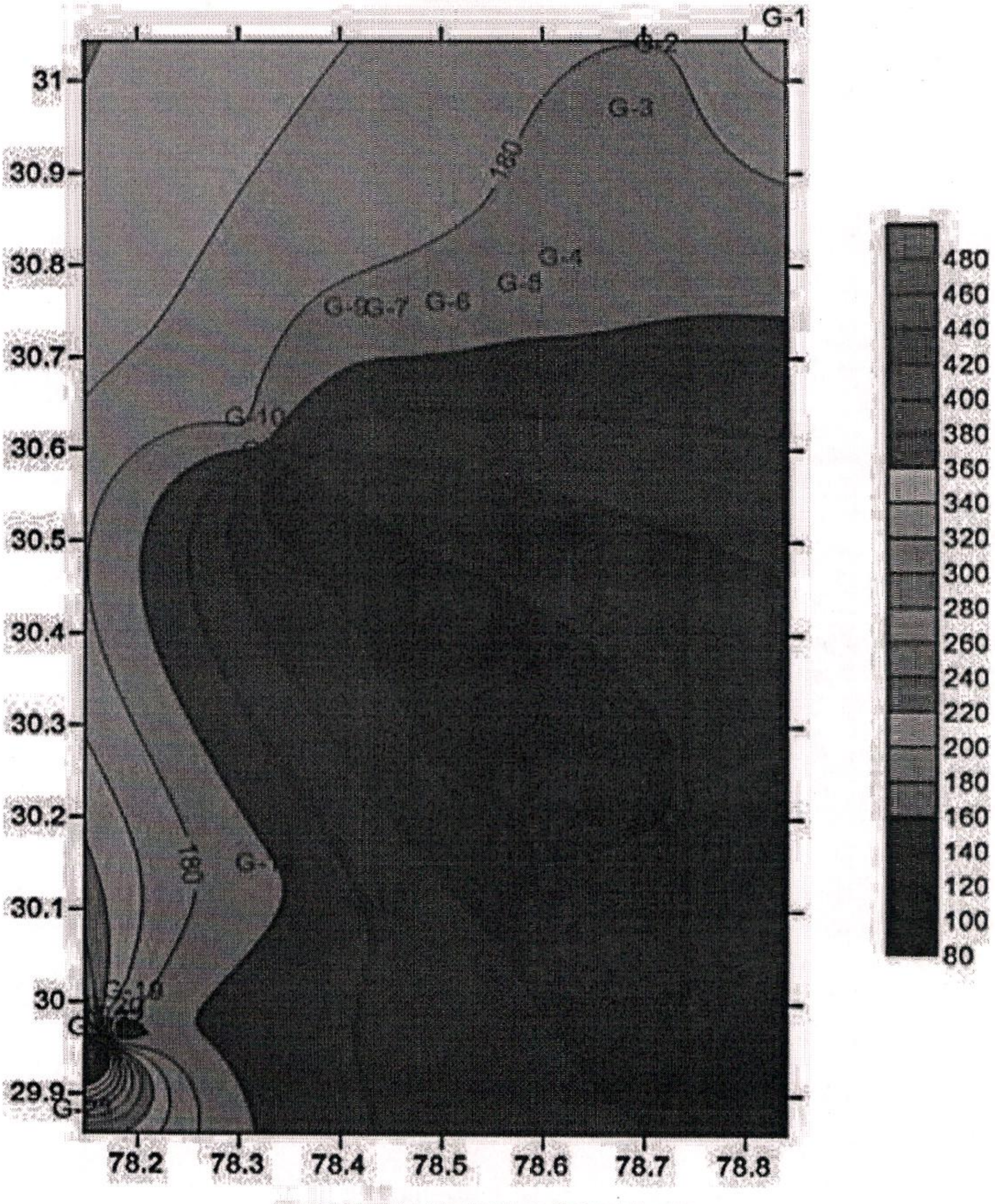

Fig 5.4 EC Contour in river Ganga

Explanation-Most of the location shows EC values in between 100-160 (Dark blue colour in graph) or in between 160-220 (Light maroon colour). EC values are found greater near Haridwar (Green, Yellow, Red and Pink Colour).

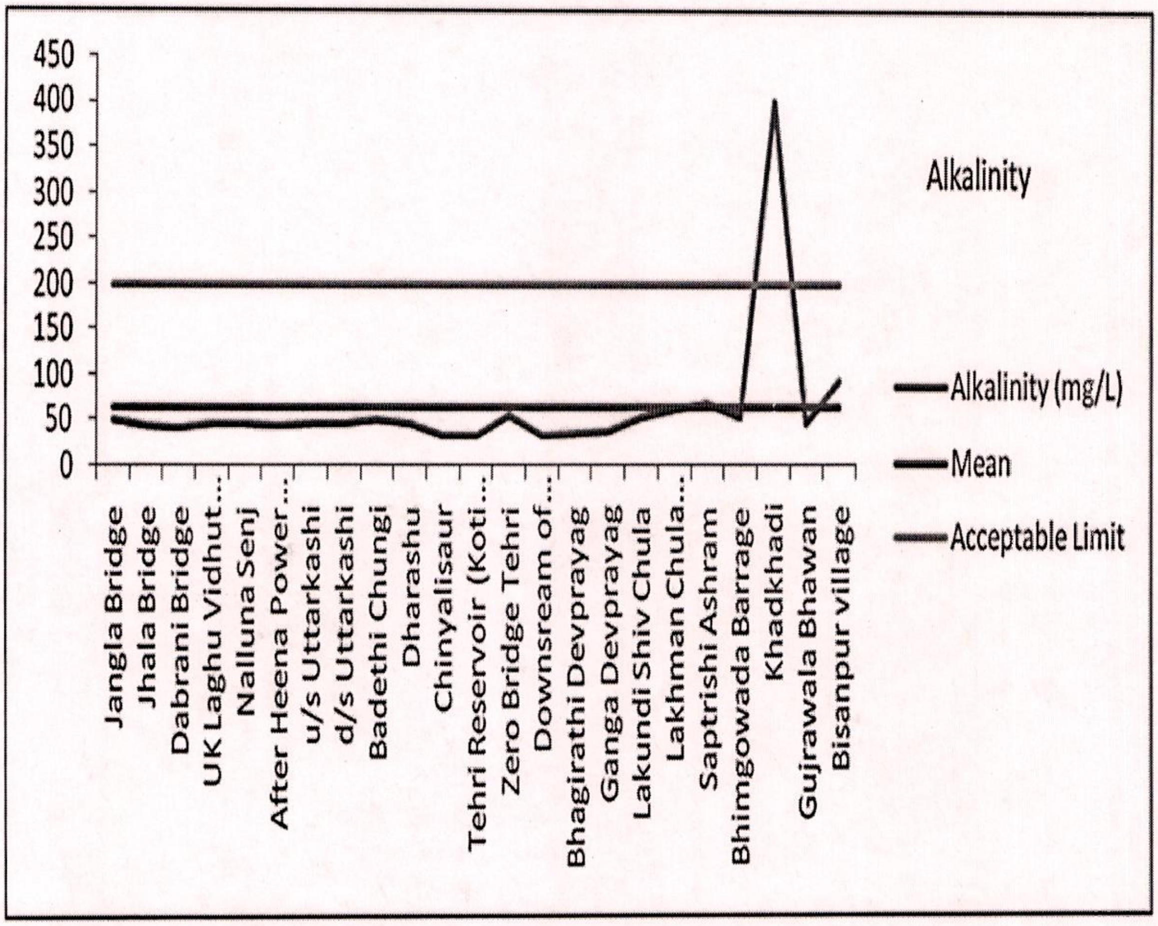

Fig 5.5 Alkalinity Trend in river Ganga

ALKALINITY- Alkalinity is a measure of the capacity of water or any solution to neutralize. The most important compounds in water that determine alkalinity include the carbonate (CO32-) and bicarbonate (HCO3-) ions.

Alkalinity has crossed the Acceptable limit at Khadkhadi (401 mg/l), otherwise concentration of alkalinity in entire length of river is almost uniform and within the permissible limit.

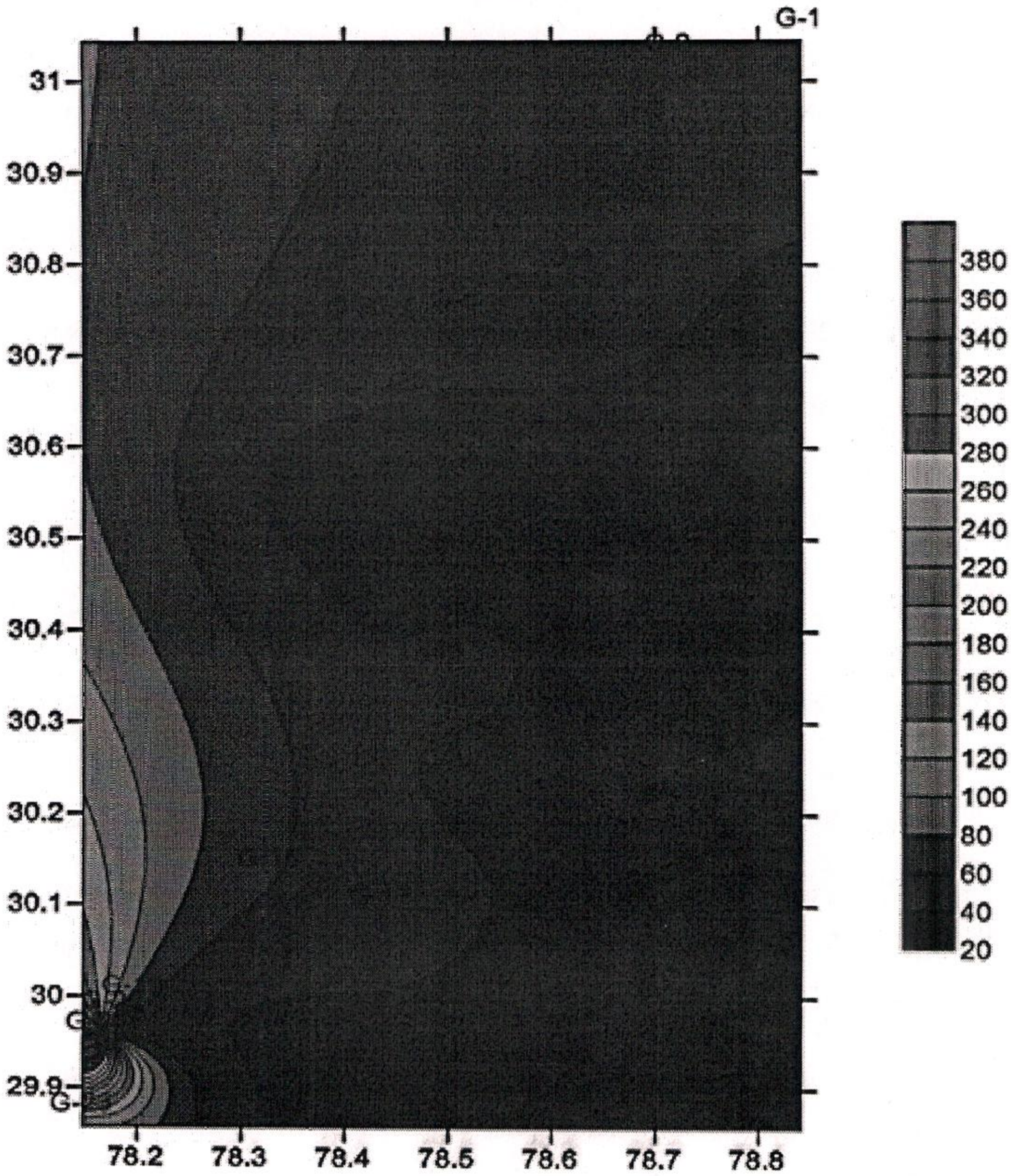

Fig 5.6 Alkalinity Contour in river Ganga

Explanation-Alkalinity values variation is shown in above contour map. It is clear from above graph that maximum nos of location have alkalinity in range of 40 to 80 mg/l (Dark Blue Colour). Alkalinity values are increasing as we move downstream from Gangotri. Highest values are shown at Haridwar (Red to Pink colour in graph).

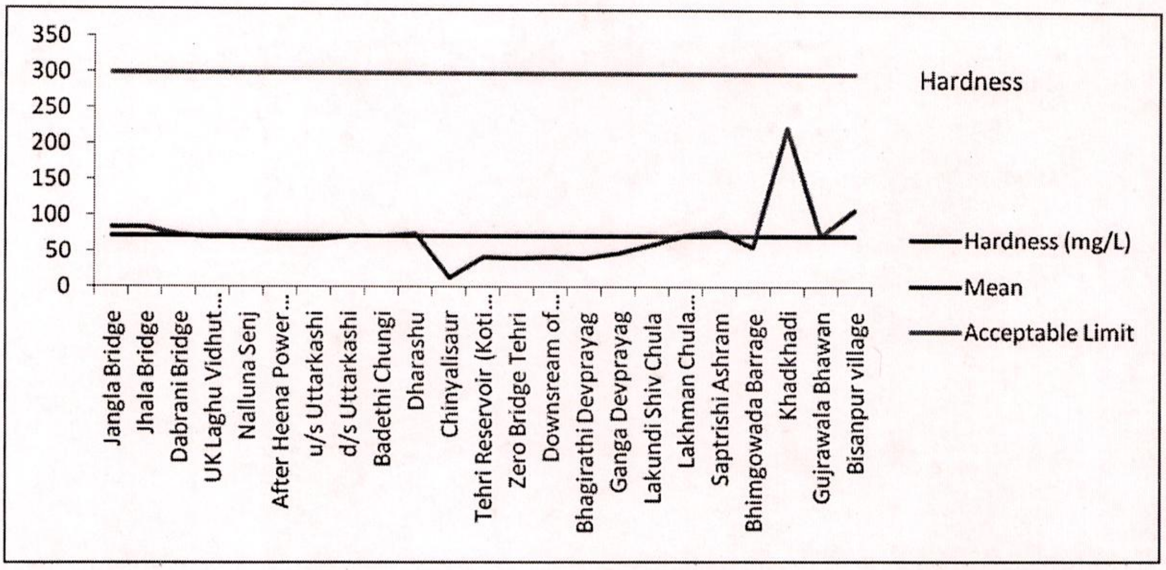

Fig 4.7 Hardness Trend in River Ganga

HARDNESS- Water hardness represents the total concentration of calcium and magnesium ions and is expressed as milligrams per litre (mg/L) of calcium carbonate. Calcium and magnesium are naturally occurring elements within geological formations found throughout watersheds. "Ideal" water hardness for drinking water ranges between approximately 50 to 100 mg/L. Hard drinking water is generally not harmful to one's health (WHO).

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.

Hardness values are found to be within specified limit along the entire length of River Ganga (from Gangotri to Haridwar) highest alkalinity is observed at Khadkhadi (224mg/l) and minimum at Chinyalisaur.

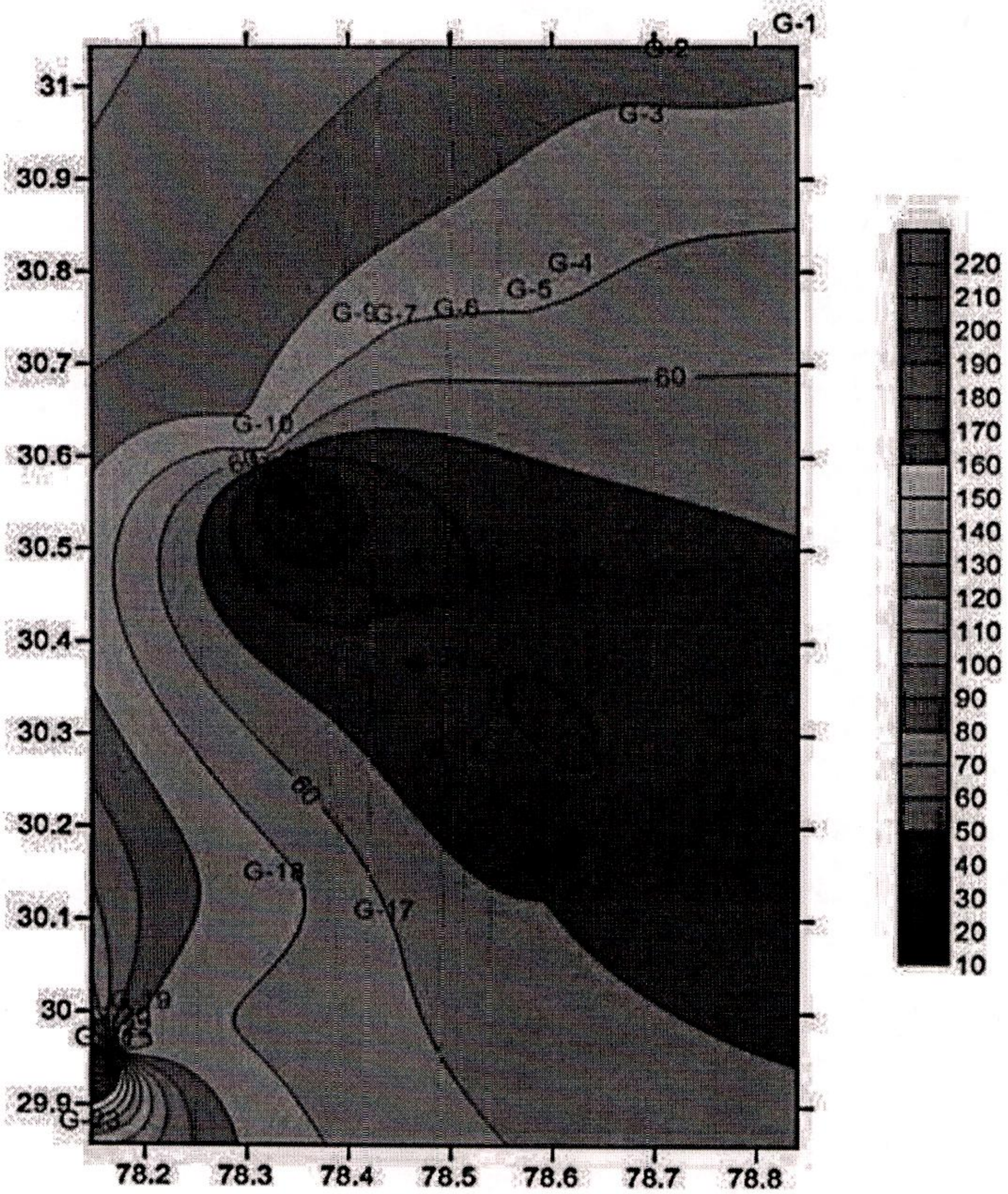

Fig 5.8 Hardness Contour in river Ganga

Explanation-It is clear from above contour map that most of the location having Hardness values in between 50 mg/l to 80 mg/l (shown maroon colour in above graph). Hardness values are higher near and at Haridwar about in range 160-220 mg/l (shown in Dark red to purple colour in above graph)

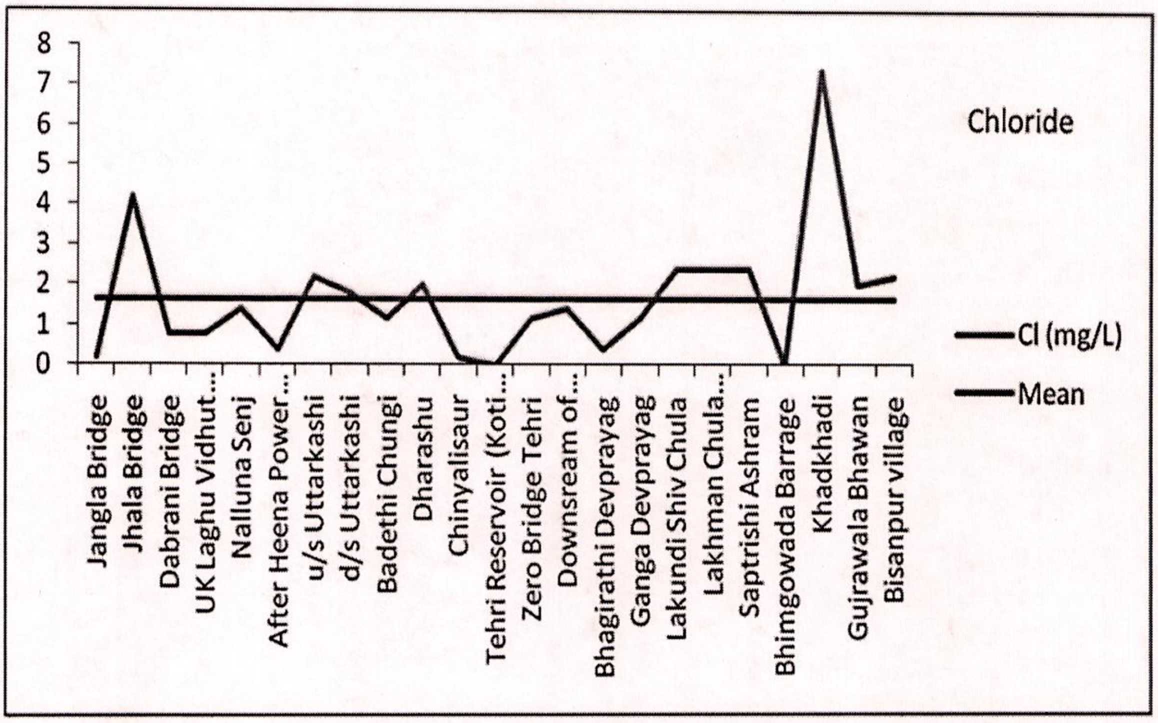

Fig 5.9 Chloride Trend in River Ganga

CHLORIDE- Chloride is a salt compound resulting from the combination of the gas chlorine and a metal. Common chlorides include sodium chloride (NaCl) and magnesium chloride ($MgCl_2$). Chlorine alone is highly toxic and is often used as a disinfectant. In combination with a metal such as sodium, it becomes essential for life. Small amounts of chlorides are required for normal cell functions in plants and animals.

Chlorides are not usually harmful to people; however, the sodium part of table salt has been linked to heart and kidney disease. Sodium chloride may impart a salty taste to water at 250 mg/L; however, calcium or magnesium chloride is not usually detected by taste until levels of 1,000 mg/L are reached.

Chloride content in River Ganga is found within prescribed limit, which shows that river is healthy. Maximum chloride concentration is found at Khadkhadi (7.4mg/l) and minimum at Tehri Reservoir.

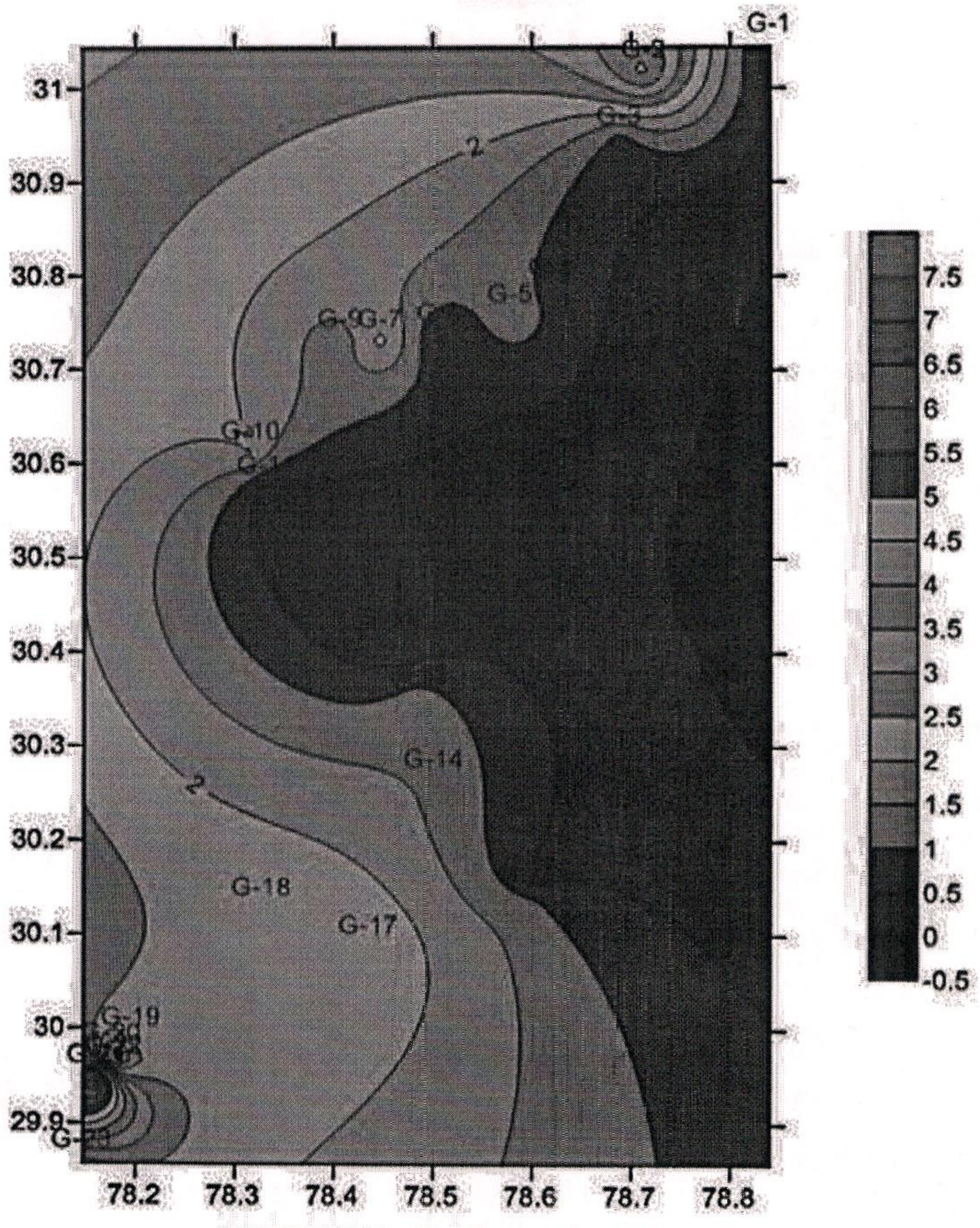

Fig 5.10 Chloride Contour in river Ganga

Explanation- In above Chloride Contour graph is clearly shown that most of the sampling location is having Chloride concentrationin range of 0-5 to 2.5 mg/l (Shown in dark blue and maroon colour in map).Maximum values are observed at or near Haridwar (shown in red and pink colour).

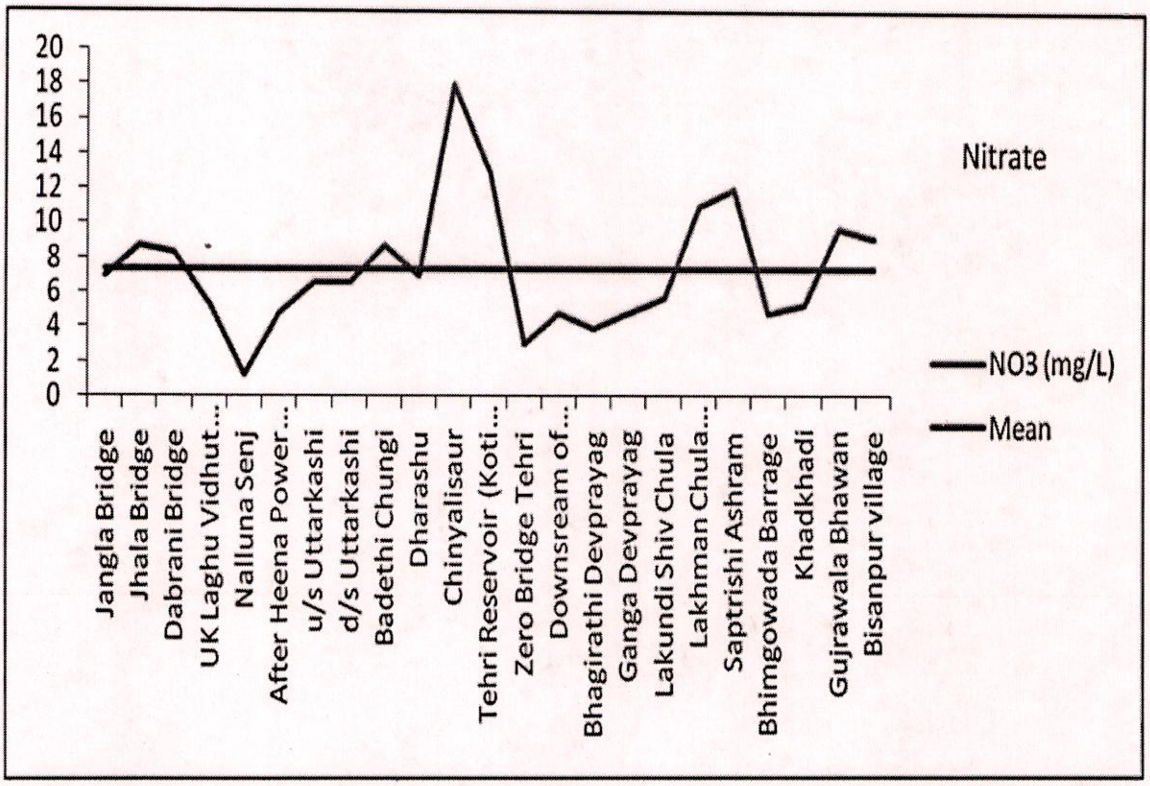

Fig 5.11 Nitrate Trend in River Ganga

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

Nitrate concentration in river Ganga is found within desired limit which indicate that river is pollution free. Maximum Nitrate is observed at Chinyalisaur and minimum at Nalluna-Senj (shown in fig 5.11).

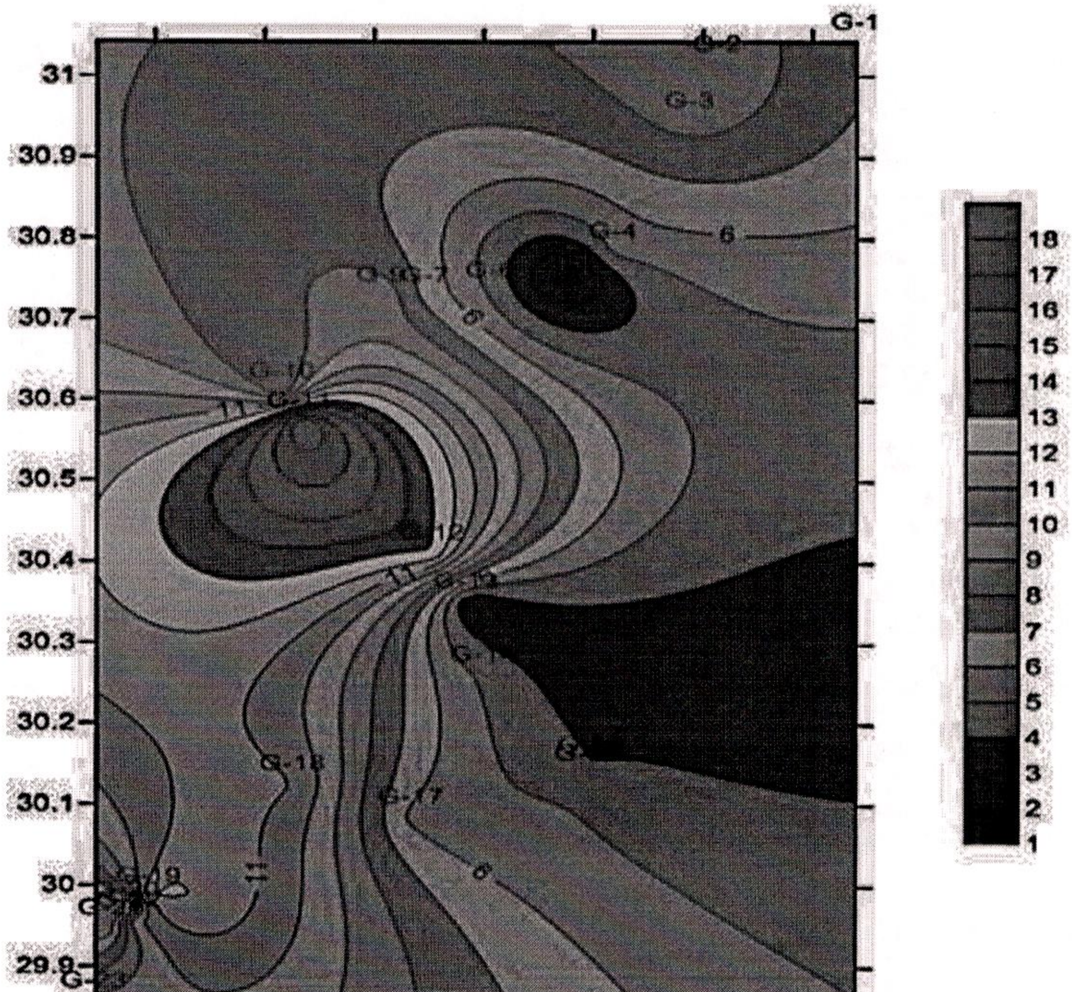

Fig 5.12 Nitrate Contour in river Ganga

Explanation-Few intermediate location has shown highest Nitrate concentration in range of 13 mg/l to 18 mg/l(shown in red and purple colour).Most of the location upper and lower reach of river shown Nitrate concentration in range of 4 to 7 mg/l (shown in maroon colour).Concentration of Nitrate does not show any close association with length and run of river.

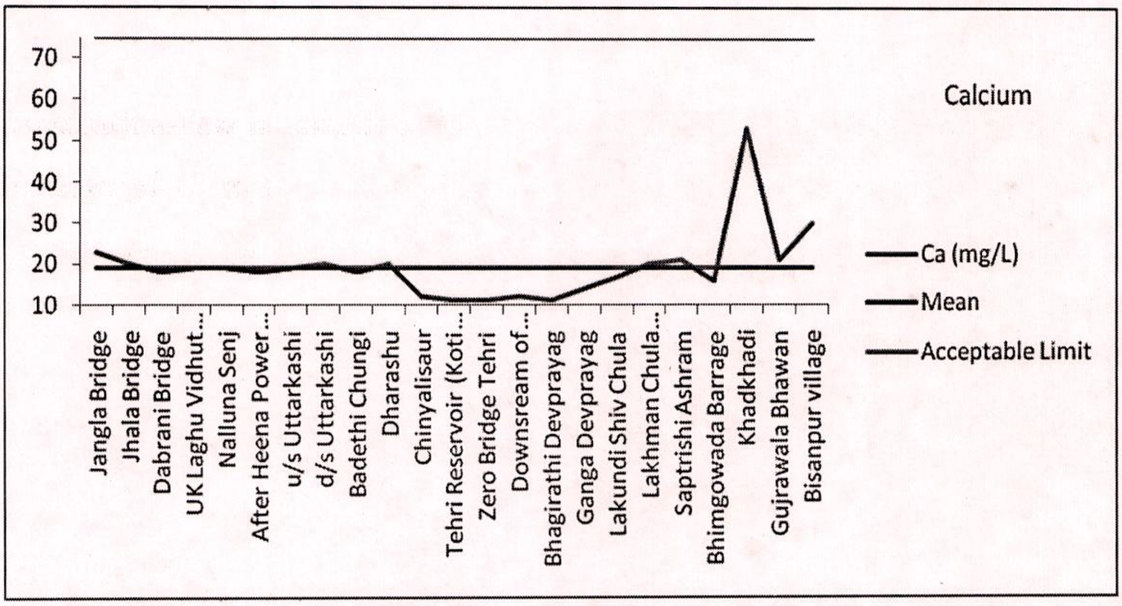

Fig-5.13 Calcium Trend in River Ganga

CALCIUM-Calcium is naturally present in water. It may dissolve from rocks such as limestone, marble, calcite, dolomite, gypsum, fluorite and apatite. Calcium is a determinant of water hardness, because it can be found in water as Ca^{2+} ions.

Environmental effects of calcium in water- Calcium is a dietary requirement for all organisms apart from some insects and bacteria. Calcium carbonate is a building stone of skeletons of most marine organisms, and eye lenses. Calcium phosphate is required for bone structure and teeth structure of terrestrial organisms. Plants mainly contain calcium oxalate. Calcium storage in plants is about 1% of dry mass. Calcium is largely responsible for water hardness, and may negatively influence toxicity of other compounds. Elements such as copper, lead and zinc are much more toxic in soft water.

Health effects of calcium in water-Calcium are a dietary mineral that is present in the human body in amounts of about 1.2 kg. No other element is more abundant in the body. Calcium phosphate is a supporting substance, and it causes bone and tooth growth, together with vitamin D. Calcium is also present in muscle tissue and in the blood. It is required for cell membrane development and cell division, and it is partially responsible for muscle contractions and blood clotting. Calcium regulates membrane activity, it assists nerve impulse transfer and hormone release, stabilizes the pH of the body, and is an essential part of conception. Calcium carbonate works as a stomach acid remedy and may be applied to resolve digestive failure. Calcium lactate may aid the body during periods of calcium deficiency, and calcium chloride is a diuretic. Hard water may assist in strengthening bones and teeth because of its high calcium concentration. It may also decrease the risk of heart conditions. Calcium carbonate has a positive effect on lead water pipes, because it forms a protective lead (II) carbonate coating. This prevents lead from dissolving in drinking water, and thereby prevents it from entering the human body.

When one takes up large amounts of calcium this may negatively influence human health. The lethal dose of oral uptake is about 5-50 mg/ kg body weight. Metallic calcium corrodes the skin when it comes in contact with skin, eyes and mucous.

Calcium concentration in River Ganga water is observed within limit and no health hazard is observed. River is healthy and pollution free. Maximum concentration is observed at Khadkhadi (53mg/l) and minimum at Tehri.

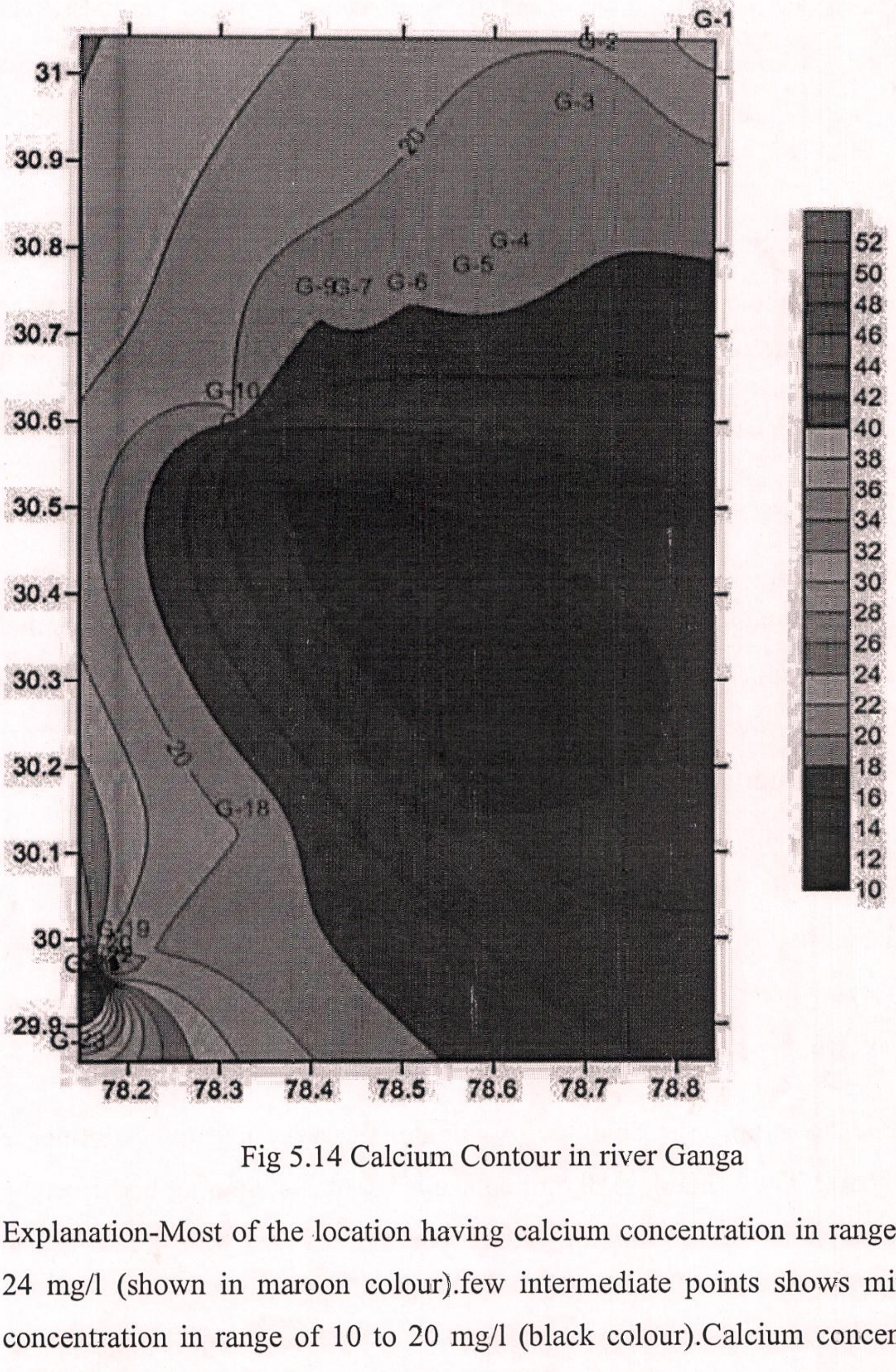

Fig 5.14 Calcium Contour in river Ganga

Explanation-Most of the location having calcium concentration in range of 18-24 mg/l (shown in maroon colour).few intermediate points shows minimum concentration in range of 10 to 20 mg/l (black colour).Calcium concentration found to be high at Haridwar (Red and Purple Colour).

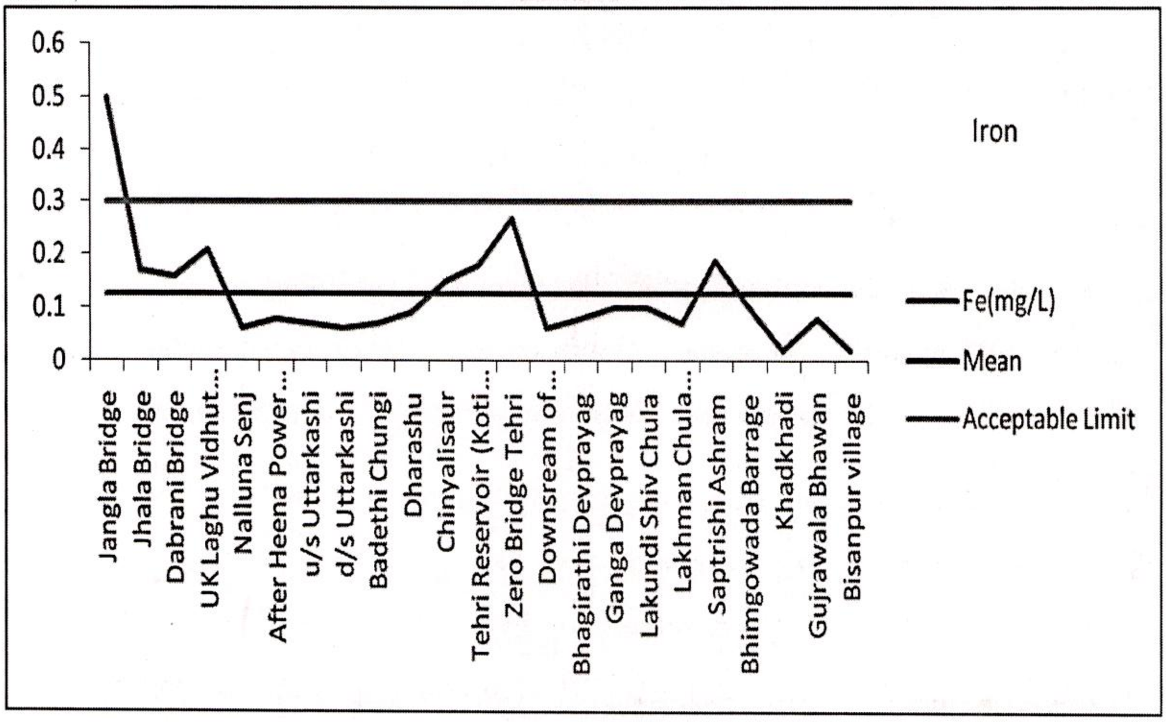

Fig 4.15 Iron Trend in River Ganga

IRON-The main naturally occurring iron minerals are magnetite, hematite, goethite and siderite. Weathering processes release the element into waters. Both mineral water and drinking water contain iron carbonate.

Environmental effects of iron in water- Iron is a dietary requirement for most organisms, and plays an important role in natural processes in binary and tertiary form. Oxidized tertiary iron cannot be applied by organisms freely, except at very low pH values. Iron is essential for nitrogen binding and nitrate reduction, and it may be a limiting factor for phytoplankton growth. Iron forms chelating complexes that often play an important role in nature, such as haemoglobin, a red colouring agent in blood that binds and releases oxygen in breathing processes. Organisms take up higher amounts of binary iron than of tertiary iron, and uptake mainly depends on the degree of saturation of physical iron reserves.

Health effects of iron in water-The total amount of iron in the human body is approximately 4 g, of which 70% is present in red blood colouring agents. Iron is a dietary requirement for humans, just as it is for many other organisms. Men require approximately 7 mg iron on a daily basis, whereas women require 11 mg. The difference is determined by menstrual cycles. The body absorbs approximately 25% of all iron present in food. In food iron is present as binary iron bound to haemoglobin and myoglobin, or as tertiary iron. The body may particularly absorb the binary form of iron. Iron is a central component of haemoglobin. It binds oxygen and transports it from lungs to other body parts. Oxygen storage also requires iron. Iron is a part of several essential enzymes, and is involved in DNA synthesis. Normal brain functions are iron dependent. In the body iron is strongly bound to transferring, which enables exchange of the metal between cells. The compound is a strong antibiotic, and it prevents bacteria from growing on the vital element. When one is infected by bacteria, the body produces high amounts of transferring. When iron exceeds the required amount, it is stored in the liver. The bone marrow contains high amounts of iron, because it produces haemoglobin. Iron deficits lead to anaemia, causing tiredness, headaches and loss of concentration. The immune system is also affected. In young children this negatively affects mental development, leads to irritability, and causes concentration disorder. Young children, pregnant women and women in their period are often treated with iron (II) salts upon iron deficits. When high concentrations of iron are absorbed, for example by haemochromatose patients, iron is stored in the pancreas, the liver, the spleen and the heart. This may damage these vital organs. Healthy people are generally not affected by iron overdose, which is also generally rare. It may occur when one drinks water with iron concentrations over 200 ppm. Iron compounds may have a more serious effect upon health than the relatively harmless element itself. Water soluble binary iron compounds such as $FeCl_2$ and $FeSO_4$ may cause toxic effects upon concentrations exceeding 200 mg, and are lethal for adults upon doses of 10-50 g. A number of iron chelates may be toxic, and the nerve toxin iron penta carbonyl is known for its strong toxic mechanism.

Concentration of iron is found within desirable limit in entire length of river from Gangotri to Haridwar except at Jangla Bridge (Due to watershed rock characteristics). The maximum concentration is observed at Jangla Bridge and Minimum at Bisanpur village and Khadkhadi but overall concentration of iron is found within desired limit which indicate healthy river condition.

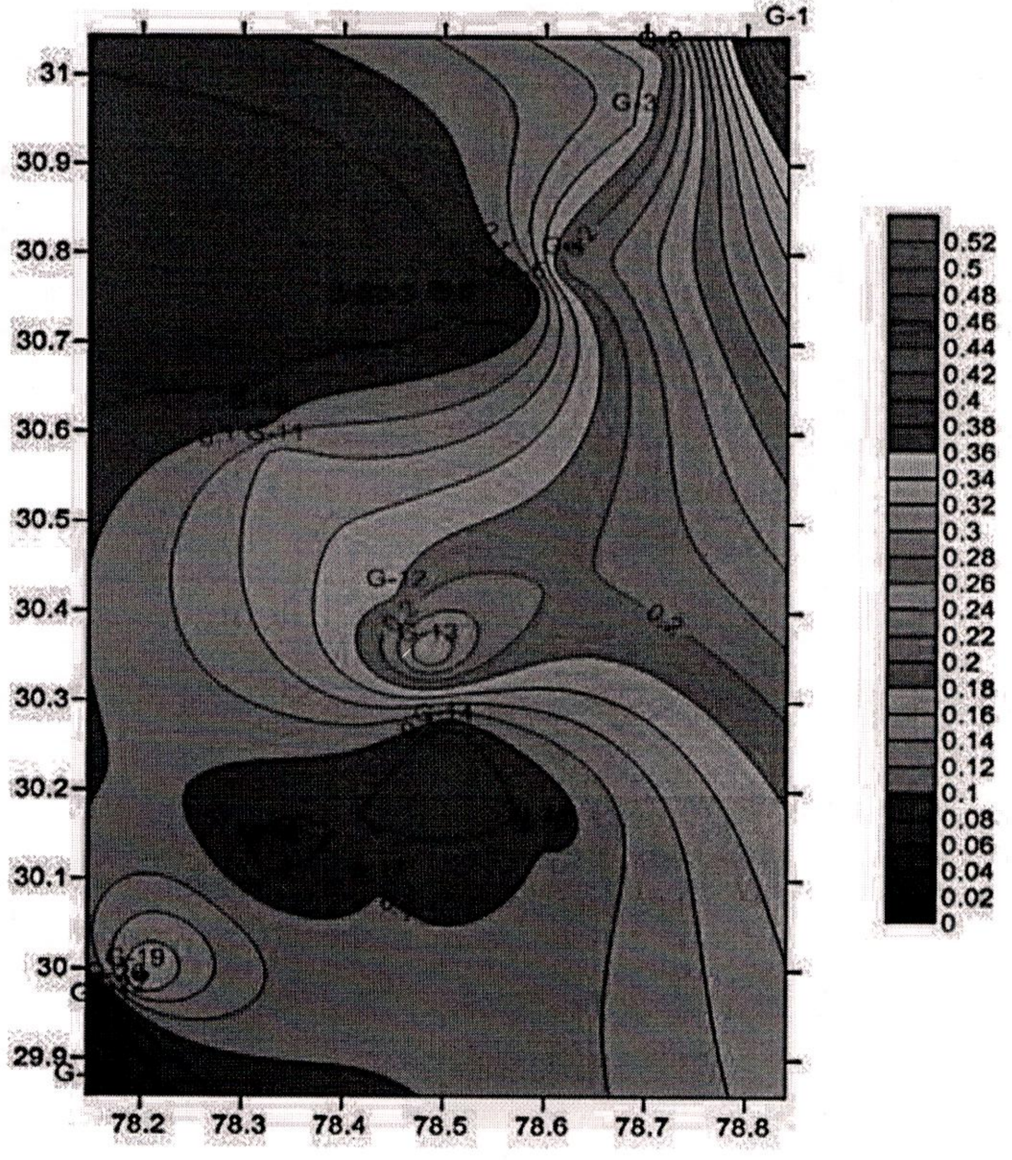

Fig 5.16 Iron Contour in river Ganga

Explanation-Above contour map shows uneven and unsymmetric distribution of Iron in river Ganga from Gangotri to Haridwar.Concentration of Iron varries site to site and there is little formation of cluster of location of same concentration.Iron concentration shown maximum at upper reach of river due (shown in red colour) but most of the location shown the concentration of iron in range of 0.02 to 0.18 mg/l.(shown in dark blue and in Maroon colour) but distribution is un -even.

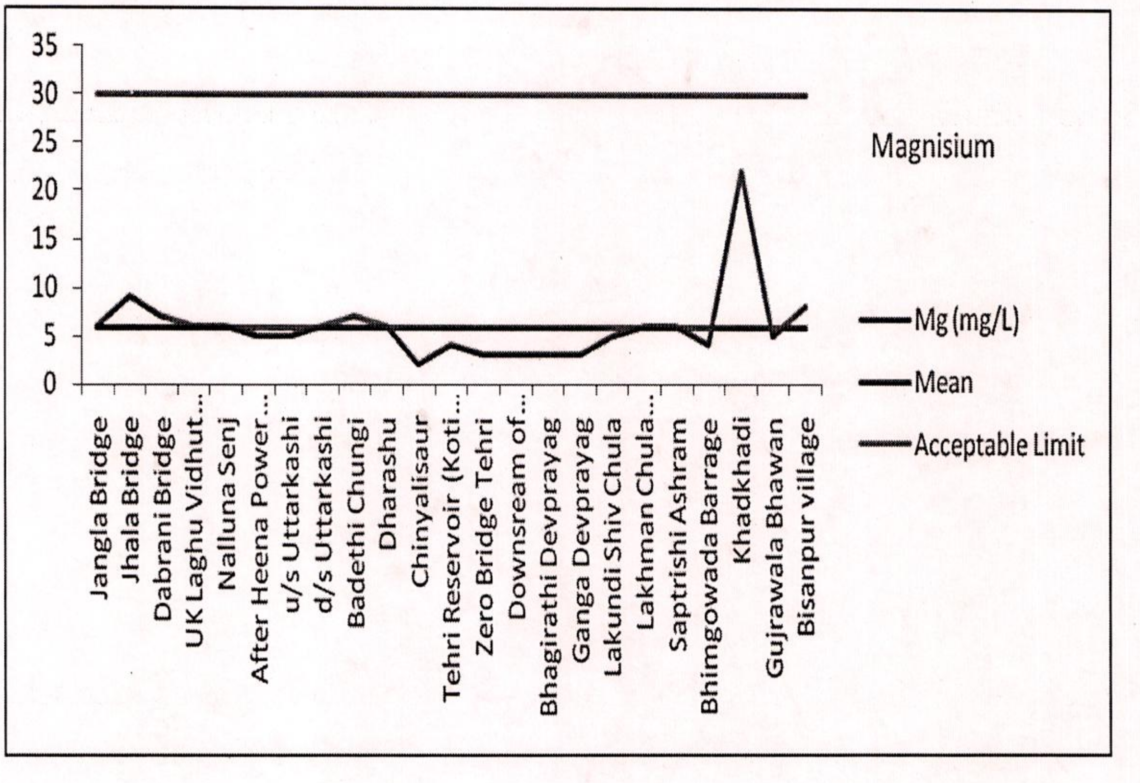

Fig 5.17 Magnesium Trend in river Ganga

MAGNESIUM-A large number of minerals contains magnesium, for example dolomite Magnesium is washed from rocks and subsequently ends up in water.

Environmental effects of magnesium in water-Magnesium are a dietary mineral for any organism but insects. It is a central atom of the chlorophyll molecule, and is therefore a requirement for plant photosynthesis. Magnesium cannot only be found in seawater, but also in rivers and rain water, causing it to naturally spread throughout the environment. Guidelines for magnesium content in drinking water are unlikely, because negative human and animal health effects are not expected.

Health effects of magnesium in water- Human body contains about 25 g of magnesium, of which 60% is present in the bones and 40% is present in muscles and other tissue. It is a dietary mineral for humans, one of the micro elements that are responsible for membrane function, nerve stimulant transmission, muscle contraction, protein construction and DNA replication. Magnesium is an ingredient of many enzymes. Magnesium and calcium often perform the same functions within the human body and are generally antagonistic. There are no known cases of magnesium poisoning. At large oral doses magnesium may cause vomiting and diarrhoea. High doses of magnesium in medicine and food supplements may cause muscle slackening, nerve problems, depressions and personality changes. As was mentioned before, it is unusual to introduce legal limits for magnesium in drinking water, because there is no scientific evidence of magnesium toxicity. In other compounds, for example asbestos, magnesium may be harmful.

Magnesium in river Ganga- Magnesium concentration found maximum at Khadkhadi and minimum at Chinyalisur but both limit are within prescribed limit which indicated that river is pollution free and there is no health hazards.

Concentration of magnesium is varying from site to site. Variation does not follow any specific trend, it is unsymmetrical in nature. Detail and comparatively variation in magnesium for all location is shown in magnesium contour map below.

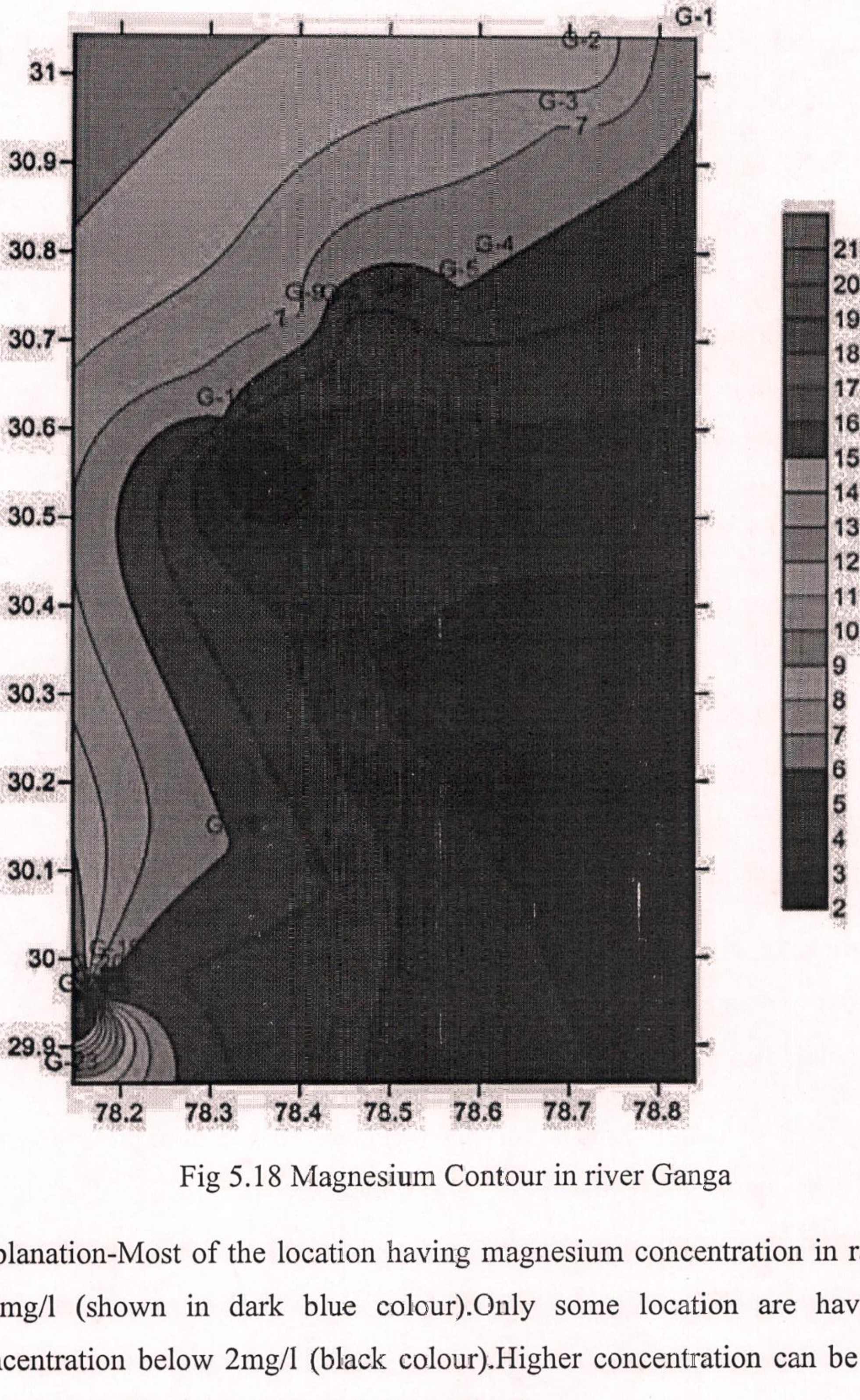

Fig 5.18 Magnesium Contour in river Ganga

Explanation-Most of the location having magnesium concentration in range of 3-4mg/l (shown in dark blue colour).Only some location are having Ca concentration below 2mg/l (black colour).Higher concentration can be clearly seen near the Haridwar (Red and Pink Colour).

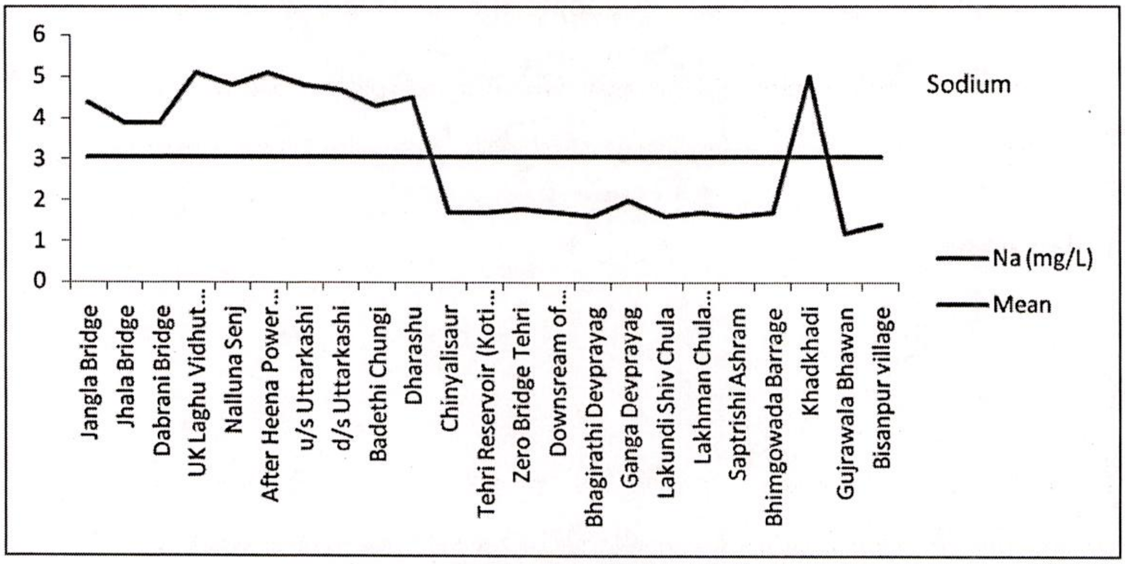

Fig 5.19 Sodium Trend in river Ganga

SODIUM-Sodium compounds naturally end up in water. Sodium stems from rocks and soils. Not only seas, but also rivers and lakes contain significant amounts of sodium. Concentrations however are much lower, depending on geological conditions and wastewater contamination.

Environmental effects of sodium in water-Sodium are attributed water hazard class 2, in other words it is a risk when present in water. Sodium chloride however is not a risk and is attributed water hazard class 1. Sodium is a dietary mineral for animals. Plants however hardly contain any sodium. The LC_{50} value for gold fish is 157 mg/L. Sodium hypo chlorite from sanitary cleansers may contribute to chlorinated hydrocarbon formation. It is a dietary mineral, partially responsible for nerve functions. Blood serum contains 3.3 g/L sodium. It regulates extra cellular fluids, acid-base balance and membrane potential, partially together with potassium. This causes increased blood pressure, arteriosclerosis, oedema, hyperosmolarity, confusion and increased risk of infection from excessive Na^+ intake. Sodium shortages may lead to dehydration, convulsion, muscle paralysis, decreased growth and general numbness. Generally, humans require about 300 mg sodium chloride per day to warrant a balanced sodium level. People that have diarrhoea or other health effects that increase salt requirements need a higher dietary amount of sodium than usual. Adult intake of kitchen salt is on average 9 g per day, which translates to approximately 4 g of sodium. People with heart and kidney disease are recommended a sodium poor diet.

Status of Sodium in River Ganga-The sodium concentration in river Ganga from Gangotri to Haridwar is found within limit. The maximum concentration of Sodium is observed at UK Laghuvidhut pariyojana site and at Naluna -Senj at Khadkhadi the concentration of Sodium is observed 5.0 mg/l .But as a conclusion it can be say that river is pollution free and Healthy in terms of Sodium.

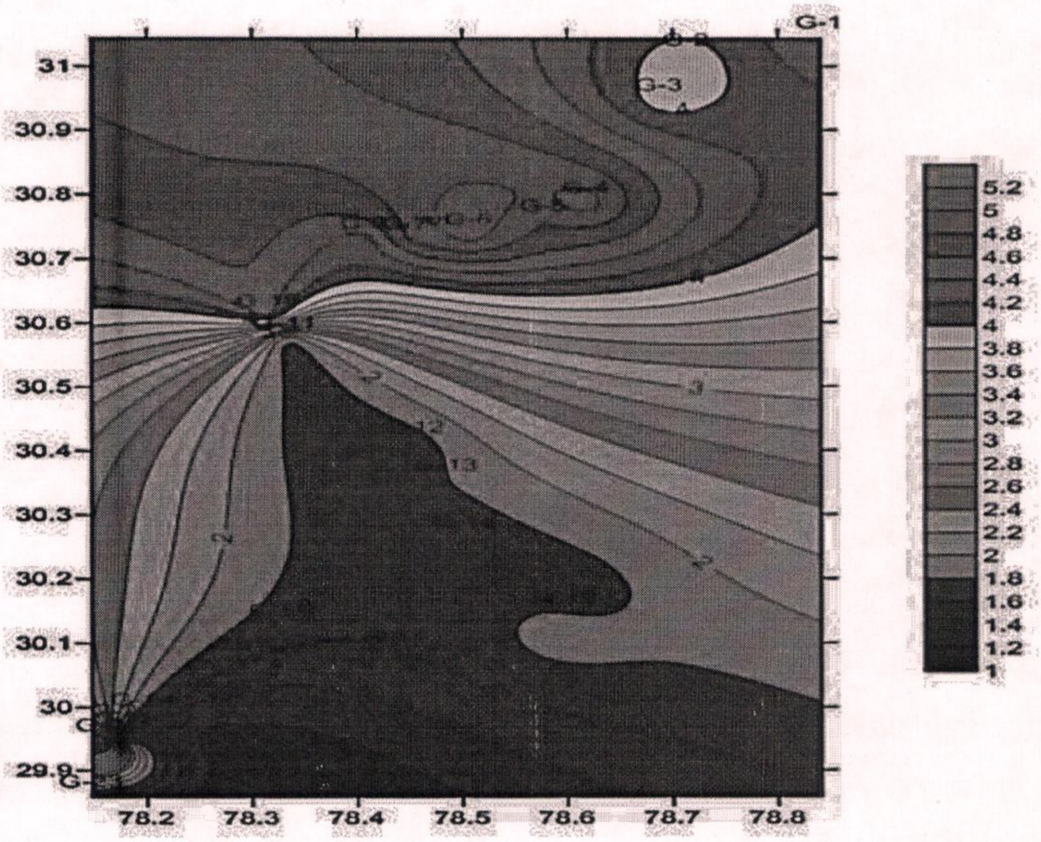

Fig 5.20 Sodium Contour in river Ganga

Explanation-Spatial variation of Sodium concentration does not show a definite pattern of variation.We can say that this parameter does not much link with length of river. Few locations shows high sodium concentration near the Gangotri and also there is some location which shows higher concentration of Sodium near the Haridwar (shown in Red and Purple colour in map).But it is clear from above graph that most of the locations are having Sodium concentration in range of 1.2 to 1.8 mg/l (dark blue colour) at middle and lower reach whereas most of the location in upper reach shows concentration in range of 4 to 5.2 mg/l (red and pink colour).

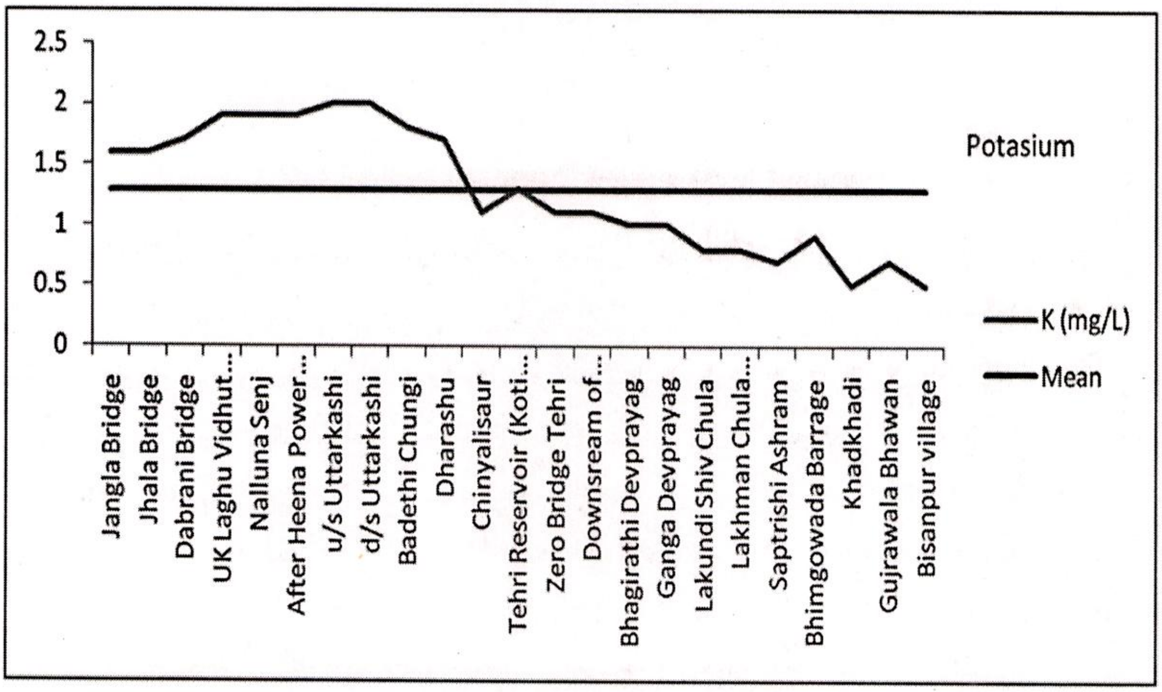

Fig 5.21 Potassium Trend in river Ganga

POTASSIUM-Potassium occurs in various minerals, from which it may be dissolved through weathering processes. Examples are feldspars (orthoclase and microcline), which are however not very significant for potassium compounds production, and chlorine minerals carnalite and sylvite, which are most favourable for production purposes. Some clay minerals contain potassium.

Environmental effects of potassium in water-Potassium are a dietary requirement for nearly any organism but a number of bacteria, because it plays an important role in nerve functions. Potassium plays a central role in plant growth, and it often limits it. Potassium from dead plant and animal material is often bound to clay minerals in soils, before it dissolves in water. Consequently, it is readily taken up by plants again. Ploughing may disturb this natural process. Consequently, potassium fertilizer is often added to agricultural soils. Plants contain about 2% potassium (dry mass) on average, but values may vary from 0.1-6.8%. Mosquito larvae contain between 0.5 and 0.6% potassium, and beetles contain between 0.6 and 0.9% potassium (dry mass). Potassium salts may kill plant cells because of high osmotic activity. Potassium is weakly hazardous in water, but it does spread pretty rapidly, because of its relatively high mobility and low transformation potential. Potassium toxicity is usually caused by other components in a compound, for example cyanide in potassium cyanide. The LD_{50} value for rats is 5 mg/kg. For potassium bromate this is 321 mg/kg, and for potassium fluoride this is 245 mg/kg. Examples of LD_{50} values for water organisms include 132 mg/L for fish and 1.16 mg/L for daphnia.

Health effects of potassium in water- Potassium is a dietary requirement for us, and we take up about 1-6 g per day at a requirement of 2-3.5 g per day. The total potassium amount in the human body lies somewhere between 110 and 140 g and mainly depends upon muscle mass. The muscles contain most potassium after red blood cells and brain tissue. Vital functions of potassium include its role in nerve stimulus, muscle contractions, blood pressure regulation and protein dissolution. It protects the heart and arteries, and may even prevent cardiovascular disease. The relation of sodium to potassium used to be 1:16, and is now about 3:1, which mainly prevents high sodium uptake. Potassium shortages are relatively rare, but may lead to depression, muscle weakness, heart rhythm disorder and confusion. Potassium loss may be a consequence of chronic diarrhoea or kidney disease, because the physical potassium balance is regulated by the kidneys. When kidneys operate insufficiently, potassium intake must be limited to prevent greater losses.

Skin contact with potassium metals results in caustic potash corrosion. This is more hazardous than acid corrosion, because it continues unlimitedly. Caustic potash drops are very damaging to the eyes.
The intake of a number of potassium compounds may be particularly harmful. At high doses potassium chloride interferes with nerve impulses, which interrupts with virtually all bodily functions and mainly affects heart functioning. Potassium alum may cause stomach complaints and nausea at concentrations as low as 2 g, and may be corrosive and even lethal in higher concentrations. Potassium carbonate is lethal to adults at doses above 15 g. The same goes for potassium tartrate at 1 g, and for potassium cyanide at only 50 mg. Potassium dichromate is lethal at between 6 and 8 g, and 30 g of potassium nitrate causes severe intoxication, which may result in death. Because of its strongly corrosive mechanism potassium hydroxide concentrations between 10 and 12 ml in a 15% caustic may be lethal. Potassium permanganate is applied in bleaches and disinfection, and is lethal at between 5 and 8 g.

Status of Potassium in river Ganga-Concentration of potassium is found within prescribed limit. Which shows that river is pollution free from Gangotri to Haridwar and there is no Health hazard. The maximum concentration is observed at Upstream of Uttarkashi and minimum at Khadkhadi and Bisanpur village.

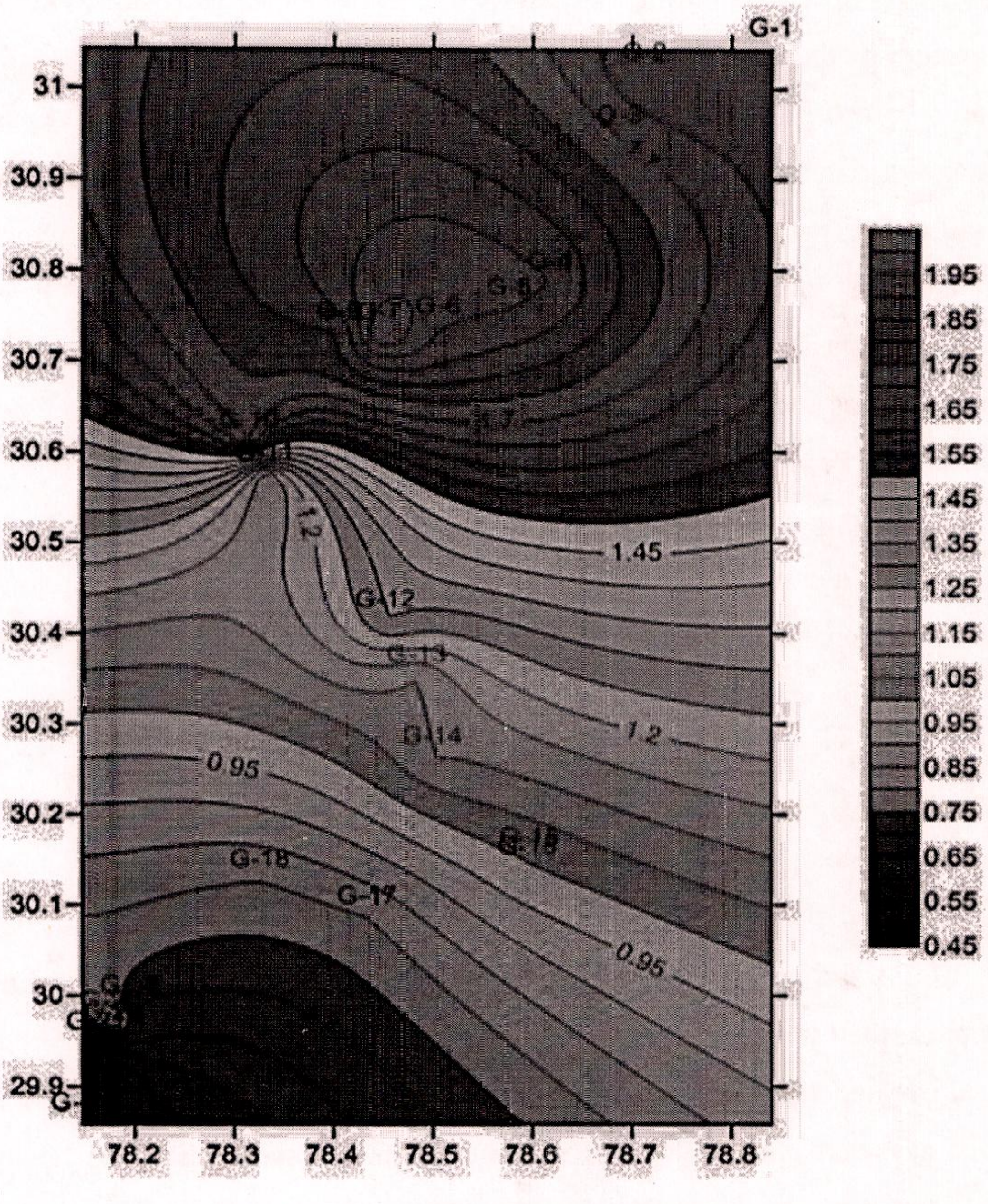

Fig 5.22 Potassium Contour in river Ganga

Explanation- Most of the upper reach location have shown higher concentration of range 1.55 mg/l to 1.95 mg/l (shown in dark red and purple colour in map) of Potassium that concentration of lower reach location (shown in dark blue and maroon colour) which have Potassium concentration in range of 0.55 to 0.95 mg/l.

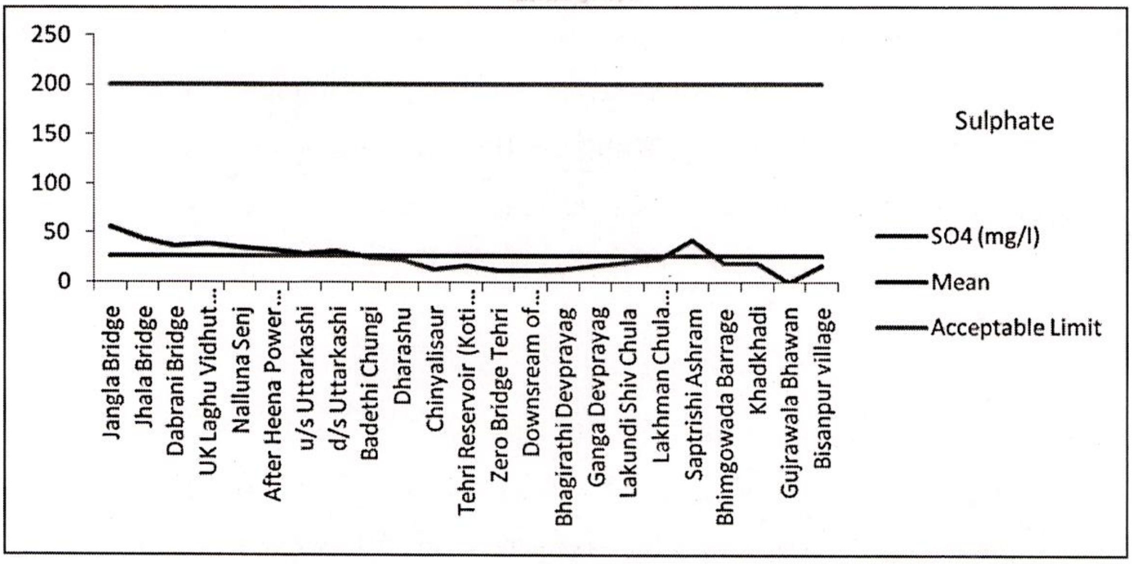

Fig 5.23 Sulphate Trend in river Ganga

SULPHATE (SO_4) – Sulphate can be found in almost all natural water. The origin of most sulphate compounds is the oxidation of sulphite ores, the presence of shales, or the industrial wastes.

Health Hazard due to excess Sulphate-People not used to drinking water with high levels of sulphate can experience dehydration and diarrhea. Kids are often more sensitive to sulphate than adults. As a safety measure, water with a sulphate level exceeding 400 mg/l should not be used in the preparation of baby food. Older children and adults become used to high sulphate levels after a few days Animals are also sensitive to high levels of sulphate. In young animals, high levels may cause severe, chronic diarrhea, and in some cases, death. As with humans, animals tend to become used to sulphate over time. Diluting water high in sulphate with water low in sulphate can help avoid problems of diarrhea and dehydration in young animals and animals not used to drinking high sulphate water.

Sulphate in River Ganga-Sulphate in River Ganga is found within limit and hence river is free from sulphate pollution from Gangotri to Haridwar and there is no health hazard due to excessive sulphate. However Sulphate concentration is not uniform in entire length of river, maximum sulphate concentration is observed at Gangotri (54mg/L) and minimum at Alaknanda (12mg/l).

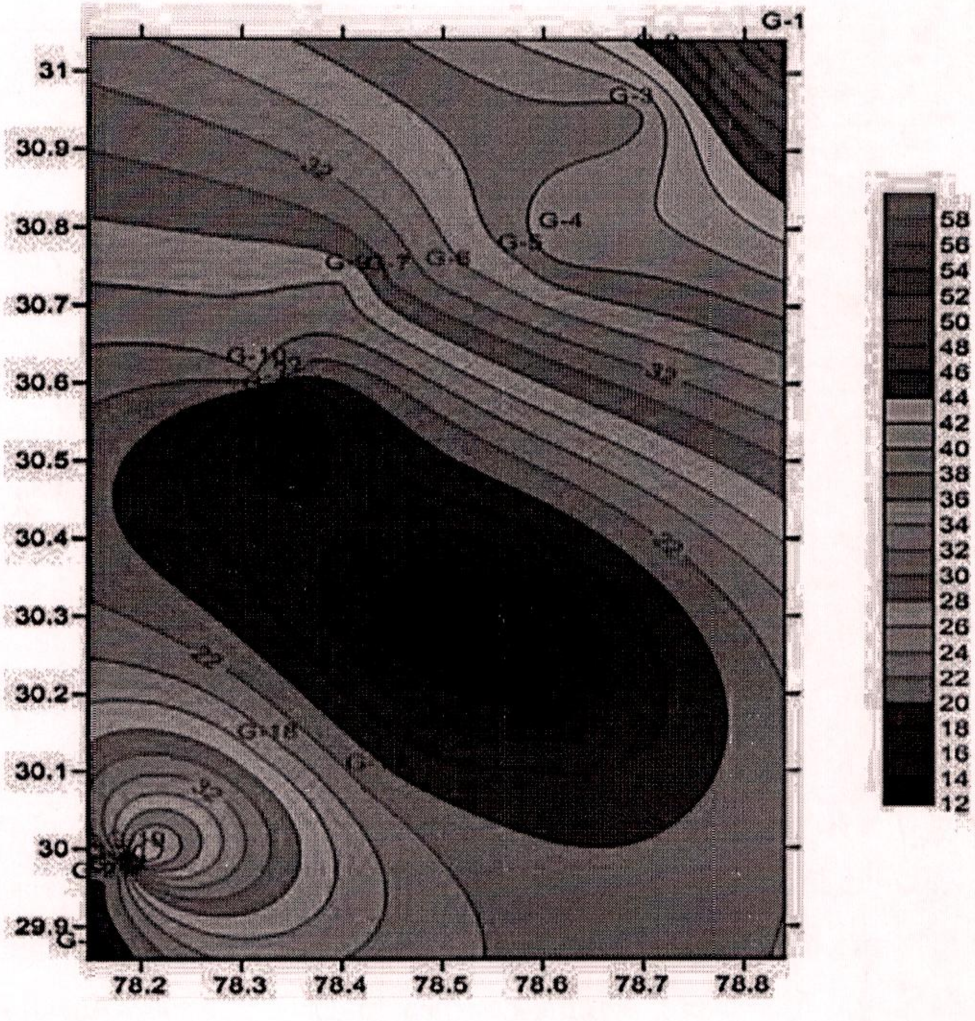

Fig 5.24 Sulphate Contour in river Ganga

Explanation-The concentration of Sulphate also do not show any functional relationship with length of river. It varies with location to location and cannot be predicted concentration at specific location due to uneven and un-symmetric distribution. However highest concentration is observed near Gangotri of range 44 mg/l to 58 mg/l (shown in dark red and purple colour in map) and minimum concentration is observed at intermediate location of range 12-14 mg/l.

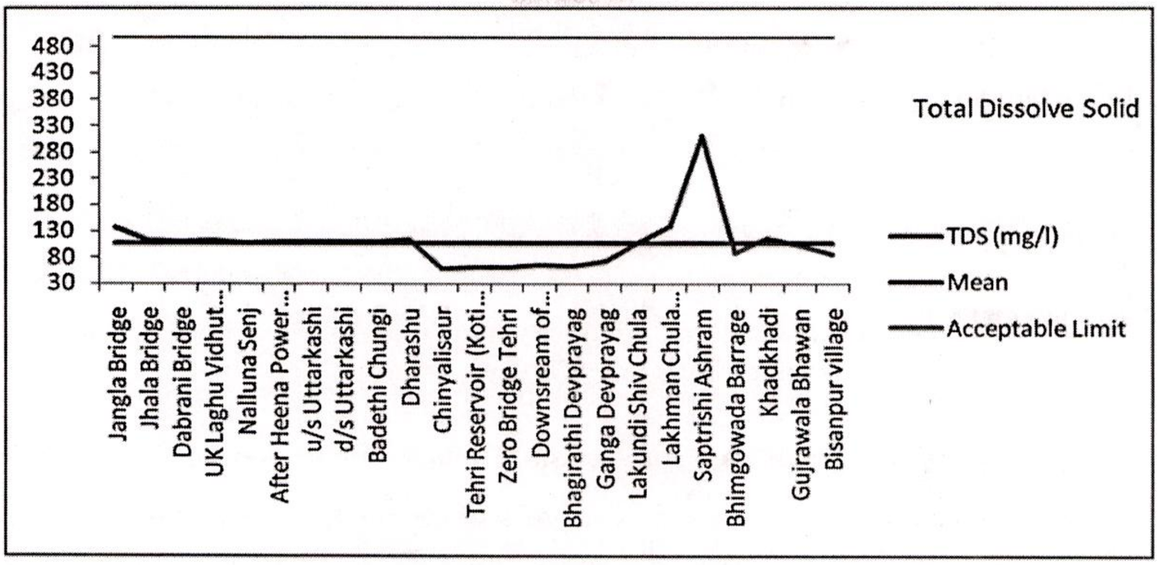

Fig 5.25 TDS Trend in river Ganga

TOTAL DISSOLVE SOLID

Amount of particles that are dissolved in the water is called TDS. It may include all suspended solids that may or may not pass through a filter.

Factors influence the amount of total dissolved solids in water-

1. Some dissolved solids come from organic sources such as leaves, silt, plankton, and industrial waste and sewage. Other sources come from runoff from urban areas, road salts used on street during the winter, and fertilizers and pesticides used on lawns and farms.

2. Some dissolved solids come from inorganic materials such as rocks and air that may contain calcium bicarbonate, nitrogen, iron phosphorous, sulfur, and other minerals. Many of these materials form salts, which are compounds that contain both a metal and a non-metal. Salts usually dissolve in water forming ions. Ions are particles that have a positive or negative charge.

3. Since rain water contributes to most of the water in a watershed, it contributes to the amount of TDS in a watershed. Rain water is almost pure with less than 10 mg/L of TDS.

Health and Environmental effect of TDS-

1. A constant level of minerals in the water is necessary for aquatic life. Changes in the amounts of dissolved solids can be harmful because the density of total dissolved solids determines the flow of water in and out of an organism's cells. Many of these dissolved solids contain chemicals, such as nitrogen, phosphorous, and sulphur, which are the building blocks of molecules for life.

2. Concentration of total dissolved solids that are too high or too low may limit the growth and may lead to the death of many aquatic organisms.

3. High concentrations of total dissolved solids may reduce water clarity, which contributes to a decrease in photosynthesis and lead to an increase in water temperature. Many aquatic organisms cannot survive in high temperatures.

4. It is possible for dissolved ions to affect the pH of the body of water, which in turn may influence the overall health of many aquatic species.

5. If TDS levels are high, especially due to dissolved salts, many forms of aquatic life are affected. The salts act to dehydrate the skin of animals.

6. High TDS concentrations may add a laxative effect to the water or cause the water to have an unpleasant mineral taste.

TDS in River Ganga-TDS in river Ganga (from Gangotri to Haridwar) is found within prescribed limit. Its values vary from location to location .Maximum TDS is observed at Saptarishi Aashram (311mg/l) and minimum at upstream of Uttarkashi (57mg/l). But overall water quality is good in river Ganga.

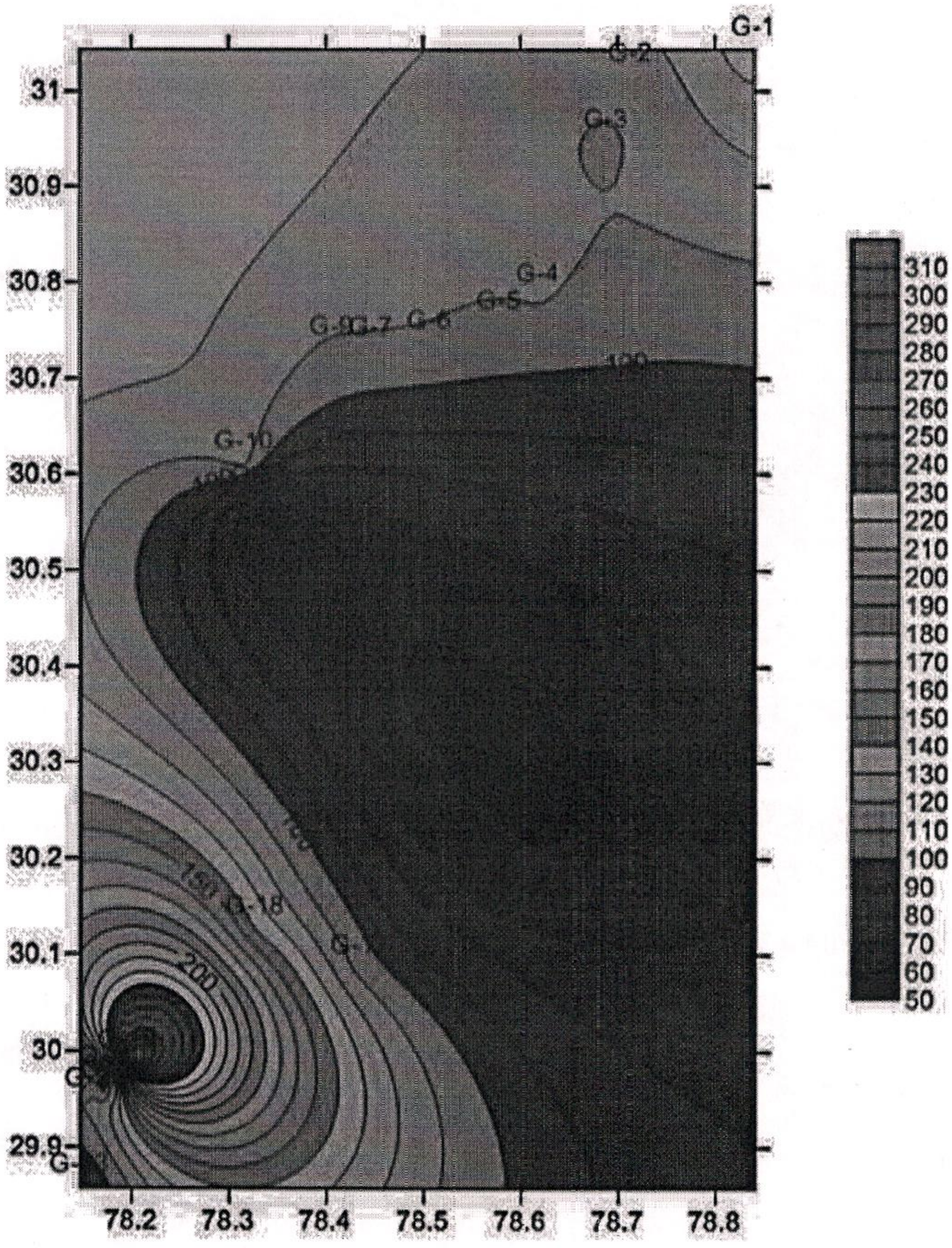

Fig 5.26 TDS Contour in river Ganga

Explanation-Variation of TDS concentration shows close relationship with run of the river .It is increasing in trend as river moves from Gangotri to Haridwar. However some intermediate location also shown low concentration than upper reaches (shown in dark blue colour). Highest concentration of TDS is observed near Haridwar in range of 230 to 310 mg/l (red and purple colour).

5.2 CHADDHA DIAGRAM

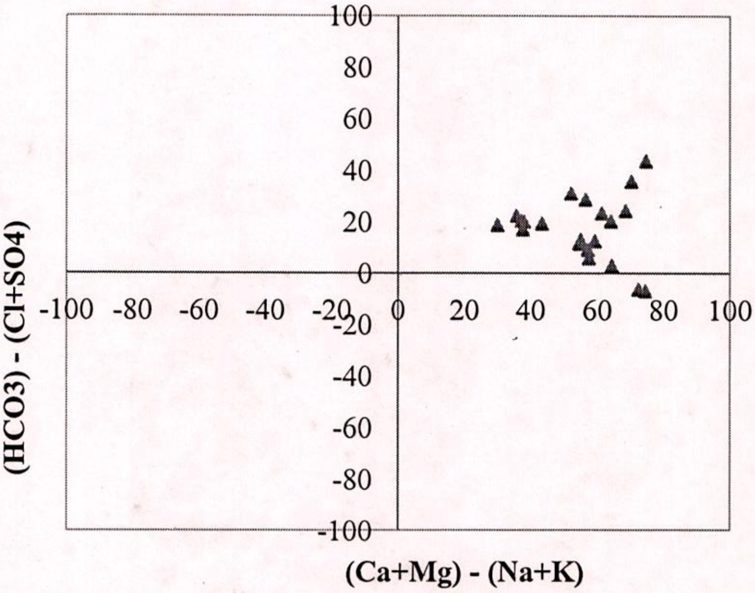

Fig-5.27 Chaddha Diagram

(Ca+Mg)-(Na+K) values were plotted against HCO_3-(Cl+SO4) to characterize the water samples. In most of the samples, the water is Ca-Mg-HCO_3 type. The water samples from Gangotri to Loharingapala were of Ca-Mg-Cl-SO4 type.

5.3 HOT SPOT MATRIX-It is matrix to Identifying that location where water Quality is worst and need immediate control measures to restore and Retreat and Preserve the water Quality again.

These sites sites are those sites which are directly affected by any point source of pollution. To restore and preservance water quality of such location need frequent supervision monitoring and continuous surveillance.

In order to restore the water Quality of such location identification of source of pollution is first essential step.

Abbreviation used-

ME-Mean Value Exceeded

MV-Maximum Value

LE-Limit Exceeded.

Priority Number = 10 (LE) +5 (MV) +ME

Where 10 and 5 are Weightage factors

The location which got highest Priority number that will be considered as Hot Spot.

Priority Number =Not Applicable, if atleast 1 Parameter is not exceeded Limit Value.

Although River Ganga is Pollution free from Gangotri to Haridwar but to identify the most sensitive location and location to get priority of regular monitoring, we used Hot Spot Matrix Method which is shown in next page.

Highest Priority number is-32 at G-21 (**Khadkhadi**) means it is most Sensitive location and required frequent, monitoring, Assessment and Surveillance.

Deviation at Khadkhadi may be due to discharge of partially treated sewage into the river Ganga from Jagjeet pur Sewage treatment plant.

There is immediate need to increase treatment capacity of the STP by introducing more units. Also care taken to Nallas,which discharge into the river directly although such Nalls are few.

Location Code	pH.	EC (µs /cm)	Alkalinity (mg/L)	Hardness (mg/L)	Cl (mg/L)	NO3 (mg/L)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Fe (mg/L)	TDS (mg/l)	SO4 (mg/l)	LE	ME	MV	Priority No
G-1	5.9	ME	51	ME	0.2	7	ME	ME	ME	ME	LE	ME	MV	1	7	1	22
G-2	5.8	ME	43	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	0	11	0	11
G-3	6.2	ME	41	ME	0.8	ME	ME	ME	18	ME	ME	ME	ME	0	9	0	9
G-4	6.2	ME	47	ME	0.8	5.3	MV	ME	ME	ME	ME	ME	ME	0	8	1	13
G-5	ME	ME	47	70	1.4	1.3	ME	ME	ME	ME	0.06	ME	ME	0	8	0	8
G-6	6.4	ME	45	68	0.4	4.8	MV	ME	18	5	0.08	ME	ME	0	4	1	9
G-7	6.6	ME	46	68	ME	6.6	ME	MV	ME	5	0.07	ME	ME	0	6	1	11
G-8	6.7	ME	47	ME	ME	6.6	ME	MV	ME	ME	0.06	ME	ME	0	8	1	13
G-9	6.4	ME	51	ME	1.2	ME	ME	ME	18	ME	0.07	ME	ME	0	8	0	8
G-10	ME	ME	47	ME	2	7	ME	ME	20	ME	0.09	ME	24	0	7	0	7
G-11	ME	89	33	14	0.2	ME	1.7	1.1	12	2	0.15	57	14	0	2	0	2
G-12	ME	96	34	43	0	ME	1.7	1.3	11	4	0.18	61	17	0	2	0	2
G-13	6.4	94	55	41	1.2	3.1	1.8	1.1	11	3	0.27	60	13	0	0	0	0
G-14	ME	100	34	43	1.4	4.8	1.7	1.1	12	3	0.06	64	12	0	1	0	1
G-15	ME	99	35	42	0.4	4	1.6	1	11	3	0.08	63	14	0	1	0	1
G-16	ME	111	38	49	1.2	4.8	2	1	14	3	0.1	71	17	0	1	0	1
G-17	ME	139	52	61	ME	5.7	1.6	0.8	17	5	0.1	ME	21	0	3	0	3
G-18	ME	166	61	ME	ME	11	1.7	0.8	20	ME	0.07	ME	25	0	5	0	5
G-19	ME	ME	ME	ME	ME	MV	1.6	0.7	21	ME	0.19	MV	ME	0	7	2	7
G-2-0	ME	135	52	57	0	4.8	1.7	0.9	16	4	0.1	88	20	0	1	0	1
G-21	MV	MV	LE	MV	MV	5.3	5	0.5	MV	MV	0.02	ME	20	1	2	4	32
G-22	ME	160	47	ME	ME	ME	1.2	0.7	ME	5	0.08	102	20	0	5	0	5
G-23	ME	217	ME	ME	ME	ME	1.4	0.5	ME	ME	0.02	86	17	0	7	0	7
Mean Values	6.28888	127.81818	45.3	50.545454	0.8	5.4733333	1.9	0.884615	15.64285	3.818181	0.097368	72.44444	18				

Table 5.3 Hot Spot Matrix

CONCLUSION

Overall water Quality of River Ganga from Gangotri to Haridwar is found Healthy and Pollution free. However, most of the parameters were in increasing as the river travels. Maximum concentration for most of the parameter was observed at Khadkhadi (Haridwar) which is an indication of impact of pollution due to anthropogenic activities.

Drains which directly or indirectly discharging into the river without proper treatment is found to be major source of pollution. Policy should to be framed for proper treatment of the drains before reaching river Ganga, so that water quality could be maintained. Co-ordination integration, participatory approach among various agencies, departments and groups should to be essential part of Ganga Rejuvenation Scheme.

REFERENCES

Arvind Kumar Rai, Biswajit Paul and Nawal Kishor,(2011), a study on the sewage disposal on water quality of harmu River in ranchi city jharkhand,International Journal of plant and Environmental sciences vol-2,2012

Bahukhandi Kanchan Deoli and Bartarya S.K,(2014), major ion chemistry of asanrivercatchment of dehradun district (impact assessment of anthropogenic sources),Octa Journal of Environmental Research, 2014,Vol. 2(2): 168-177.

Bharti N and Katyal.D,(2011), Water quality indices used for surface water vulnerability assessment, international journal of environmental sciences volume 2, no 1, 2011

C.K. Jain,(2002), A hydro-chemical study of a mountainous watershed-the Ganga, National Institute of Hydrology, Environmental Hydrology Division, JalVigyanBhawan, Roorkee 247 667, India .Water Research 36 (2002) 1262–1274

Dhananjay Kumar, Anjali Verma, NamitaDhusia and Nandkishor More,(2013), Water Quality Assessment of River Gomti in Lucknow , Volume 3, Issue 3: 337-344.

Gadekar M.R.,GonteR.N,Paithankar V.K, Sangale Y.B and Yeola N.P.(2012),River water Quality degisnation, International Journal of Emerging Technology and Advanced Engineering (ISSN 2250-2459, Volume 2, Issue 9, September 2012)

Lenntech Water Treatment Sollution.(http://www.lenntech.com)

Mohammad Alam and J.K. Pathak,(2010), Rapid Assessment of Water Quality Index of Ramganga River, Western Uttar Pradesh (India) Using a Computer Programme, Nature and Science 2010;8(11).

Md. AshiqurRahman and Dhia Al Bakri,(2010), A Study on Selected Water Quality Parameters along the River Buriganga, Bangladesh,Iranica Journal of Energy & Environment 1 (2): 81-92, 2010

Nighojkar Abhineet and ER. D.Dohare,(2014), Physico-Chemical Parameters for Testing of Present Water Quality of KhanRiver at Indore, International Research Journal of Environment Sciences Vol. 3(4), 74-81, April (2014)

Pankaj Kumar Roy, Deeya Ray, Somnath Pal, Gourab Banerjee, ArunabhaMajumder and AsisMazumdar,(2014), Qualitative and Quantitative Assessment of Pollutional Load in River Ganga in West Bengal Using Statistical Technique, World Applied Sciences Journal 29 (5): 634-640, 2014

Richa Seth , Manindra Mohan , Prashant Singh ,Rakesh Singh , RajendraDobhal ,Krishna Pal Singh , Sanjay Gupta,(2014), Water quality evaluation of Himalayan Rivers of Kumaunregion,Uttarakhand, Appl Water Sci DOI 10.1007/s13201-014-0213-7

R.M.Bhardwaj (2005), Water quality monitoring in india- Achievements and constraints,Central Pollution Control Board, IWG-Env, International Work Session on Water Statistics, Vienna, June 20-22 2005.

Report of CPCB on Pollution trend of river Ganga 2013.

S. P. Gorde1, M. V. Jadhav,(2013), Assessment of Water Quality Parameters, Journal of Engineering Research and Applications , ISSN : 2248-9622, Vol. 3, Issue 6, Nov-Dec 2013, pp.2029-2035

SukarmaThareja, Siddhartha Choudhury and PriyankaTrivedi,(2011), Assessment of Water Quality of Ganga River in Kanpur by Using Principal Components Analysis, Pelagia Research Library Advances in Applied Science Research, 2011, 2 (5):84-91

Smita Jain (2012), Assessment of water quality at the three Stations of Chambal River, international journal of environmental sciences volume 3, no 2, 2012

Sharda.A.K, Sharma. M.P,(2013), Water quality assessment of Swan River in Himachal Pradesh, Alternate Hydro Energy Centre, Indian Institute of Technology .international journal of environmental sciences volume 4, no 3, 2013

Vikram Bhardwaj, DhruvSen Singh and A K Singh,(2010), Water quality of the ChhotiGandak River using principal component analysis, Ganga Plain, J. Earth Syst. Sci. 119, No. 1, February 2010, pp. 117–127

Yadav S.S. and Kumar Rajesh,(2011), Monitoring Water quality of Kosi River in Rampur District,Uttar Pradesh, Pelagia Research Library Advances in Applied Science Research, 2011, 2 (2): 197-201