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Water Quality

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Water Centric Cities of the Future –Macro scale Assessment of the Impacts of the Bindal River on the Dehradun City

Soumya Kanti Ghosh, Debasish Buragohain, Anoop Jaiswal

24.1 INTRODUCTION

Water centric sustainable urban developments recognize the ecological value of surface water resources and restore the ecological integrity of the water, the riparian and flood zones through integrated resource management. The concepts of the new paradigm of sustainable water centric ecocities have been emerging for the last fifteen years in environmental research and landscape design laboratories in several countries, including Europe, Asia, Australia, United Arab Emirates, USA and Canada (Bartaraya and Deoli, 2012). Many concepts have been developed by landscape architects to incorporate surface water bodies to a closed loop hydrological cycle system that maximizes reuse and recycling (Novotny, 2010). Water bodies within cities pick up a variety of pollutants such as atmospheric dust, asphalt automotive discharges, metals, bird/animal/human faeces (Xiao et al, 2006; Kim, 2006 and Wada, 2010) resulting in deterioration of water drainage, quality and environmental functions, such as providing an ecological habitat, self-purification, and riparian scenery. To throw light on the importance of water bodies within cities, a study was undertaken in Dehradun to provide insights on a dynamic water system which is on the verge of dying.

Dehradun city has emerged as an important business, educational and cultural destination in north India after becoming the capital of newly carved out Uttarakhand state since the year 2000. Moreover, the city is the wholesale trading centre for the entire hill region of the Uttarakhand state. The city is also well-known for its salubrious climate, natural beauty, places for tourist's attraction and institutions of national and international importance. The resident population of the city

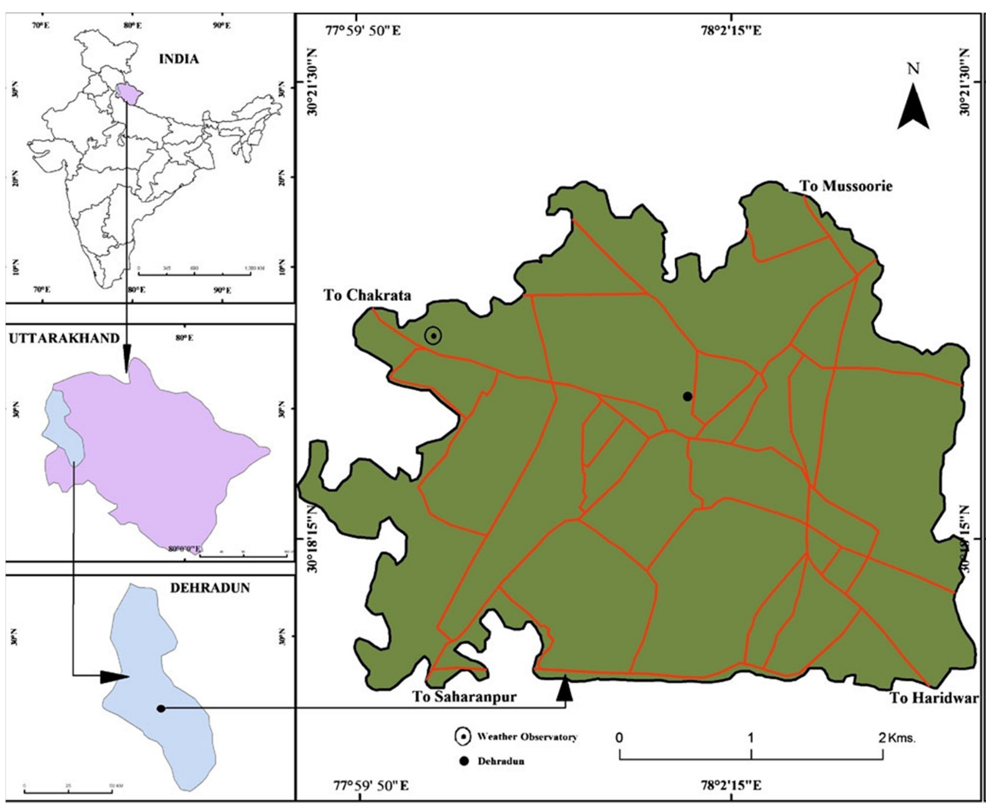

Figure 24.1: Extent of Dehradun city and location of meteorological station considered in this study

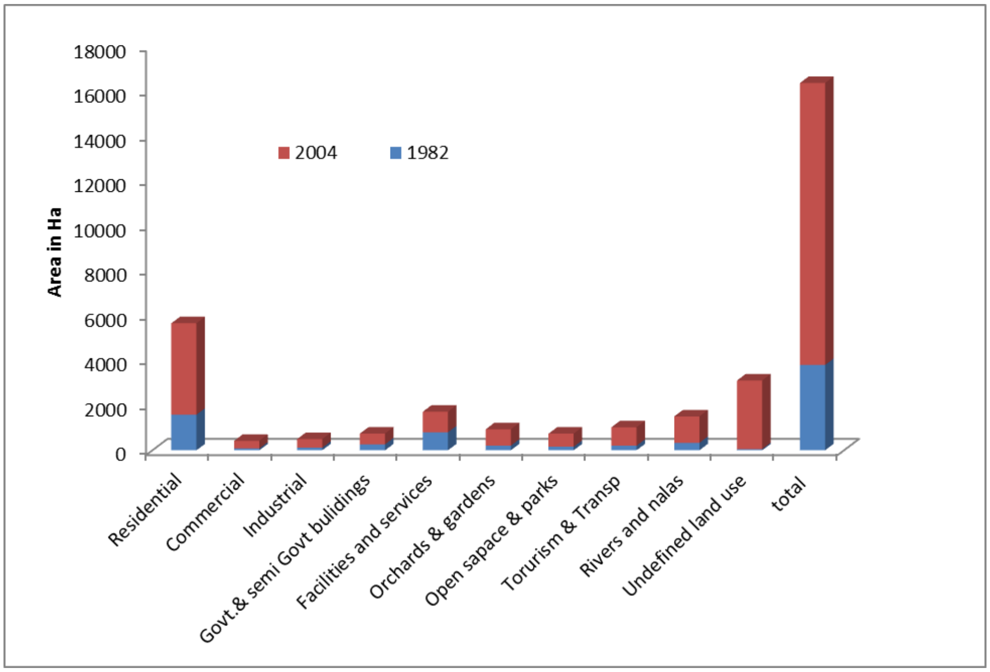

Figure 24.2: Comparison of land use pattern of Doon Valley in 1982 and 2004

grew very fast during 1991–2011 and it registered a growth of about 114 per cent during the last two decades. In addition, the population of the Dehradun city was predicted to grow at the rate of 3.5 per cent from 2010 to 2014, and 3 per cent from 2015 to 2019 (Uttaranchal Urban Development Project, UUDP 2007). About one million Indian and foreign tourists visit the city every year in the form of floating population (UUDP 2007).

The city includes basins of some important rivers like the Ganges, the Yamuna, Tons and Bindal rivers. The Bindal River is the city's main artery and flows through the heart of the city. About 50 years back, it was a perennial river which had surplus supply of mountain water and thriving fish population. The decline of the river started river with the beginning of encroachments around the banks. Large parts of the river bed were cemented which resulted in a major decrease in the water volume of the river (Ground Water Brochure, 2011). Studies elsewhere have reported that land use changes due to rapid encroachment along the river has impacted on near-surface hydrological parameters such as infiltration rates, saturated hydraulic conductivity under various types of groundcovers and soils (Dunne and Leopold 1978; Foo and Tan,1985; Chuah, 1987).

Today the river resembles and is treated as a major sewer. The water that flows through the river is loaded with sewerage, garbage, industrial effluents and heavy metal concentration. Sadly, municipal planning has been as such that all nearby settlements have their sewerage flowing into the river, which is deteriorating the hydrological conditions of the river and causing greater incidences of pollution.

24.2 METHODOLOGY

The following study areas were examined for the extraction of relative impacts of the Bindal River on the city.

24.2.1 Accounting the total built-up area of Dehradun

Thorough research of the data available on the number of settlements that have been built up in the city during the past 10 years has been conducted to compile the situation of population stability in the city as well as the built-up area.

24.2.2 Accounting the water quality of the Bindal River

The water analysis of the Bindal River was performed for the detection of heavy metals using Inductive Coupled Plasma-Mass Spectroscopy (ICP-MS) (Boevski and Daskalova, 2007) as earlier reported (Kumar, Bisht, Joshi, 2010) and the result thus obtained was compared with the permissible concentration allowed, as well as the previously scripted data (Kumar, Bisht, Joshi, 2010).

24.2.3 Assessment of impact on the Bindal River bank population

Following the preceding analysis report, a detailed questionnaire survey was conducted among the people living in the slum on the banks of the Bindal River, under the Bindal bridge, Chakrata Road.

- Period of Inhabitation
- Size of the Families
- Source of Income
- Site for Garbage Disposal
- Availability of Safe Drinking Water
- Incidence of Common Diseases in the area
- Common stray animals in the area
- Problems faced due to differential state of water levels and flow

- Sanitation and toilet facilities
- Government aid if any

Further, a detailed inspection of the type of plant species growing in the river banks was conducted to study the nature of the soil in the banks.

24.3 RESULTS

Land is the main natural resource for life support systems. The land and land cover changes are equally important elements of the larger problem of global and regional environmental changes.

The urban population of the valley has grown 3.4 fold during four decades (1961-2001) and is causing immense pressure for built up area. The water body (seasonal streams) has shown little change in area due to encroachment by slum dwellers and land developers. The city has witnessed large portions of land which have been converted into built-up area. The exponential increase of the total built-up area recorded by the Mussorie Dehradun Development Authority from 1982 to 2004 (Table 24.1) and then an increase in land use from 2004 to 2010. Thus, an unstable growth in encroachments had occurred in the city over the last two and a half decades.

Next, the ICP-MS analysis of the river water from Bindal shows that there has been an increase in the concentrations of Zn, Mg, Cu, Co, Cr, Ni, Pb and Mn (Table 24.2). Ni concentration has increased over the last two years which is harmful owing to the moderate polluting grade of Ni; but what is really alarming is the rapid increase noted in the heavy pollutant – Cu. Its increase has been the reason for the immobilization of most other heavy metals resulting in sedimentation. The study conducted previously in this regard had reported similar observations (Kumar *et al.*, 2010). However, in the present study conducted in the monsoon, no fish were found in the water as it was too shallow to sustain any aquatic ecosystem. Also, the common flora of the area was merely mosses; one or two specimens of *Parthenium hysterophorus* were spotted. Apart from this, the area close to the water was devoid of any other vegetation. Though the vegetation high up the banks was quite heavy with species of *Lantana camara, Eleusine indica, Achyranthes aspera,* and *Melia azedarach*. According to sources without any valid citation and the locals of the city, the Bindal River was a perennial river with abundant water volume and a thriving fish population. It was a lifeline for the then inhabitants of Dehradun as an important source of water. However, today, the river has flowing water for less than six months. It has been changed into a seasonal river mostly used as a sewer outlet for the city.

Table 24.1: Development of built up area in Dehradun city during 1982–2004.

Type of Urban Land use	Built up area (ha.) 1982	Built up area (ha.) 2004	Growth in Built up area (%.) 1982-2004
Residential	1588.8	4071.8	156.3
Commercial	81.0	341.4	321.5
Industrial	113.4	383.4	238.1
Govt. & Semi-Govt. Buildings	267.2	479.6	79.5
Facilities & Services	802.2	915.4	14.1
Orchards & Gardens	205.7	728.4	254.1
Open Spaces & Parks	156.0	584.9	274.9
Tourism & Transportation	203.0	822.0	304.9
Rivers & nalas	331.5	1179.3	255.7
Undefined Land use	55.0	3058.8	5461.5
Total	**3802.8**	**12565.0**	**230.4**

Table 24.2: Increase in the concentration of heavy metals in the Bindal river water from 2010 to 2013.

Metal	Concentration in Bindal River water ($\mu g\ l^{-1}$ except permissible column and Mg; it is in $mg\ l^{-1}$)		
	Permissible	In 2010 (Kumar, Bisht and Joshi)	In 2013
Zn	15	53.83	54.47
Mg	30	38.3	37.96
Cu	15	26.5	29.83
Co	1	1.85	2.91
Cr	5	10.83	11.45
As	0.05	5.5	5.47
Ni	3.0	13.76	14.21
Pb	0.1	2.1	2.21
Mn	2	99.66	100.83

The survey as a whole revealed the grim scenario of the socio-economic condition of the people dwelling in the slum at the Bindal bridge, Chakrata Road. The slum shelters a population of about 1,700 as recorded through local Census, of which most of the families have been living in that area for more than 30 years. The average size per family was found to be 6-7, sometimes recorded as high as 14-15 members. Majority of the population is composed of juveniles of which most are males. The source of income of the respective families varied from daily labour, vending to even begging. All the families that were surveyed reported that they dumped their garbage in the river. There is scarcity of drinking water in the area. The entire slum has only 2 municipal tap water outlets which supply water daily for 1.5 hours for the entire population. The commonly diseases of the area were malaria, jaundice, pneumonia, typhoid, dysentery, amoebiasis, diarrhoea and dengue, all of which are water-borne diseases. The common stray animals were pigs and stray dogs. A remarkable number of kites were also spotted hovering over the area. The differential condition of the water levels was reported as being troublesome by the locals. The banks would often get flooded due to rain and water would flow into the huts causing chaos throughout the slum. The people used the nearby bushes or fields for lavatory purposes and for bathing. The children were, however, found to be bathing in the river water itself which carries garbage. At one point in the river was a large electrical pole the base of which was jammed with wastes and garbage of all sorts. Finally, the entire population that was surveyed denied that they received any governmental aid.

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24.4 CONCLUSION

The Bindal River has been subjected to rigorous exploitation since the past 4-5 decades due to increasing encroachment by humans. Today the river has lost its ecological stability owing to over-exploitation by increasing human settlements. The river water, sediment and aquatic life-forms have suffered huge incidences of metal pollution. The water was reported with high amount of dissolved metals much higher than the stipulated ambient water quality standards. The precipitation of lead, copper, manganese, chromium and zinc might be the result of alkaline pH in the form of insoluble hydroxides, oxides and carbonates. Metals such as chromium, copper and nickel have interacted with organic matter in the aqueous phase which has caused its accumulation and high concentration in the sediment. Copper, which is considered to be a heavy polluting agent in water by the USEPA, has been reported in increased levels at all sites along the river. Mineralogical studies of polluted sediments indicated that heavy metals were associated with fine particles of silt and clay that had large surface areas and the tendency to adsorb and accumulate metal ions due to their intermolecular forces. The study revealed that large quantities of effluents occurred in the river due to movement of fertilizers, agricultural ash, industrial effluents and anthropogenic wastes particularly in the downstream of the river. The heavy metals that occur in the river water had greater tendencies to avoid degradation and thus got accumulated in the sediments, the phytoplanktons and even in human beings. The presence of phytoplankton could justify the presence of heavy metals in the river and, incidentally they were found in abundance at all possible sites of study. The survey was an eye-opener to the misery that the slum area had been subjected to. Most of the people were unwilling to participate in the survey and seemed to have accepted their way of living along the banks. They faced problems of flood and diseases from the river water. The people were totally unaware of the harm that the polluted river could inflict upon them. The river bed was bereft of any notable vegetation. The heavy metal deposition in the sediments had narrowed chances of natural resurrection. The area was the live example of negligence and ignorance leading to the pathetic life of the people who lived along the banks as well as the depletion of any other notable life forms.

ACKNOWLEDGEMENT

Authors appreciate the cordial assistance rendered by Dr. V. Jeeva, DDG, Indian Council of Forestry Research and Education, during the study.

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25

Effect of Management Practices and Disturbances on Quantity and Quality of River Ganga near Patna

Neetu Bharti, A.K. Ghosh, A.K. Singh and Rajeev Kumar

25.1 INTRODUCTION

Rivers are the most important natural water resource widely used for domestic, industrial and agricultural purposes (Jain, 2009). Ganga is the longest river in India, if flows 2,525 km, right from Himalayas to the Bay of Bengal. It has its origin at the Gangotri glacier at an altitude of 7,010 m above mean sea level in the Uttarkashi district of Uttrarkhand. Patna lies in the Middle Ganga Basin of India where the river water quality and flow has been severely affected by a large number of anthropogenic activities like sewage, hospital waste discharge, crematoria, carcass disposal, etc. Increasing anthropogenic activity has caused a direct depletion in the hydrobiological and limnological status of the aquatic system (Khanna *et al*., 1993).

The River Water Quality Index (RWQI) is an environmental indicator which takes into account the chemical, biological and physical data and summarizes it into a simple composite description of water quality. The purpose of RWQI is to show relative differences between sites and to help identify degradation or improvement that may have a human cause (Parmar and Singh, 2011). A single number cannot reveal the exact condition of water quality as many of the parameters are not included in the index. The RWQI presented is not specifically aimed at human health or aquatic life regulations. The water quality index is a dimensionless number with values ranging between 0–100. A higher index value represents good water quality (Cude, 2000; Pandey and Sundaram, 2002).

Zooplanktons are important component of freshwater communities. They are a heterogeneous assemblage of minute floating animal mainly represented by various taxonomic groups such as Rotifera, Cladocera and Copepoda. Zooplanktons play major role in the food web of an aquatic ecosystem and form an intermediate link between primary and tertiary production. Study of plankton diversity and their ecology greatly contributes to an understanding of the basic nature and general economy of an aquatic habitat (Srivastava, 2013). Estimation of the plankton composition and diversity has often been utilized to evaluate the overall health of river ecosystem. The factors regulating river plankton abundance may be hydrological (discharge, water residence time), chemical (nutrient concentrations), physical (light conditions) and biotic (grazing, competition). The physico-chemical parameters also affect plankton distribution, sequential occurrence and species diversity (Jhingran, 1991).

Diversity indices are good indicators of pollution in aquatic ecosystems. The Shannon index is an unweighted measure and takes into account not only the number of species but also the relative quantities of species. Variations in the indices may be considered to reflect the changes in the biomass. A diversity index greater than 3 indicates clean water and values in the range of 1 to 3 is characteristic of moderately polluted conditions. Values less than 1 characterize heavily polluted conditions (Wilhm and Dorris, 1966; Mason, 1998). Number of species and even distribution of individuals per species are the two important components of species diversity which increases with increased number of species and more even distribution of individuals among species. Therefore, diversity measures both species richness and species evenness (distribution of individuals among the species) in a community (Poole, 1974).

This study aims to assess the seasonal variation in water quality of river Ganga at Patna and its influence on zooplanktons diversity. An attempt was made to determine the relationship between the physico-chemical parameters and distribution of zooplanktons using Water Quality Index (WQI) and Shannon-Wiener diversity index.

25.2 METHODOLOGY

The present study was carried out in River Ganga at Patna (Bihar, India) from December, 2009 to November, 2010. Four sites were established along the river, located between 25°36' N to 25° 39' N and 85°08' to 85°12' E, at an altitude of 53 m above mean sea level. Patna supports a population of 16,83,200 (Census 2011) and poses an impact on River Ganga directly or indirectly.

25.2.1 Study area

The water of river Ganga at Site-1 appeared to be clean and pristine in winter and summer and silty in monsoon season and was considered as the reference point. There was no anthropogenic activity at this site. Site-2 (Anta Ghat) and Site-3 (Ghagha Ghat) presented muddy, filthy and unaesthetic condition round the year. The Site-2 has already experienced sand and silt deposition causing the channel to move north and the change is irreversible. The sedimentation at Site-3 has started accelerating and can meet the same fate as Site-2. These two sites experience the maximum anthropogenic interferences in the form of municipal discharge at Site-2 and hospital waste discharge nearby Site-3. The Site-4 (Gai Ghat) was relatively clean round the year except during the monsoon season.

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25.2.2 Water Quality Measurement

Analysis of physico-chemical parameters were done directly at each station, where the water temperature, turbidity, pH and dissolved oxygen were measured. Water samples were stored in polyethylene bottles (1 litre capacity) and brought to the laboratory for further analysis. In the laboratory, chloride, phosphate, nitrate, total alkalinity, total hardness was analyzed using Standard Methods (APHA, 1998) and Trivedy and Goel (1984). Water Quality Index (WQI) was calculated by using Unweighted Harmonic Square Mean Formula (Lumb *et al*., 2011).

25.2.3 Zooplankton Analysis

Zooplanktons were collected by filtering 50 litres of sub-surface water of Ganga River through a plankton net made up of bolting silk No. 25 with mesh # 55 μm and finally concentrated to 50 ml. The plankton sample was immediately preserved with 4 per cent formalin and brought to laboratory for further analysis. In the laboratory, 1 ml of sample was taken out with a graduated pipette and transferred to a Sedgwick-Rafter plankton counting cell and it was then covered with a rectangular cover slip. The counting of zooplankton was done using a light microscope. Before counting, zooplanktons were identified with the help of available standard literature for their identification. The numbers of zooplanktons counted were converted to numbers per litre following methods suggested by Sinha *et al.* (1994).

25.3 RESULTS AND DISCUSSION

The physico-chemical variables used to calculate WQI of River Ganga at different sites have been presented in Table 25.1. The purpose of this index is to show relative differences of water quality influenced by prevailing anthropogenic activities at the respective sites. The WQI at sites ranged from minimum 11.08 during monsoon season at Site-3 to maximum 73.29 in winter at Site-1 (Table 25.1). At Site-1, the WQI calculated were minimum during the monsoon season (56.07) and maximum in winter (73.29). This site was considered as a control since the site showed no visible direct anthropogenic activity. The site lies in the middle channel of River Ganga. At Site-2 (Anta Ghat), the WQI calculated were minimum during monsoon (40.61) and maximum in winter (49.20). This site experiences the most direct and numerous anthropogenic activities and has undergone the most significant changes in landscape. The current flow in this region seems to attain almost static condition which might be the cause of sedimentation and deposition of silt and thus for a gradual shift in river channel towards north as compared with 1976 Topo sheet and LANDSAT TM satellite data 2012. At Site-3 (Ghagha Ghat), the minimum WQI found during monsoon season (11.08) and maximum in summer (66.83). The site lies on downstream of Site-2 and also witnesses a large number of anthropogenic interferences. The hospital waste finds its outlet nearby this site. The site is also experiencing fast sedimentation since 2010 and may in the near future meet the same fate as Site-2, forcing the river channel to shift further north. At Site-4 (Gai Ghat), the minimum WQI was recorded during monsoon season (42.21) and maximum in winter (70.65). The site also witnessed a large number of anthropogenic activities, the most significant being ferry boats carrying mined sand. As a whole, the water quality of River Ganga near Patna ranged from poor to very poor.

Table 25.1: WQI at sampling sites in River Ganga

Sampling Sites	Winter	Monsoon	Summer
Site 1	73.29	56.07	72.94
Site 2	49.20	40.61	48.75
Site 3	63.96	11.08	66.83
Site 4	70.65	42.21	66.82

Rivers often contain an abundance of zooplankton, even though these organisms lack the ability to swim against current. They are good indicators of changes in water quality, because they are strongly affected by environmental conditions and respond quickly to changes in environmental quality. Riverine zooplankton community composition may be controlled by turbulence and water velocity, water quality most likely plays a critical role in structuring this community (Wahl *et al.*, 2008). Three major zooplankton groups dominate freshwater ecosystems – the Rotifera, Cladocera and Copepoda and their nauplii. A total of 30 species of zooplankton were recorded by collecting samples in three different seasons. Species richness of Rotifera was found high, while species richness of Cladocera and Copepoda was found to be low. Diversity indices are good indicators of pollution in aquatic ecosystems. Variations in the Shannon-Weiner Diversity Index (H') values reflect the changes in water quality. A diversity index (H') greater than 3 indicates clean water, values in the range of 1 to 3 shows moderately polluted conditions and values less than 1 characterize heavily polluted conditions.

In the present study, Shannon-Weiner Diversity Index (H') was used to classify water quality on the basis of zooplankton assemblage. The S-W diversity index (H') calculated using zooplankton communities are given in Table 25.2. At Site-1, the minimum H' calculated in monsoon season (2.56) and maximum in summer (3.06). The H' corresponds to the trend exhibited by WQI in monsoon and a higher diversity in summer. The zooplankton showed the major peak of growth in summer and led to increased species diversity and abundance in summer season. At Site-2, the minimum H' calculated in monsoon season (1.67) and maximum in summer (2.24). Similar trend in H' was also noticed at Site-1. At Site-3, the minimum H' calculated in monsoon season (2.19) and maximum in winter (2.63).The trend exhibited by H' matched with the trend WQI at Site-3. At Site 4, the minimum H' calculated in monsoon season (1.54) and maximum in summer (2.55). The trend exhibited by H' matched with the trend WQI at Site-4.

Table 25.2: H' at sampling sites in River Ganga

Sampling Sites	Winter	Monsoon	Summer
Site 1	2.90	2.56	3.06
Site 2	2.01	1.67	2.24
Site 3	2.63	2.19	2.57
Site 4	2.32	1.54	2.55

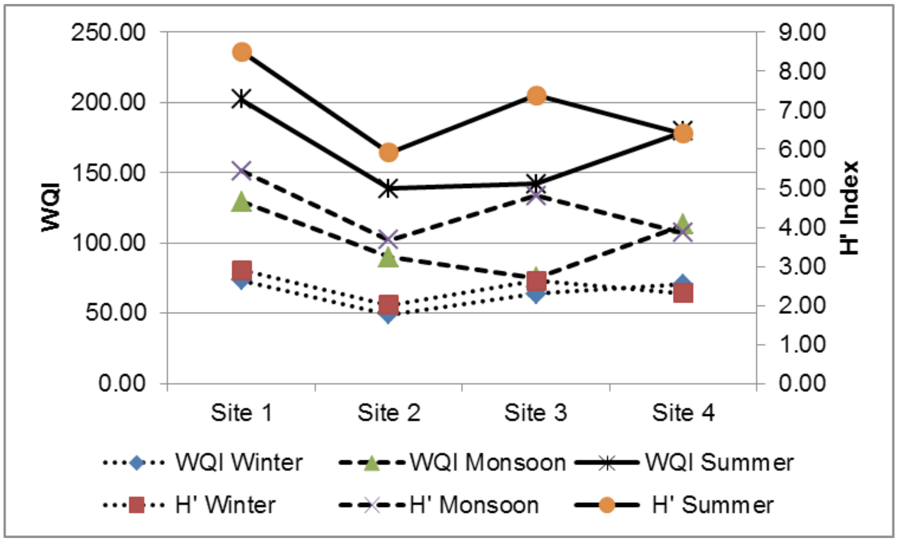

Figure 25.1: WQI and H' values at various sampling sites

The velocity and discharge of water within a river also has direct and indirect effects on the biota. The level of water and discharge in the river is minimum in the summer season and increases considerably during the monsoon season. Changes in zooplankton abundance, diversity, per cent composition were observed seasonally in the present study. The WQI and H' at the four sites have been compared in Fig 25.1. While, analyzing the S-W Diversity Index value, it shows that the water quality of River Ganga varies from clean to moderately polluted. Contrary to this, the value of WQI indicates that water quality ranging from poor to very poor.

In this study, it was found that the zooplankton samples studied at Site-2 showed maximum herniation (18.75 per cent) in their bodies. Various indicator species have been recognized like *Brachionus* (Mola, 2011), *Keratella, Moina* (Bilgrami,1991) which are found in abundance in degraded/eutrophic water. In the present study, *Brachionus* amongst Rotifers and *Moina* amongst Cladocera were also found to be most abundant at Site-2 (Anta Ghat) during monsoon and presented eutrophic conditions.

The present study clearly reveals that biological communities are very responsive to the water quality and the physical and chemical parameters should be supplemented by biological indicators also because they respond to the entire range of biogeochemical factors in the environment.

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GIS Based Water Quality Assessment and Proposed Management Plan of the "Ganga River" at Haridwar, Uttarakhand, India

Mukesh Prasad, M.M Kimothi and Pratibha Naithani

26.1 INTRODUCTION

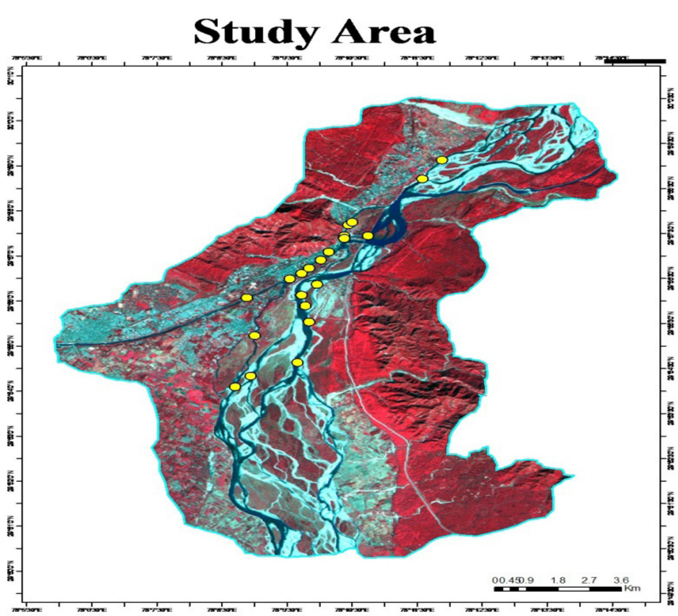
Ganga is the national river of India and is considered sacred. It is about 2,525 km long, flows from Himalayas to Bay of Bengal across 52 cities and 48 towns (Parua, 2010). Its two parent streams, the Alaknanda and the Bhagirathi, join at Devprayag to form the River Ganga. The two parent streams are snow-fed and owe their origin to Himalayan glaciers. At Rishikesh-Haridwar, the Ganga cuts across the Shivalik Hills to enter the plains. Therefore, Haridwar is known as the Gateway of God. The Ganga occupies a unique position in the cultural ethos of India, from times immemorial, it has been India's river of faith, devotion and worship (Alter, 2001).The Ganga Basin supports rich biodiversity as well. It is home to a number of resident and migratory birds. It has over 140 fish species including the Gangetic Dolphin, declared as the national aquatic animal by Government of India, 90 amphibian species and five areas that support birds found nowhere in the world (Parua, 2010). Scientists believe that the "zebrafish" found in the river has ability the to regenerate its cardiac muscle, which may hold the key to the discovery of drugs and treatment, which could allow the human heart to heal itself after a heart attack (Spence *et al.*, 2007). Ganga decomposes organic waste 15-25 times faster than other rivers. It has an extraordinary high rate of re-aeration, the process by which a river absorbs atmospheric oxygen. Experts observe that Ganga, once called the "reservoir of oxygen" was the only river in the world that had 12 ppm (12mg/l) of oxygen, however oxygen content has now reduced to 4-8 ppm today at many places (Puttick, 2008). However, as per World Wide Fund For Nature (WWF), Ganga ranks in the top 10 rivers at risk and if pollution is not managed, the river will completely degraded. With time and because of increased human intervention, the Ganga has become polluted. As the river passes through the cities, billion of litres of human faeces, industrial and agricultural waste find their way into it, destroying the natural ecosystem of the river and threatening the population depending on it. Thus, the water of Ganga is overloaded with pollutants. In fact, according to a study, it is feared that a dip in Ganga might lead to some skin diseases (CPCB, 2008).

GIS is a computer programme capable of assembling, storing, manipulating, and displaying geographically referenced information. The advantage of using a GIS map is the ease in displaying and integrating a wide range of information (e.g., land use, point source discharges, and water supply sites, etc., at a scale chosen by the user (Ganapathy and Ernest, 2004). The study has been carried out to develop a water quality map by using GPS and Geographical Information System (GIS) techniques and analytical lab analysis of water collected from different sampling stations of Haridwar (Uttarakahand). This database will be used as a user-friendly decision support tool, with the objective of being readily used to identify problems, establish relations with other spatial variables and serve as a tool in the decision making process. Some management plans (recommendations) have been developed for River Ganga at Haridwar.

26.2 METHODOLOGY

Haridwar district, covering an area of about 2,360 sq. km, lies in the western part of Uttarakhand state of India. Its latitude and longitude are 29.58°N and 78.13°E, respectively, and height from sea level is 249.7 m. The study area covers a 10-12 km long stretch from upper Dudhiya Dham to Kankhal area of the Ganga

Figure 26.1: Study area at Haridwar



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falling between latitude 29^0 58'-29^0 54' N and the longitude 78^0 58'- 78^0 08' E (Fig. 27.1). Five sampling stations – A) Dudhiya dham, B) Har Ki Pauri, C) Chandi Ghat, D) Lalji wala (Rori Belwala), E) Kankhal Area – were selected for this purpose and five samples were collected from each site, amounting to a total of 25 samples. The sampling sites were selected on the basis of an earlier study (Khanna, 1986), so that a comparative study could also be done and also cover the complete stretch of the river at Haridwar.

The water quality parameters included pH, Dissolved Oxygen (mg/l), Total Solids(mg/l),Total Suspended Solids(mg/l), Total Dissolved Solids(mg/l) and Transparency (cm) and these were analysed at Forest Research Institute laboratory using APHA (APHA, 1995) manual and CAPRI manual. LISS-III data was taken for land use land cover map and was prepared using ERDAS Imagine of the study area (Haridwar region). Point coverage (GPS point) was also prepared using Arc. GIS 9.3. Taking point coverage map, the different layers of pollutants generated and interpolated with spatial analysis. Spatial Variation maps (Isoline maps) for various major pollutants were also prepared using same Arc GIS 9.3 software. Point coverage was prepared for different layers of water quality parameters created with the help of GIS Arc Veiw 9.3 interpolation technique.

26.3 RESULT AND DISCUSSION

The value of the water quality parameters varies from site to site. But the important parameter Table 26.1 and Figure 26.2 show that the water quality at the (A) Dhudhiya Dham, the first sampling station is quite good but as we move down the river towards (E) Khankhal Area the water quality starts degrading.

The value of Dissolved Oxygen (DO), when the river enters the city, it is around 6.8 mg/l and when it leaves the city, the value decreases up to 4 mg/l in Khankhal area, clearly showing that the water starts deteriorating not only for the humans but becomes a great threat to the biodiversity in the river. During the period of investigation, four samples out of 25 showed DO below bathing level (5mg/l). Presence of DO in water may be due to direct diffusion from air and photosynthetic activity of autotrophy. Not only the dissolved oxygen but transparency of the river water also decreases as we move from sampling station A (Dudhiya Dham) to Sampling Station E (Kankhal Area). It was observed during of the time of field visit, that sewage directly entered into the river without any treatment at many places in Khankhal Area.

The value of total solids (TS) and Total Dissolved Solids (TDS) also showed highest value (1080 mg/l and 91 mg/l) at (E)Khankal area and lowest (360 mg/l and 25.4 mg/l) at (A) Dudhiya Dham. As the river passes through Haridwar, thousands of litres of sewage, industrial and sometimes agricultural waste find their way into it, destroying the natural ecosystem of the river and threatening the population depending on it. It has been reported that over thousands of litres of sewage is dumped directly into the river everyday in Haridwar city.

The transparency zonation map was created, three zones were selected, <50 cm, 50-60 cm and >60 cm. It was seen that the water transparency decreases from Dhudiya Dham (Sampling station A) to Kankhal Area (Sampling station E). The value of dissolved oxygen of the river at sampling station A is high. Its zonation map were categorized on basis of <4 ppm, 4-6 ppm and >6 ppm. The lowest value of DO observed 3.74 mg/l at many places like Har Ki Pauri, Chandi Ghat and Khankhal area. The highest value of DO observed 6.24 mg/l at Dhudiya Dham. It has

Table 26.1: Shows the value of different parameters of water quality at different sampling sites of Five Sampling Stations

Samplin	Sampling Sites	Latitude	Longitude	Colour	Air Temp. (	Water Temp.	Velocity (m/s	Transpar	DO(mg/l)	COD(mg/l	PH	TS(mg/l)	TDS(ms/l))	TSS(mg/
	Dudhiya dham(sapt sarovar)													
A	dudhia dham(A1)	29 58 19.07	78 58 06.01	clear/ Blu	32.00	18	0.151	62	6.24	88	7.96	400	23	377
A	dudhia dham(A2)	29 58 51.02	78 11 33.08	clear/ Blu	34.00	20	0.190	90	7.82	112	8.59	200	25	175
A	sapt sarovar(A3)	29 59 18.02	78 11 53.00	Blue/Alge	31.60	24	0.200	85	5.54	96	8.47	400	26	374
A	bhimgoda wetland(A4)	29 57 36.04	78 10 44.06	Green	30.00	18	0.333	65	5.99	128	8.12	600	24	576
A	Dhudhiya Dham (A5)	29 27 47.02	78 10 49.09	Green	27.00	18	0.200	45	5.82	140	8.02	200	23	177
	Har ki Pauri													
B	opposite to bekunth ashram(B1)	29 57 49.06	78 10 27.04	green	30.05	20	0.101	42	5.74	84	8.2	1000	84	916
B	opposite to jairam ashram(B2)	29 57 54.05	78 10 29.04	blue	34.00	20	0.206	43	4.99	132	8.29	1600	76	1524
B	Har ki pauri near shiv statue(B3)	29 57 41.08	78 10 25.07	green	31.00	20	0.146	30	5.40	156	8.4	600	89	511
B	Har ki pauri near Clock Tower(B4)	29 57 35.07	78 10 21.06	green	32.00	19.5	0.105	53	4.57	116	8.36	1000	69	931
B	Har ki pauri(B5)	29 57 32.00	78 10 23.01	green	32.00	20	0.636	42	6.74	168	7.98	600	82	518
	Chandi Ghat.													
C	chandi ghat near flyover(C1)	29 56 32.04	78 09 59.07	green	31.00	18.5	0.320	53	5.32	136	8.51	1000	99	901
C	singh dwara(C2)	29 56 18.21	78 09 43.58	green	29.50	17.5	0.627	42	6.50	92	8.19	1000	92	908
C	Prem Nagar Ashram(C3)	29 56 04.09	78 09 45.13	green	29.50	18.6	0.509	54	5.40	88	7.82	400	38	362
C	Chandi Ghat (C4)	29 55 40.68	78 09 49.66	green	30.00	18	0.672	53	5.40	176	7.96	800	50	750
C	Chandi Ghat (C5)	29 56 13.00	78 08 54.03	green	31.00	19.5	0.732	52	5.85	124	8.05	600	54	566
	Lalji wala(Rori Belwala)													
D	ALKNANDA GHAT(D1)	29 56 47.00	78 09 44.01	green	31.00	19	0.712	48	5.40	96	8.2	600	45	555
D	OPPOSITE TO RAM DHAM(D2)	29 56 38.00	78 09 34.02	green	27.00	18	0.583	50	5.82	52	8.37	800	48	752
D	OPPOSITE TO HANUMAN MANDIR(I	29 56 53.01	78 09 49.06	green	30.00	19	0.560	53	4.47	136	8.21	1000	110	890
D	NEAR SATABDI SETU(D4)	29 57 03.08	78 10 02.06	green	31.00	18	0.396	48	4.16	136	8.18	800	58	742
D	B/T BATABDHI SETUA ND SHIV SETU	29 57 15.00	78 10 09.07	green	31.00	18	0.567	56	5.99	96	8.36	1000	68	932
	Kankhal Area													
E	GURUKUL KANGRI UNIVERSITY(E1)	29 54 48.40	78 09 38.21	green	31.00	18.5	0.739	52	5.32	176	8.62	800	58	742
E	JWALAPUR BASTI(E2)	29 54 36.36	78 04 38.35	green	30.50	19.5	0.681	54	4.57	184	8.19	1000	83	917
E	JATWARA BRIDGE(E3)	29 54 28.97	78 08 58.18	green	30.50	19	0.690	43	5.74	146	8.51	1600	98	1302
E	JWALAPUR POWER COOPERATION (	29 55 23.15	78 08 58.62	green	28.90	18	0.708	40	4.40	163	8.52	1400	116	1484
E	AAVDOOT MANDAL GHAT(E5)	29 54 12.75	78 08 41.06	ST	27.00	18.5	0.676	52	4.57	108	7.78	1200	102	1098

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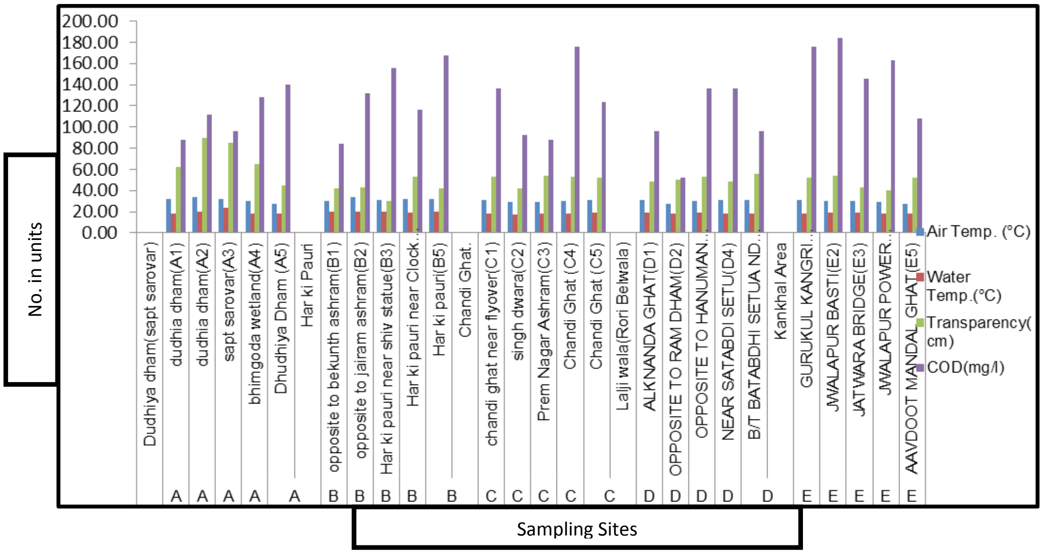


Figure 26.2: Showing the status of Water Quality parameter (Air and Water Temperature, Water Transparency and Chemical oxygen Demand) of the Ganga river at Haridwar, Uttarakhand. Chemical Oxygen Demand (COD)

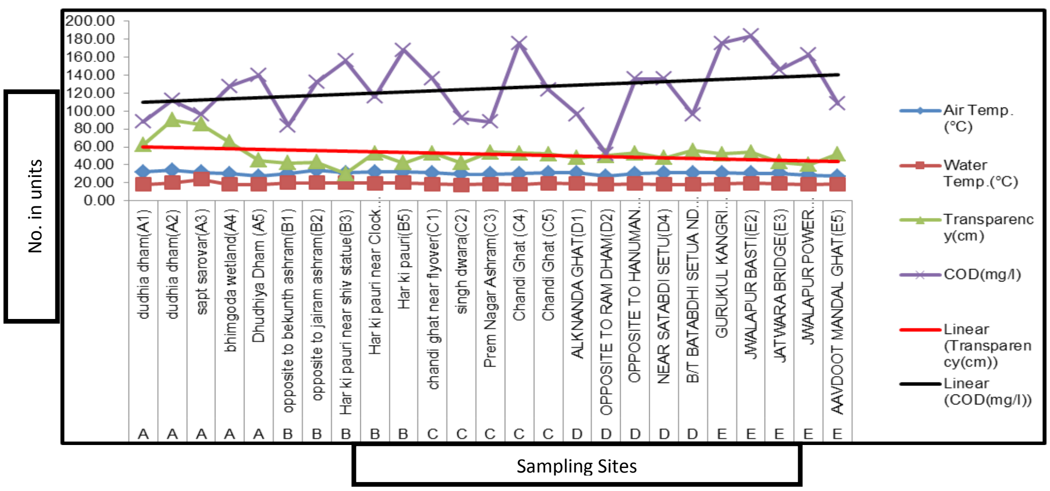
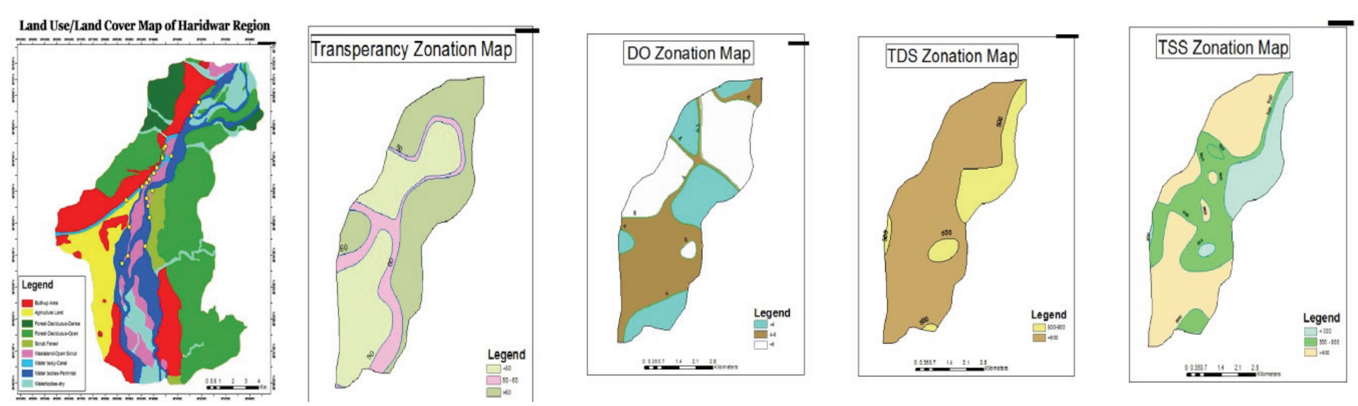


Figure 26.3: Showing the Trend of Transparency and Chemical Oxygen Demand(COD) of the Ganga River at Haridwar, Uttarakhand

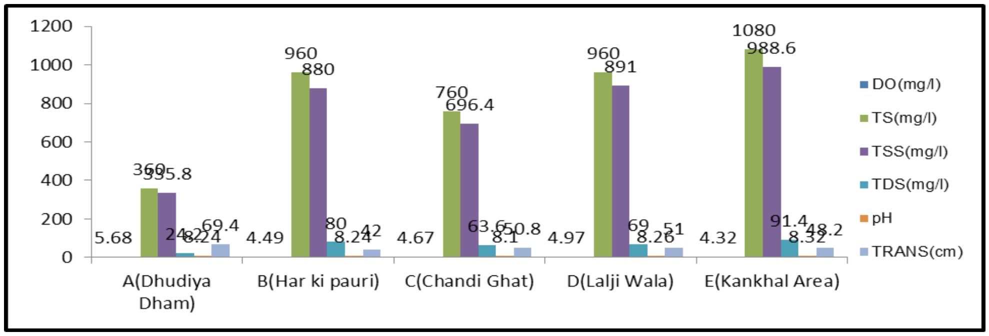
Figure 26.4: GIS based Map for different parameters

GIS based map:



a) Land Use map b)Transparency(cm) c) DO(mg/l) d)TDS(mg/l) e) TSS(mg/l)

Figure 26.5: Overall Value Water Quality Parameter at different sampling sites of the Ganga River at Haridwar, Uttarakhand



been observed that the water of the river cannot be used directly for drinking purpose. Total solids zonation map were created and categorized on 500-900 mg/l and > 900 mg/l. The amount of total solids increases as we move from sampling station A (Dhudiya Dam) to sampling station E (Kankhal Area) to about 1,000 mg/l. The total suspended solids was categorized in three categories <300 mg/l, 300-900 and > 900 mg/l. Total dissolved solids categorized in three categories <50 mg/l, 50-100 mg/l and > 500 mg/l and it increases as we move from Dudhiya Dham (sampling station A) to Kankhal area (sampling station E).

26.3.1 Current status of water quality at Haridwar

The average value of the water quality shows that the water get polluted at Haridwar. The value of Dissolved Oxygen, when river enters into the city it is around 6.8 mg/l when it leaves the city it value decreases up to 4mg/l at the Khankhal area. That clearly shows that the water starts deteriorating not only for the human use but is also a great threat to biodiversity of the river. During the period of investigation, four samples out of 25 samples showed DO below bathing level (5mg/l). Presence of DO in water may be due to direct diffusion from air and photosynthetic activity of autotrophy.

Not only the dissolved oxygen but transparency of the river water also decreases as we move from sampling station A (Dudhiya Dham) to sampling station E (Kankhal Area). It has been seen during of the time of field visit, that this is due to the huge amount of sewage directly entering into the river without any treatment at Khankhal Area. The value of total solids (TS) and total dissolved solids (TDS) also showed highest value (1080 mg/l and 91 mg/l) at Khankal area and lowest (360 mg/l and 25.4 mg/l) at Dudhiya Dham.

Table 26.2: Comparative Data of Water Quality Parameters of the Ganga River at Haridwar of March 2011 and March 1986

Samp. stations	A		B		C		D		E	
Parameters	2011	1986	2011	1986	2011	1986	2011	1986	2011	1986
DO(mg/l)	5.68	10.29	4.49	10.5	4.67	9.79	4.97	7.99	4.32	NA
pH	8.24	7.78	8.24	7.94	8.1	7.96	8.26	7.96	8.32	NA
Transparency(cm)	69.4	158	42	120.5	50.8	80	51	180.2	48.2	NA
TS(mg/l)	360	170	960	181	760	164	960	152	1080	NA
TSS(mg/l)	335.8	162.5	880	179	696.4	155	891	150	988.6	NA
TDS(mg/l)	24.2	7.5	80	2	63.6	9	69	2	91.4	NA

Figure 26.6: Comparison of DO (mg/l) of March1986 and March 2011

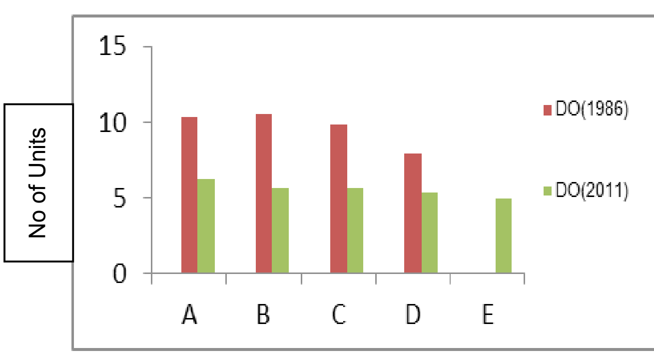
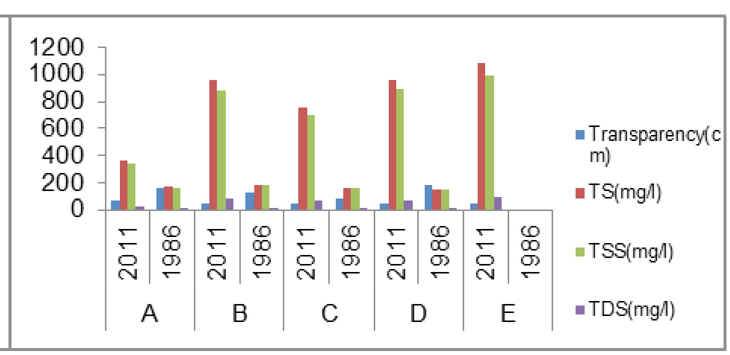


Figure 26.7: Comparison of water parameters of March 1986 and March 2011



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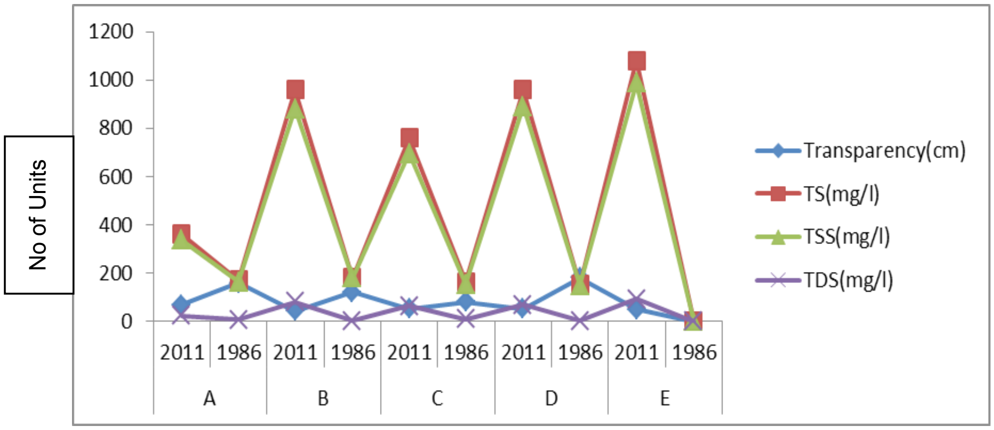

Figure 26.8: Comparison of water quality parameters of March 1986 and March 2011

26.3.2 Comparative study

The comparative study of water quality parameter during March 2011 and March 1986, shows there is drastic deterioration in the water quality. The dissolved oxygen was around 12 mg/l of oxygen in 1986. But today however, oxygen content has reduced to 4-8 mg/l. This is despite the fact that the Ganga Action Plan has already started and there are number of other initiatives taken by state (Sparsh Ganga Programme) and the Centre (National Ganga River Basin Authority), besides civil society and NGOs.

26.4 RECOMMENDATION (MANAGEMENT PLAN)

The proposed management plan includes *legal* (pay polluter principle, complete ban on use of the plastic bags, their replacement with a natural alternative, rehabilitation and resettlement of illegal encroachment along the banks of the river), *social* (stakeholders participation and partnership-development of Uttarakhand River Basin Council-URBC, Education and Awareness). The *scientific* component includes provisions like efficient STP (sewage treatment plant), phyto-remediation, River Bank Regulation System (RBRS), Ganga River Information Centre (biodiversity, ecology & environment and hydrology) and the Water Quality Assessment Model (AVSWAT, QUAL2E).

ACKNOWLEDGEMENTS

The authors are thankful to Uttarakhand Space Application Centre (U-SAC), Vasant Vihar, Dehradun, Uttarakhand, for providing technical and logistic support. The authors are also thankful to Forest Research Institute for providing laboratory support for analysis and FRI (Deemed) University for the other support.

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