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A Project Report on

"WATER QUALITY ASSESSMENT OF RIVER GANGA AT HARIDWAR, UTTARAKHAND"

NATIONAL INSTITUTE OF HYDROLOGY (NIH),

ROORKEE, HARIDWAR, UTTARAKHAND

Submitted in partial fulfillment of the requirements for the award of the degree of

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Institute of Environment and Sustainable Development
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CERTIFICATE

I hereby declare that the project work entitled" **WATER QUALITY ASSESSMENT OF RIVER GANGA AT HARIDWAR, UTTARAKHAND"** is an authentic record of my own work carried out at "National Institute of Hydrology, Roorkee" as required for the six months project semester for the award of degree of M.Sc. (Environmental Science & Technology), under the guidance of "Dr. Rajesh Singh", during 15 July 2015 to 15 January 2016.

Date: 8 March 2016

Pradeep Gautam

(Candidate Signature)

Certified that the above statement made by the student is correct to the best of our knowledge and belief.

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Abstract

As the river Ganga is a sacred river & also the lifeline for people living nearby, increased settlement in and around Haridwar has increased concerns about the quality of river Ganga. This study is an overview of the current water quality of river Ganga at Haridwar. Water samples were collected at an interval of 15 days from 5 study sites and analyzed for pH, Electrical Conductivity (EC), Turbidity (NTU), Total Alkalinity (TA), Total Hardness (TH), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Sodium (Na^+), Potassium (K^+), Calcium (CaH), Magnesium (MgH), Sulphate (SO_4^{2-}), Nitrate (NO_3^-), Chloride (Cl^-), Phosphate (PO_4^{3-}), Silica (Si), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Coliform (TC) and Faecal Coliform (FC). In order to get a view on the current river water quality, an attempt of has been made to develop WQI for Drinking & Irrigation purposes.Chemical analyses of water samples showed that calcium and bicarbonate are the dominant cation and anion, respectively. The water type is Ca-Mg-HCO_3 based on hydro-chemical facies using Piper's diagram. The results were compared with the drinking water standard (BIS 10500: 2012) and it clearly indicates that water quality for drinking purpose is of poor quality while it is of Excellent quality for Irrigation Purposes.

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INTRODUCTION

Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels. Water borne diseases cause about 1.8 million deaths annually. Diarrhea occurs worldwide and causes 4% of all deaths & 5% of health loss to disability. It is most commonly caused by gastrointestinal infections which kill around 2.2 million people globally each year, mostly children in developing countries (WHO 2015). In addition to the acute problems of water pollution in developing countries, developed countries also continue to struggle with pollution problems.

Water is typically referred to as polluted when it is impaired by anthropogenic contaminants and either does not support a human use, such as drinking water, or undergoes a marked shift in its ability to support its constituent biotic communities, such as fish. Natural phenomena such as volcanoes, algae blooms, storms, and earthquakes also cause major changes in water quality and the ecological status of water. Surface water is on the surface of the planet such as in stream, river, lake, wetland, or ocean. It can be contrasted with groundwater and atmospheric water.

With only 3 % of total fresh water available for life on land. Clean, fresh drinking water is essential to human and other life. However, in many parts of the world especially in developing countries there's a water crisis, and it is estimated that by 2025 more than half of the world population will be facing water-based vulnerability. Water plays an important role in the world economy, as it functions as a solvent for a wide variety of chemical substances and facilitates industrial cooling and transportation.

Many Indian cities are experiencing moderate to severe water shortages due to implicit effects of agricultural growth, industrialization and urbanization. These shortages would be further aggravated by population stress and irrigation requirements.

One of the most effective ways to communicate information on water quality status and trend is by using indices. Water quality index (WQI) is commonly used for summarizing water quality and comparing water quality of different water bodies. It is defined as "**a rating reflecting the composite influence of different quality parameters on the overall quality of water**".

Sources of surface water pollution are generally grouped into two categories based on their origin - Point & Non-Point Sources. Point source water pollution refers to contaminants that enter a waterway from a single, identifiable source, such as a pipe or ditch while Nonpoint source pollution refers to diffuse contamination that does not originate from a single discrete source.

Interactions between groundwater and surface water are complex. By its very nature, groundwater aquifers are susceptible to contamination from sources that may not directly affect surface water bodies. A spill or ongoing release of chemical or radionuclide contaminants into soil may not create point or non-point source pollution but can contaminate the aquifer below, creating a toxic plume. The movement of the plume, called a plume front, may be analyzed through a hydrological transport model or groundwater model. Analysis of groundwater contamination may focus on soil characteristics and site geology, hydrogeology, hydrology, and the nature of the contaminants.

Oxygen-depleting substances may be natural materials such as plant matter (e.g. leaves and grass) as well as man-made chemicals. Other natural and anthropogenic substances may cause turbidity (cloudiness) which blocks light and disrupts plant growth, and clogs the gills of some fish species. Alteration of water's physical chemistry includes acidity (change in pH), electrical conductivity, temperature, and eutrophication.

Although the vast majority of bacteria are either harmless or beneficial, a few pathogenic bacteria can cause disease. Coliform bacteria are commonly used as a bacterial indicator of water pollution. High levels of pathogens may result from on-site sanitation systems (septic tanks, pit latrines) or inadequately treated sewage discharges.

Organic water pollutants include Detergents, Disinfection by-products found in chemically disinfected drinking water, such as chloroform, Food processing waste, Insecticide and herbicides, a huge range of organohalides and other chemical compounds, etc.

Inorganic water pollutants include Acidity caused by industrial discharges (especially sulfur dioxide from power plants), Ammonia from food processing waste, Chemical waste as industrial by-products, Fertilizers containing nutrients--nitrates and phosphates—which are found in storm water runoff from agriculture, as well as commercial and residential use, etc.

Decisions on the type & degree of treatment, control of wastes, and the disposal & use of adequately treated wastewater, must be based on a consideration all the technical factors of each drainage basin, in order to prevent any further contamination or harm to the environment.

In urban areas of developed countries, domestic sewage is typically treated by centralized sewage treatment plants. Well-designed and operated systems (i.e., secondary treatment or better) can remove 90 percent or more of the pollutant load in sewage.

LITERATURE REVIEW

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

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

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

3. **Analysis of water quality parameters of river ganga during Maha-Kumbh, Haridwar; Naveen Kumar Arora et al. (2012)** explained the Water Quality of River Ganga during mass bathing in Maha Kumbh at haridwar in terms of microbiological & molecular analysis. This study showed that there was a steep rise on the mass bathing events. Results concluded that untreated sewage and organic matter were mixing in the river.

4. **Assessment of Ganga river ecosystem at Haridwar, Uttarakhand, India with reference to water quality indices; R. Bhutiani et al. (2014)** explained that The River Ganga Index by Ved prakash et al. showed that water quality ranged between medium

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

5. **A proposed new diagram for geochemical classification of natural waters and interpretation of chemical data; D. K. Chadha (1999)** has proposed a new hydro chemical diagram for the classification of natural waters & identification of hydro chemical processes. The proposed diagram differs from the Piper & Durov diagrams and the shape of main study is different. Also, the proposed diagram can be constructed on most of the spreadsheet software packages. The proposed diagram is constructed by plotting the differences in mill equivalent percentage between alkaline earths and alkali metals, expressed as percentage reacting values, on the X axis; and the difference in mill equivalent percentage between weak acidic anions and strong acidic anions, also expressed as percentage reacting values, on the Y axis.

6. **Evaluation of Ganga Water for Drinking Purpose by Water Quality Index at Rishikesh, Uttarakhand, India; Avnish Chauhan and Suman Singh (2011)** intended to calculate water quality index (WQI) for river Ganga at Rishikesh for drinking, recreation and other purpose by using eight water quality parameters. At site 1, 2 & 3 water quality index ranged from 13.87-1714.76, 14.59-1386 & 27.29-1077.9 respectively but the results of the water quality index clearly indicated that the Ganga water at Rishikesh is unfit for drinking, recreation and other purposes.

7. **Evaluation of water quality index for drinking purposes of river Subernarekha in Singhbhum District; Kavita Parmar & Vineeta Parmar (2010)** explained that WQI values at various sampling stations there is progressing decline in WQI values along the downstream indicated that an increase in pollution is due to effluent discharge by various industries along the stretch. Water quality in Subarnarekha varied from excellent to marginal range by Bhargava WQI method. The poorer water quality index at S4 Sampling station is due to anthropogenic activities.

8. **Seasonal Variation of Water Quality in Betwa River at Bundelkhand Region, India; *Sarita Verma (2009)*** *explained that the purpose of study was to investigate the water quality and to find out the variations in physico-chemical properties. This study is being carried out at Bundelkhand Region & 19 samples were collected from the Betwa River. EC has positive* correlation with chloride and sodium whereas its show negative correlation with phosphate hardness and chloride show strong positive correlations with fluoride and sodium respectively which indicate that is one parameter will raise the other dependent will be also increased calcium shows a strong negative correlation with magnesium.

OBJECTIVE

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

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

Freshwater resources are declining at a rapid rate which may cause a great problem during mass gatherings. Hence, 5 sites namely-Chilla, Bhimgoda Barrage, Guru Kashdi Ghat, Har ki Pauri and Vishnu Ghat were selected for Ganga river water quality assessment for suitability of drinking and irrigation purposes.

Main goal of this study was to evaluate:

- The changes in physico-chemical & Bacteriological parameters over a period of time.
- WQI for drinking, health & irrigation purposes
- Effect of mass bath on river water quality

STUDY AREA

This study was being carried out on river Ganga at haridwar (29.9560^0 N, 78.1700^0 E). Haridwar is an ancient city, which is regarded as one of the seven holiest places (Sapta puri) to the Hindus. Sampling was being carried out for 6 months interval at an interval of 14 days starting from July to November 2015.

Samples were collected from 5 sites:-

SITE	LOCATION	LATITUDE	LONGITUDE
1	CHILLA	N 29^0 58.630'	E 078^0 12.941'
2	BHIMGODA BARRAGE	N 29^0 57.597'	E 078^0 10.744'
3	GURU KASHDI GHAT	N 29^0 58.355'	E 078^0 11.154'
4	HAR KI PAURI	N 29^0 57.324'	E 078^0 10.255'
5	VISHNU GHAT	N 29^0 57.401'	E 78^0 9.569'

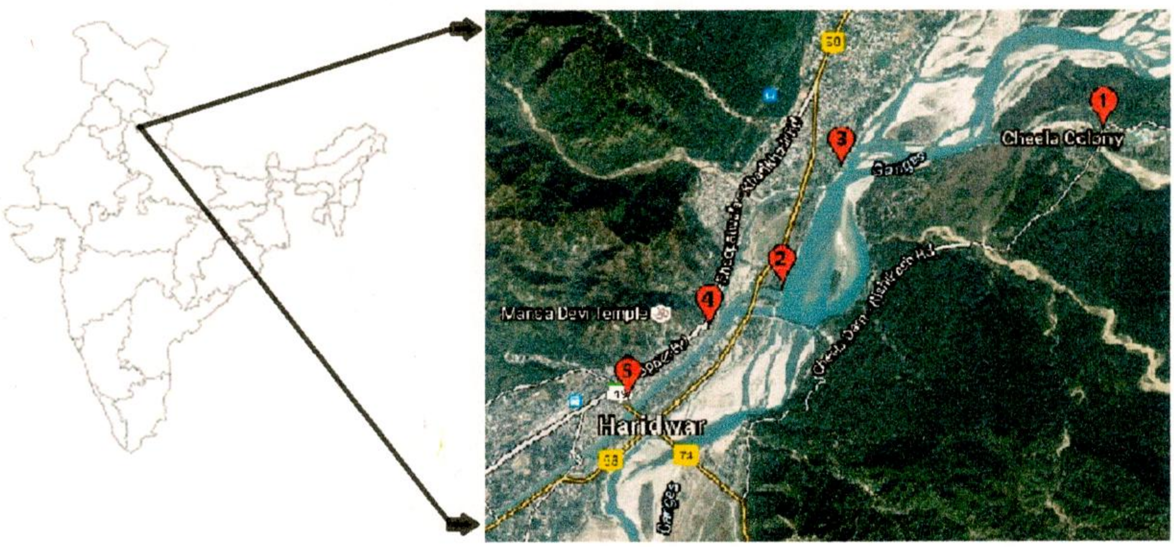

Fig 1. *Study area map showing sampling site locations*

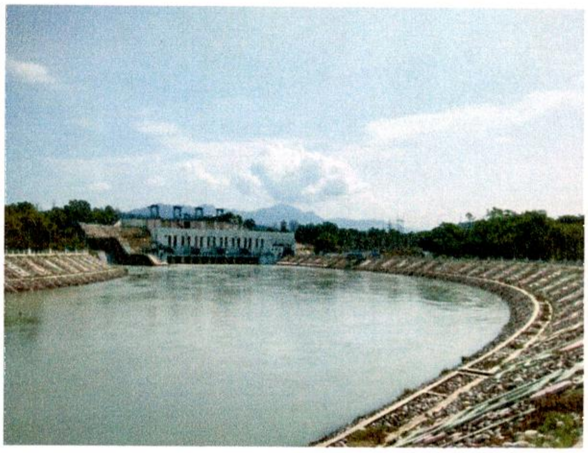

Fig 2. Chilla (S1)

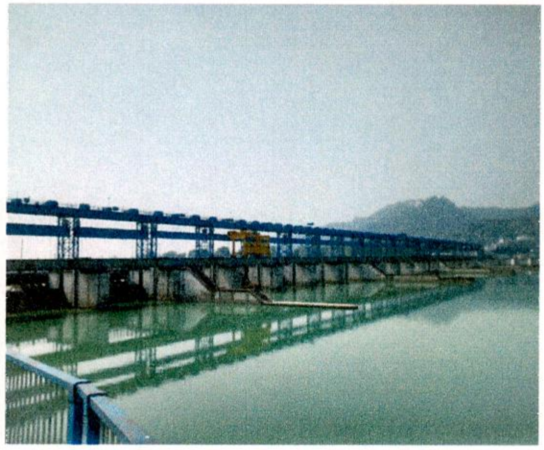

Fig 3. Bhimgoda Barrage (S2)

Fig 4. Guru Kashdi Ghat (S3)

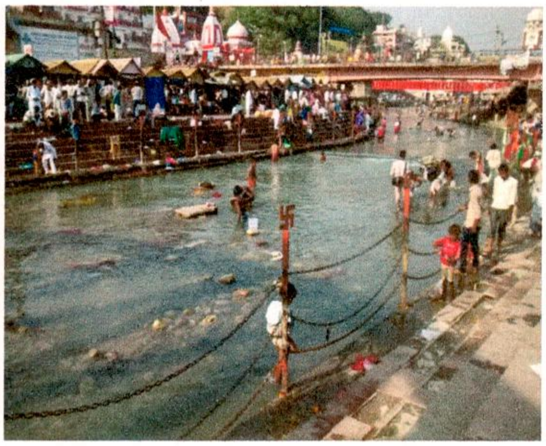

Fig 5. Har ki Pauri (S4)

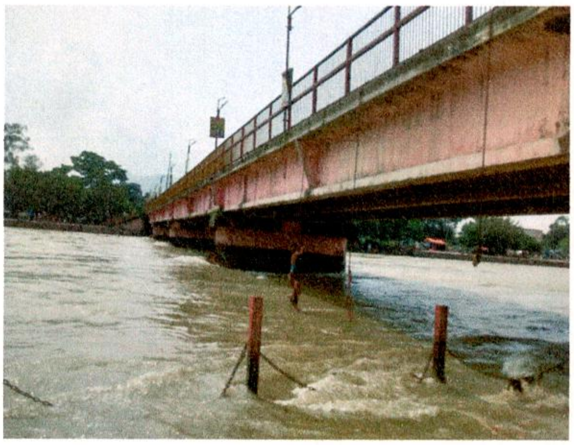

Fig 6. Vishnu Ghat(S5)

MATERIALS & METHODS

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

Table 1. Samples were analyzed for various parameters using following methods

PARAMETER	**METHOD USED**
Ph	HACH pH meter
EC	HACH EC meter
Turbidity	HACH Turbidity meter
Total Suspended Solids	Gravimetric method
Total dissolved Solids	Gravimetric method
Total Alkalinity	Titrimetric Method
Total Hardness	Titrimetric Method
Calcium Hardness	Titrimetric Method
Magnesium Hardness	Titrimetric Method
Chloride	Titrimetric Method
Dissolved Oxygen	Winkler Azide Method
Biological Oxygen Demand	Winkler Azide Method
Sulphate	Turbiditric Method
Sodium	Flame Photometric Method
Potassium	Flame Photometric Method
Nitrate	Hydrazine reduction method
Phosphate	Stannous Chloride Method

Silica	Molybdosilicate Method
Total Coliform	MPN method
Faecal Coliform	MPN method

Residual Sodium Carbonate

When the carbonate concentration becomes too high, the carbonates combine with calcium & magnesium to form a solid material which settles out of the water. The sodium with alkaline & the quantity of bicarbonate and carbonate in accessed of alkaline also influence the suitability of water for irrigation. This excess is denoted by residual sodium carbonate. The water with high RSC has high pH and land irrigated by such waters becomes infertile owing to deposition of sodium carbonate as known from the black color of the soil. Further, continued usage of high RSC waters affects crop yields.

RSC is calculated as follows:

$$\mathbf{RSC = (CO_3^- + HCO_3^-) - (Ca^{2+} + Mg^{2+})}$$

SAR Value

SAR is the most commonly used for evaluating groundwater suitability for irrigation purposes. SAR values in irrigation waters have a close relationship with the extent to which Na is absorbed by soils. If water used for irrigation is high in Na and low in Ca, the ion exchange complex may become saturated with Na, which destroys soil structure because of dispersion of clay particles. As a result, the soil tends to become deflocculated and relatively impermeable. Such soils become very difficult to cultivate.

Sodium adsorption ratio can indicate the degree to which irrigation water tends to enter into cation-exchange reaction in soil. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure and becomes compact and impervious. The SAR is a ration of the concentration of sodium ions to the concentration of calcium plus magnesium ions, as follows

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

Where, all the concentrations are expressed in meq/L. For the samples analyzed, the SAR value range from **0.05 to 0.3** and according to the SAR classification 100% of water sample falls in the excellent category of which can be used for irrigation on almost all soils.

Table 2. Classification of river water for irrigation suitability for different values of SAR

S.No.	**Types of water and SAR value**	**Quality**	**Suitability for irrigation**
1	Low sodium water SAR value: 0–10	Excellent	Suitable for all types of crops and all types of soils, except for those crops, which are sensitive to sodium
2	Medium sodium water SAR value: 10–18	Good	Suitable for coarse textured or organic soil with good permeability. Relatively unsuitable in fine textured soils
3	High sodium water SAR value: 18–26	Fair	Harmful for almost all types of soil; Requires good drainage, high leaching gypsum addition
4	Very high sodium water SAR value: above 26	Poor	Unsuitable for Irrigation

If irrigation water contains relatively high amounts of bicarbonate ion, the bicarbonate can affect the calcium and magnesium concentration in a soil to which the water is applied. If irrigation water with a high SAR is applied to a soil for years, the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and a loss of soil structure and tilt. This will also lead to a decrease in infiltration and permeability of the soil to water leading to problems with crop production.

Trend Analysis

Testing water quality data for trend over a period of time has received considerable attention recently. The interest in the water quality trend arises for two reasons, **first**, the intrinsic interest in the question of changing water quality arising out of the environmental concern and activity. Secondly, there has been a substantial amount of data that is amenable to such analysis. Trend analysis determines whether the measured values of a water quality variable increase or decrease during a time period.

Water Quality Index for Irrigation & Drinking

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

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

CCME Water Quality Index (CCME WQI)

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

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

F1 = (No. of failed parameters/Total no. of parameters) *100

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

F2 = (No. of failed tests/Total no. of tests) *100

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

F3 is calculated in three steps:

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

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

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

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

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

nse = (∑excursion/total no of tests)

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

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

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

The CCME Water Quality Index (CCME WQI):

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

The divisor 1.732 normalises the resultant values to a range between 0 and 100, where 0 represents the "worst" water quality and 100 represents the "best" water quality.

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

Table 3: Table depicting quality rating of river water for different values of WQI

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

Piper Diagram

A piper diagram is a graphical representation of the chemistry of a water sample or samples for drinking purpose. It's comprised of three pieces: a ternary diagram in the lower left representing the cations, a ternary diagram in the lower right representing the anions, and a diamond plot in the middle representing a combination of the two.

The apexes of the cation plot are calcium, magnesium and sodium plus potassium cations. The apexes of the anion plot are sulfate, chloride and carbonate and bicarbonate anions. The two ternary plots are then projected onto a diamond. The diamond is a matrix transformation of a graph of the anions and cations.

CPCB classification for water use

Table 4: CPCB classification for water use

Designated Best Use	Class of Water	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	Total Coliforms Organism MPN/100ml shall be 50 or less pH between 6.5 and 8.5 Dissolved Oxygen 6mg/l or more Biochemical Oxygen Demand 5 days 20°C 2mg/l or less
Outdoor bathing (Organised)	B	Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5mg/l or more Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 Dissolved Oxygen 4mg/l or more Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Propagation of Wild life and Fisheries	D	pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	pH between 6.0 to 8.5 Electrical Conductivity at 25°C micro mhos/cm Max.2250 Sodium absorption Ratio Max. 26 Boron Max. 2mg/l

RESULTS & DISCUSSION

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

The physico-chemical analysis carried out from the different sites during July 2015 to November 2015. The study revealed that pH varied from 6.37-8.37 (maximum) at site 3 & 6.13-8.26 (minimum) at Site 5 which was within the BIS guidelines (6.5–8.5). EC ranged from 150.4-261µS/cm (maximum) at site 5 while 125-243µS/cm (minimum) at site 1 and it was found to be well within the permissible limits as prescribed in the BIS standards. Turbidity varied from 4.61-629NTU (maximum) at site 3 & 2.61-388NTU (minimum) at Site 1 which were well beyond the BIS guidelines (1-5 NTU). Higher turbidity was found to be associated with high microbial growth, dissolved solids and higher contents of nutrients. Total Alkalinity ranged from 64.2-155.4mg/l (maximum) at site 5 & 61.6-81.8mg/l (minimum) at site 3 which was well within the permissible limits of BIS standards (200-600mg/l). Chloride ranged from 8-15.4mg/l (maximum) at site 5 & 6.8-14.6mg/l (minimum) at site 1 which was well within the permissible limits of BIS standards (250-1000mg/l). Sulphate 6.75-53mg/l (maximum) at site 2 & 6.5-49mg/l (minimum) at site 1 which was well within the permissible limits of BIS standards (200-400mg/l). Nitrate varied from 1.3-20mg/l (maximum) at site 3 & 0-18mg/l (minimum) at Site 2 which were well within the BIS guidelines of acceptable limit (45mg/l). Phosphate varied from 0.09-28.9mg/l (maximum) at site 3 & 0-27.7mg/l (minimum) at Site 1. Silica ranged from 0.7-4 mg/l (maximum) at site 3 at & 0.6-3 mg/l (minimum) at site 1. Sodium ranged from 1.38-5.39 mg/l (maximum) at site 3 & 1.04-10.19 mg/l (minimum) at site 1. Potassium was found to be within 1.09-3.03mg/l (maximum) at site 1 and 1-2.13 mg/l (minimum) at site 3. Total Hardness was found to be within 59.2-167mg/l (maximum) at site 1 and 52.8-155mg/l (minimum) at site 5. Calcium Hardness was found to be in range of 36.6-113.6mg/l (maximum) at site 1 & 45.6-96.6mg/l (minimum) at site 3. Magnesium Hardness ranges from 19-60.8mg/l (maximum) at site 3 & 0.4-52.2mg/l (minimum) at site 5.

Analysis on different study sites showed that there is no significant difference between the stations investigated but there is on seasons.

Table 5: Water Quality Index for S1

DATA SUMMARY	Acceptability	Drinking	Irrigation	Health
CWQI	41	38	98	30
RATING	Poor	Poor	Excellent	Poor
F1(SCOPE)	33.33	33.33	0	50
F2(FREQUENCY)	21.67	26.27119	0	47.36842
F3(AMPLITUDE)	94.2	98.76	-3.45	99.55
No. of variables tested	6	12	3	2
No. of variables failed	2	4	0	1

Table 6: Water Quality Index for S2

DATA SUMMARY	Overall	Drinking	Irrigation	Health
CWQI	40	38	98	31
RATING	Poor	Poor	Excellent	Poor
F1(SCOPE)	33.33	33.33	0	50
F2(FREQUENCY)	21.67	25.42	0	42.11
F3(AMPLITUDE)	95.6	98.7	-3.45	99.43
No. of variables tested	6	12	3	2
No. of variables failed	2	4	0	1

Table 7: Water Quality Index for S3

DATA SUMMARY	Overall	Drinking	Irrigation	Health
CWQI	40	38	98	31
RATING	Poor	Poor	Excellent	Poor

F1(SCOPE)	33.33	33.33	0	50
F2(FREQUENCY)	20	24.58	0	42.11
F3(AMPLITUDE)	95.65	98.36	-3.45	99.35
No. of variables tested	6	12	3	2
No. of variables failed	2	4	0	1

Table 8: Water Quality Index for S**4**

DATA SUMMARY	**Overall**	**Drinking**	**Irrigation**	**Health**
CWQI	41	38	98	31
RATING	Poor	Poor	Excellent	Poor
F1(SCOPE)	33.33	33.33	0	50
F2(FREQUENCY)	18.33	23.73	0	42.11
F3(AMPLITUDE)	94.91	98.65	-3.45	99.49
No. of variables tested	6	12	3	2
No. of variables failed	2	4	0	1

Table 9: Water Quality Index for S**5**

DATA SUMMARY	**Overall**	**Drinking**	**Irrigation**	**Health**
CWQI	41	38	81	31
RATING	Poor	Poor	Good	Poor
F1(SCOPE)	33.33	33.33	33.33	50
F2(FREQUENCY)	18.33	23.73	3.33	42.11
F3(AMPLITUDE)	95.74	98.85	-3.45	99.57
No. of variables tested	6	12	3	2
No. of variables failed	2	4	1	1

It was observed that the overall quality in terms of drinking water for River Ganga at all the study sites falls under poor category throughout the research period. The parameters responsible for the poor water quality were turbidity and coliforms. Presence of coliforms may be attributed to discharge of untreated sewage. The water quality at all sites is ranked Excellent for Irrigation purposes. Water quality related to health purpose was found to be under Poor category.

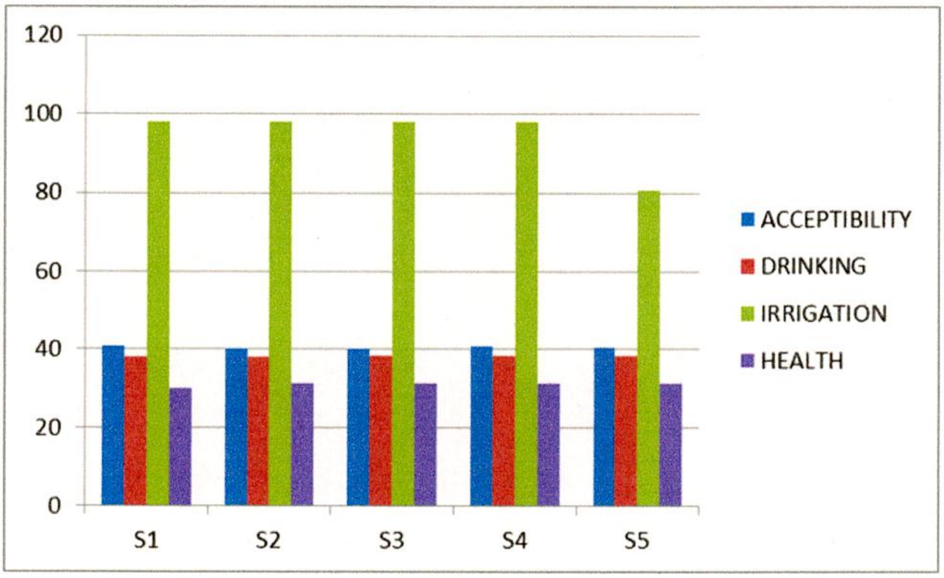

Fig 7. Graphical representation of comparison of WQI values for different sites

CPCB classification for water use

The river water quality was compared with the CPCB classification for different designated usage and it was found that the quality of River Ganga at Haridwar falls under Class B (according to CPCB classification), i.e. it can be used for outdoor bathing (mass bathing).

Piper Diagram

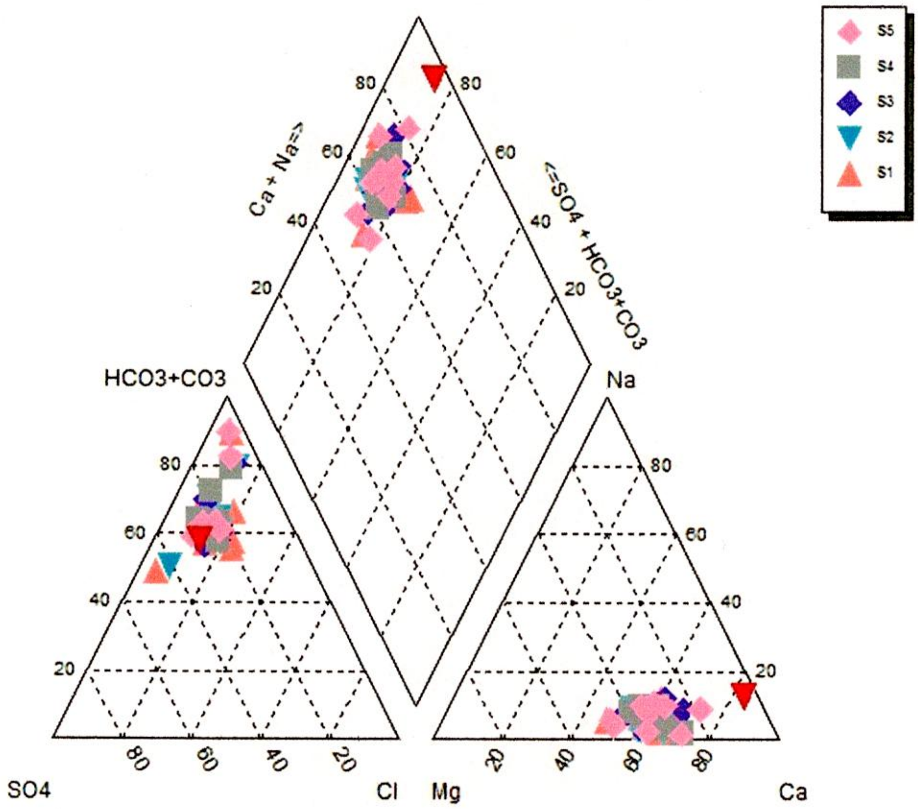

Fig. 8 Graphical representation cations & anions on a graph

The plot shows that majority of river samples fall in mixed Ca-Mg-HCO_3 type. Alkali metal (Ca^{2+} + Mg^{2+}) exceeds over the alkaline earth metal (Na^{+} + K^{+}) and the temporary hardness prevails over permanent hardness.

Temporal variations in Physico-chemical parameters

a) pH

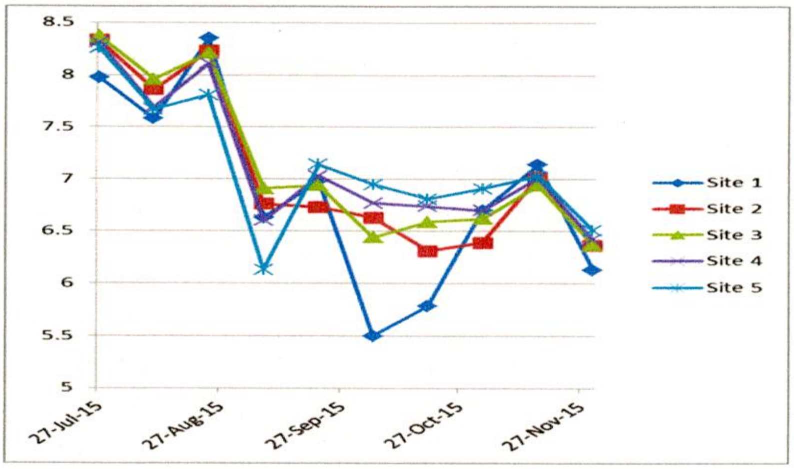

Fig 9. Variations in pH values at different study sites

As depicted in figure 9, the pH values were found to be significant due to Ghats/Ganges at different study sites. Alkaline range of pH in most of the water sample may be due to the general alkaline nature of the effluents being released into sampling sites/locations. pH values were of alkaline nature during the monsoon season but as time passes it decreases and slight variation in the pH of the river is observed. Some of the pH values having higher concentration as compared to BIS standards recommended (6.5 – 8.5) resulted due to low water flow in the river at haridwar.

b) Electrical Conductivity (EC)

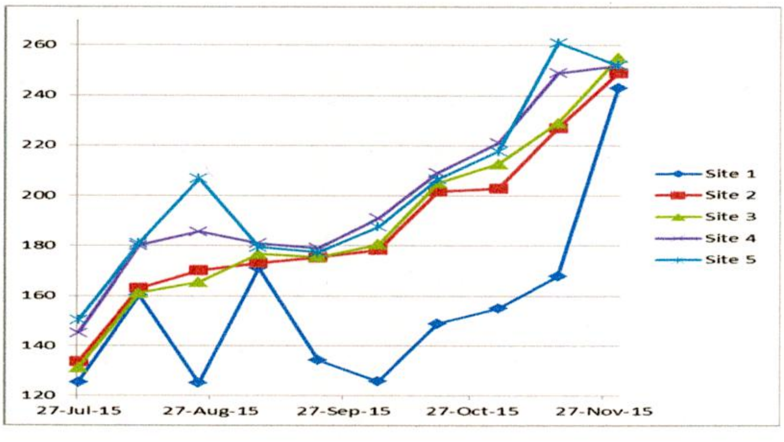

Fig 10. Variations in EC values at different study sites

As depicted in the figure 10, the EC values were found to be significant due to Ghats/Ganges at different study sites. Increase in the electrical conductivity in most of the water samples at the month of November & December may be due to the low water flow but increased amounts of solids being released into sampling sites/locations. Except for site 1, other study sites showed a steady increase in the EC values.

c) Turbidity

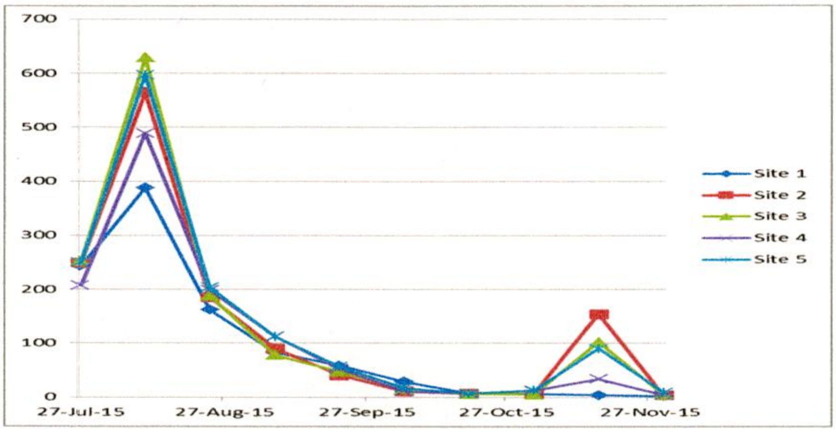

Fig 11. Variations in Turbidity values at different study sites

As depicted in fig. 11 the turbidity values were found to be significant due to Ghats/Ganges and different days of intervals. The Turbidity values having higher concentration as compared to BIS standards recommended (1-5 NTU). The different Ghats / Ganges were slightly above neutral making it not safe for drinking. The increase in turbidity indicates the presence of suspended solids and colloidal matters such as clay and silt, mostly during monsoon season.

Craun et al. *(1975)* reported that increase TDS concentrations in drinking water cause of cancer, coronary heart disease, arteriosclerotic heart disease and cardiovascular disease.

d) Total Alkalinity

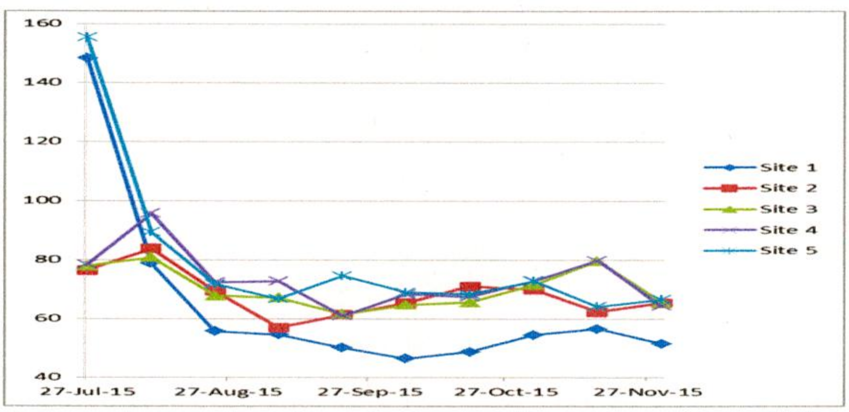

Fig 12. Variations in Alkalinity values at different study sites

As represented in fig. 12 the alkalinity value of River Ganga was found to be maximum at site 5 and minimum at site 3. The alkalinity values having lower concentration as compared to BIS standards recommended. The alkalinity values were found to be significant at the Ganges and at different study sites. High levels of alkalinity in the month of July may be due to monsoon carrying the silt, clay from the slopes into the river.

e) Chloride

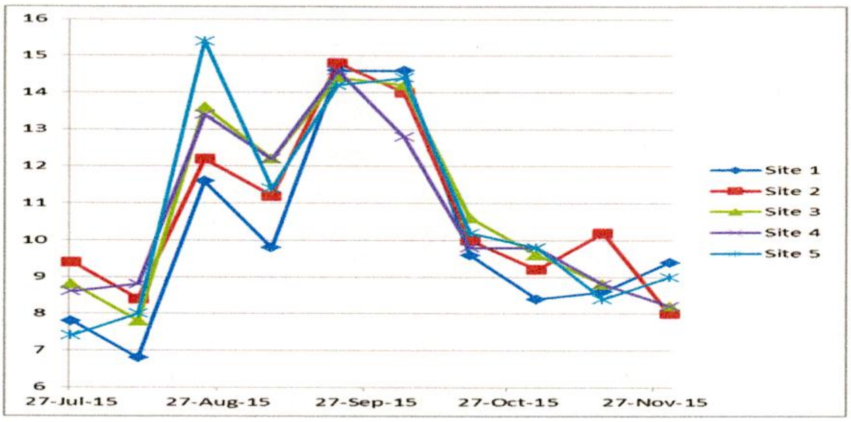

Fig 13. Variations in Chloride at different study sites

As represented in fig. 13 the chloride value of Ganga River was found to be maximum at site 5 and minimum at site 1. The chloride values were found to be significant due to Ghats/Ganges and at different days of intervals. Chloride content can increase due to decomposition of organic matter. High concentration of chloride can also be contributed by mineral deposits, and industrial wastes, as well as domestic waste. Chloride values were low in concentration when compared to BIS standards recommended.

f) Sulphate

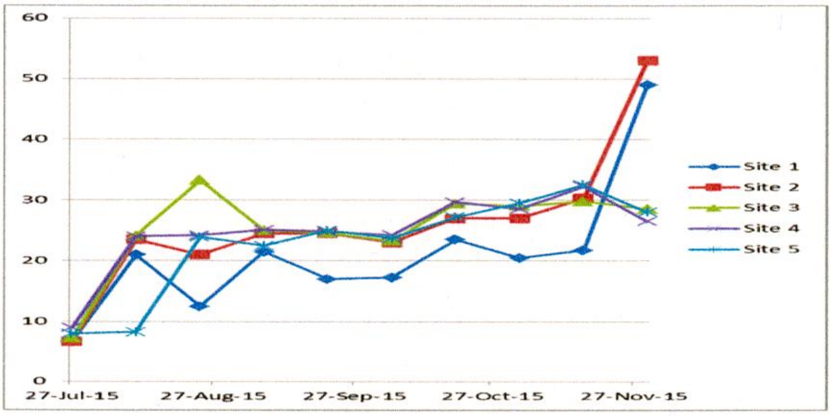

Fig 14. Variations in Sulphate values at different study sites

As represented in fig. 14, the sulphate value of Ganga river water was found to be maximum at S2 and minimum at S1. The sulphate concentration was found to be significant due to sites and different days of intervals. This sulfate values were found to be in low concentration when compared to BIS standards recommended.

g) Nitrate

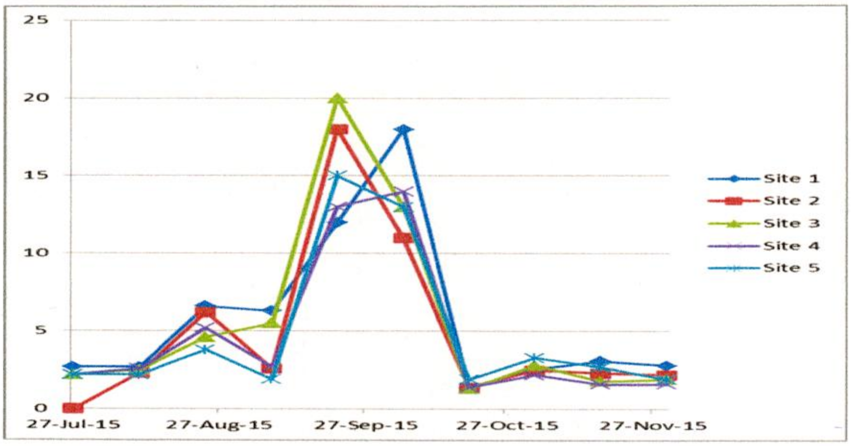

Fig 15. Variations in Nitrate values at different study sites

As represented in fig. 15, Nitrate concentration in Ganga river was found to be maximum at S3, and minimum at S2. The Nitrate concentration was found to be significant due to sites and different days of intervals. This nitrate concentration having lower concentration as compared to BIS standards recommended. This may be due decomposition of organic matter, run-off or introduction of untreated sewage.

h) Phosphate

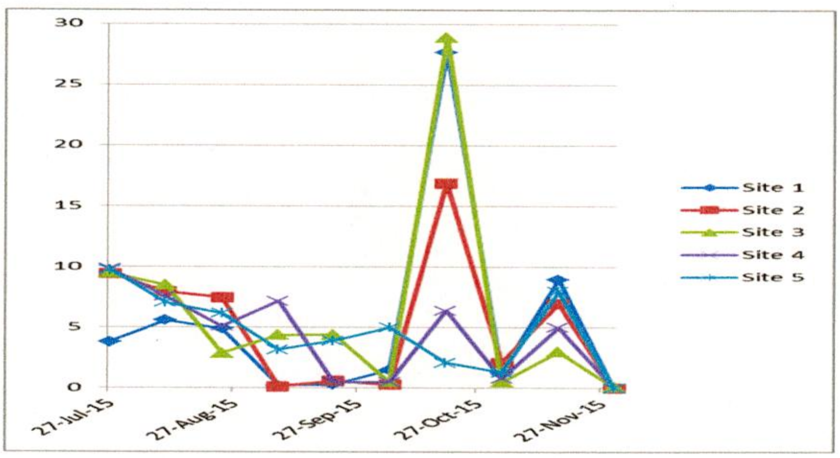

Fig. 16 Variations in Phosphate values at different study sites

The Nitrate concentration was found to be significant due to sites and different days of intervals. This nitrate concentration having lower concentration as compared to BIS standards recommended. This may be due decomposition of organic matter, run-off or introduction of untreated sewage.

i) Silica

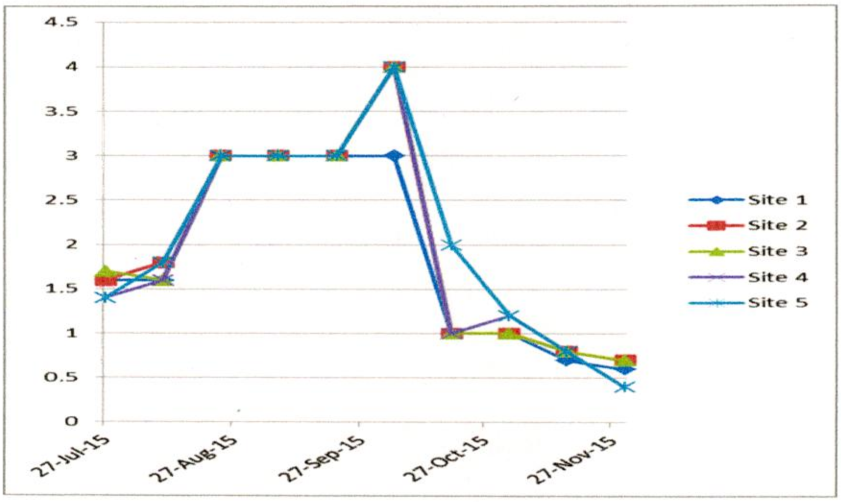

Fig 17. Variations in Nitrate values at different study sites

As represented in fig. 17, Silica concentration in Ganga river was found to be maximum at S2, and minimum at S5. The silica concentration was found to be significant due to sites and different days of intervals. Silica concentration was found to be low in concentration as compared to BIS standards recommended. Rise in the silica content may be due to low water flow.

j) Sodium

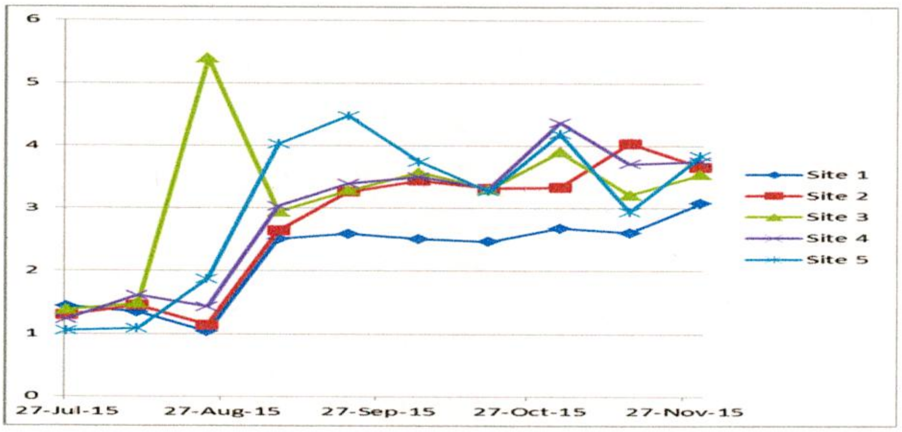

Fig 18. Variations in Nitrate values at different study sites

As represented in fig. 18, Sodium concentration in Ganga river was found to be maximum at S3, and minimum at S5. The sodium concentration was found to be significant due to sites and different days of intervals. Sodium concentration was found to be low in concentration as compared to BIS standards recommended. Rise in the sodium content may be due to low water flow.

k) Potassium

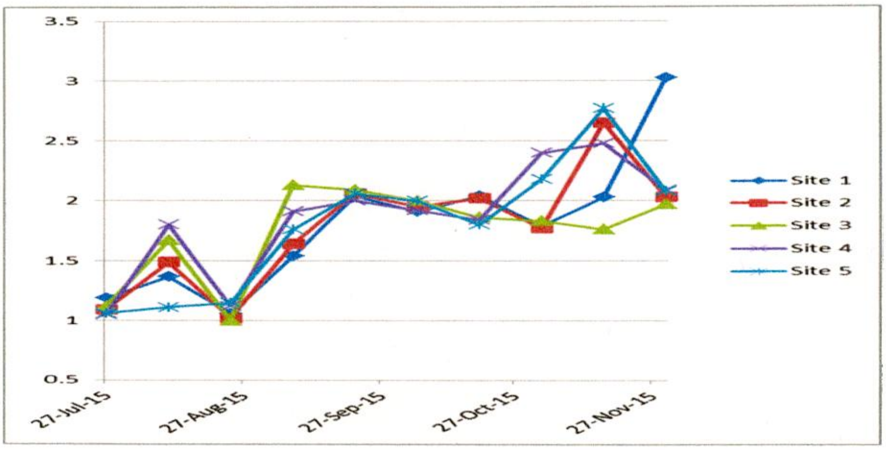

Fig 19. Variations in Potassium values at different study sites

As represented in fig. 19, Potassium concentration in Ganga river was found to be maximum at S1, and minimum at S5. The Potassium concentration was found to be significant due to sites and different days of intervals. Potassium concentration was found to be low in concentration as compared to BIS standards recommended. Rise in the Potassium content may be due to low water flow.

l) Total Hardness

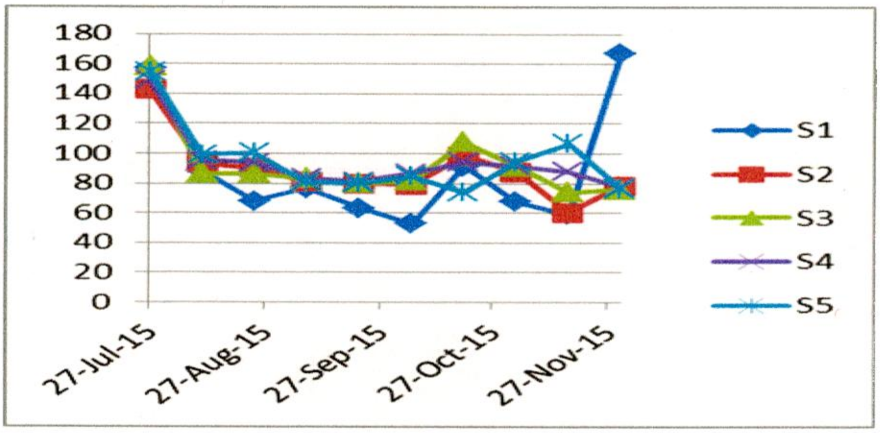

Fig. 20 Variation in Total Hardness values at different values at different study sites

As represented in fig.20, the alkalinity value of Ganga River was found to be maximum at S1 and minimum at S5. Hardness values were low in concentration when compared to BIS standards recommended. The hardness values were found to be significant due to sites and different days of intervals.

m) Calcium hardness

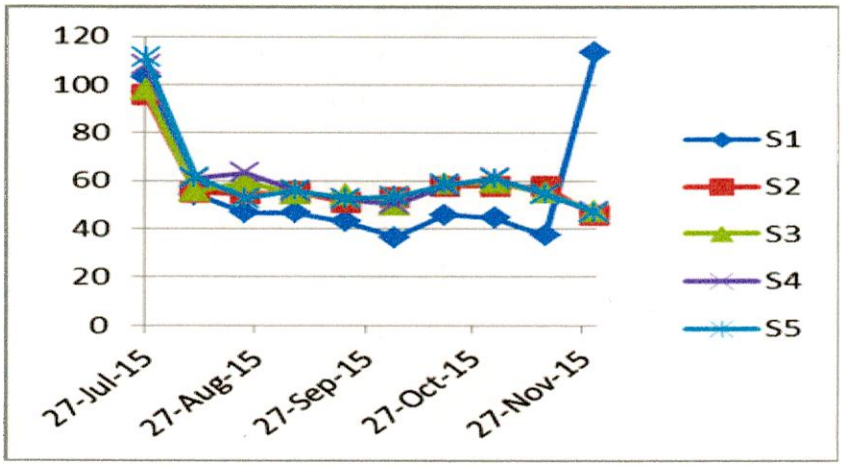

Fig. 21 Variation in Calcium Hardness values at different values at different study sites

As represented in fig.21, Calcium harness value of Ganga River was found to be maximum at S1 and minimum at S3. Calcium Hardness values were low in concentration when compared to BIS standards recommended. The calcium hardness values were found to be significant due to sites and different days of interval.

n) Magnesium hardness

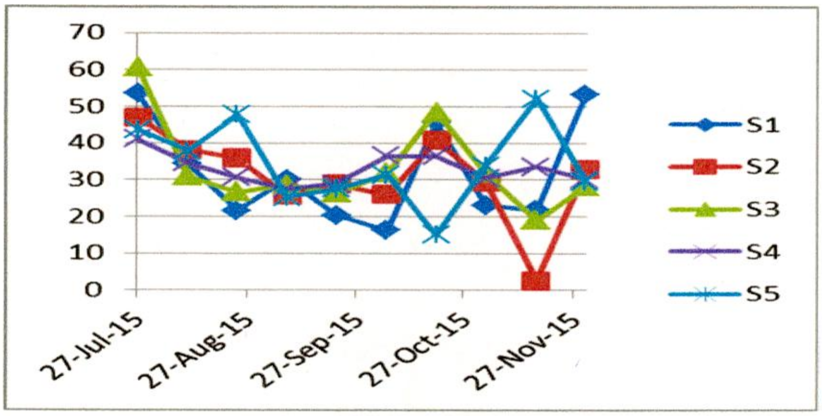

Fig. 22 Variation in Magnesium Hardness values at different values at different study sites

As represented in fig.21, Magnesium harness of river Ganga was found to be maximum at S3 and minimum at S2. Magnesium Hardness values were low in concentration when compared to BIS standards recommended. The Magnesium hardness values were found to be significant due to sites and different days of interval.

o) Total Coliform

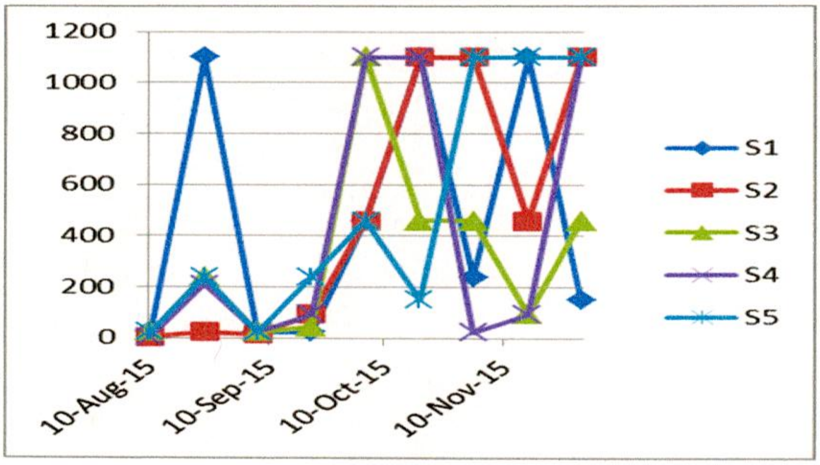

Fig. 22 Variation in Total Coliform values at different values at different study sites

As represented in fig.22, Total coliform of river Ganga was found to be maximum at S5 and minimum at S2. Total coliform values were low in concentration when compared to BIS standards recommended. The Magnesium hardness values were found to be significant due to sites and different days of interval. Variation in TC values may be due to water flow and sewage.

p) Faecal Coliform

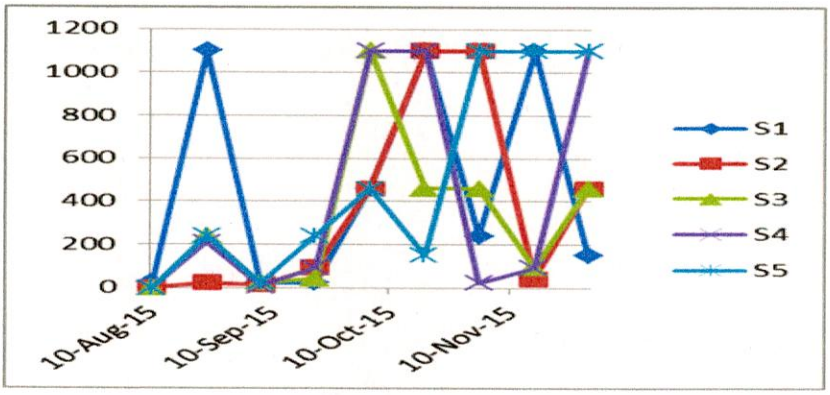

Fig. 23 Variation in Faecal Coliform values at different values at different study sites

As represented in fig.23, faecal coliform of river Ganga was found to be maximum at S5 and minimum at S2. Total coliform values were low in concentration when compared to BIS standards recommended. The Magnesium hardness values were found to be significant due to sites and different days of interval. Variation in FC values may be due to water flow and sewage.

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

CONCLUSION

1. According to CCME WQI, drinking water quality of river Ganga at the sites were found to be of poor in quality rating, thus, it should be subjected to treatment and then consumed. Irrigation water quality was found to be of excellent in quality rating. Turbidity in the water can be removed by chemical treatment followed by sand filtration.
2. Piper plot of the physico-chemical plots indicated alkali metals exceeding over the alkaline earth metals and the temporary hardness prevails over permanent hardness.
3. A hydrological variation of the river strongly influences temporal variations of river water quality, so it is necessary to analyze water quality in terms of different hydrological seasons. Variations may occur due to run-off from river catchment areas, land use & flow of river.
4. It was observed that the Coliform population in the river water increases during mass bathing and hence, the flow of the river during this type of gatherings or people taking bath should be optimized.
5. There's a great need of sewage treatment plant near the river Ganga in order to stop the discharge of untreated domestic wastewater into the river.

REFERENCES

1. APHA. 2005. Standard Methods for the Examination of Water and Wastewater, 21st edn. (American Public Health Association WWA, Washington, D.C.).

2. R. Bhutiani, D. R. Khanna, Dipali Bhaskar Kulkarni, Mukesh Ruhela; Assessment of Ganga river ecosystem at Haridwar, Uttarakhand, India with reference to water quality indices; Appl Water Sci DOI 10.1007/s13201-014-0206-6

3. Assessment of Water Quality of River Ganga along Ghats in Varanasi City, U. P., India; tarence thomas, meenu mishra, h. thomas, arun a. david, ram bharose and d.venkat reddy; international journal of earth sciences and engineering ISSN 0974-5904, Vol. 04, No. 04, August 2011, pp. 698-711

4. ARCHANA MISHRA and B.D. TRIPATHI, Seasonal and Temporal variations in physico-chemical and bacteriological characteristics of river Ganga in Varanasi;
5. *Current World Enviroment* Vol. 2(2), 149-154 (2007)

6. *Sarita Verma;* Seasonal Variation of Water Quality in Betwa River at Bundelkhand Region, India; Global Journal of Environmental Research 3 (3): 164-168, 2009
7. ISSN 1990-925X

8. http://www.researchgate.net/publication/233413301

9. Spatial and Temporal Variations of water quality in Cao-E River of Eastern China; CHEN Ding-jiang, LU Jun, YUAN Shao-feng, JIN Shu-quan, SHEN Ye-na;
10. Journal of Environmental Sciences Vol 18, No. 4, pp. 680-688, 2006

11. www.wikipedia.com

12. http://www.unitedlifejournals.com/ijals/view-article.php?id=359

13. Naveen kumar arora, sakshi tewari and sachin singh; ANALYSIS OF WATER QUALITY PARAMETERS OF RIVER GANGA DURING MAHA KUMBH, HARIDWAR, INDIA;

14. Vijay Sharma, Sushil Bhadula and B. D. Joshi; Nature and Science, 2012;10(6); Impact of Mass Bathing on water quality of Ganga River during Maha Kumbh-2010

15. *Sarita Verma;* Global Journal of Environmental Research 3 (3): 164-168, 2009; Seasonal Variation of Water Quality in Betwa River at Bundelkhand Region, India

16. A.A. Kazmi, Akansha Bhatia, Azfar Shaida, Meena Sharma, Markus Stark and R. C. Trivedi; Journal of Indian Water Society, vol 33, No. 3, July 2013; A SHORT SCREENING STUDY ON WATER QUALITY OF INDIAN RIVERS AND LAKES

17. N. Semwal and P. Akolkar; Water quality assessment of sacred Himalayan rivers of Uttaranchal

18. TARENCE THOMAS, MEENU MISHRA, H. THOMAS, ARUN A. DAVID, RAMBHAROSE and D. VENKAT REDDY; International Journal of Earth Sciences and Engineering; ISSN 0974-5904, Vol. 04, No. 04, August 2011, pp. 698-711; Assessment of Water Quality of River Ganga along Ghats in Varanasi City, U. P., India

19. Ashok Kumar, B.S. Bisht, V.D. Joshi, A.K. Singh and Amitabh Talwar; J Hum Ecol, 32(3): 169-173 (2010); Physical, Chemical and Bacteriological Study of Water from Rivers of Uttarakhand

20. H. Kulshrestha and S. Sharma; Journal of Environmental Biology, April 2006, 27(2) 437-440 (2006), April 2006, 27(2) 437-440 (2006), Impact of mass bathing during Ardhkumbh on water quality status of river Ganga.

21. Er. Srikanth Satish Kumar Darapu, Er. B. Sudhakar, Dr. K. Siva Rama Krishna, Dr. P. Vasudeva Rao and Dr. M. Chandra Sekhar; *ISSN: 2248-9622 www.ijera.com Vol. 1, Issue 2, pp.174-182*; Determining Water Quality Index for the Evaluation of Water Quality of River Godavari.

22. A.Q.Dar, Saima Showkat, Saqib Gulzar; *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X PP 51-58;* Trend Analysis and Spatial Assessment of Various Water Quality Parameters of River Jehlum, J&K, India for an Inclusive Water Quality Monitoring Program