Introduction

Background

Everything that exists on earth is sustained by water. Fresh water habitat occupies relatively a small proportion of the earth's surface as compared to marine and terrestrial habitat, but it’s importance to man is far greater than it’s area (Odum 1996). Freshwater is precious, as well as a finite natural resource to man’s varied activities. Like other aquatic ecosystem, streams and rivers are specialized habitats of plants and animals. Aquatic ecosystems are particularly highly susceptible to change induced by anthropogenic activities.

Rivers play an important role in everyday life of human beings. Rivers are common property of social and ecological value and flow in its own right crossing the natural barriers as well as political jurisdiction. Thus a river is a responsibility of the country and people.

Rivers and groundwaters are major sources of drinking water in Nepal. Over time, the country’s requirements of water for drinking and personal hygiene, agriculture, religious activities, industrial production, and hydropower generations have increased. Major towns and cities in the Hills have acute problems of water availability. In the Kathmandu Valley, water supply meets only 79% of the total urban demand of 145 million liters/ day during the rainy season (Sharma 1978). The carpet industries alone consume about 6.1 million liters of water per day and generate 5.5 million liters of waste water daily (Miyoshi 1987).

With time, water requirements have increased for drinking and personal hygiene, religious activities, fisheries, agriculture, such as irrigation and livestock supply, industrial production, hydropower generation, and recreational activities such as bathing, rafting and fishing, and so on. The extent of human activities that affect the freshwater has increased radically during the past few decades. The degree of socio-economic activities, urbanization, industrial operations and agricultural production has a widespread impact on water resources. As a consequence, very multifarious inter-relationships versus socio-economic factors and natural hydrology have developed. For instance, gross organic pollution leads to disturbance of oxygen balance, which is often accompanied by severe pathogenic contamination resulted from enrichment with nutrients of various origins, particularly domestic sewage, agricultural run-off and agro-industrial effluents. With applications of increasing amounts of agrochemical, agricultural land use has caused widespread deterioration of surface aquatic ecosystem resulting the extinction of various aquatic fauna (Sharma 1996, 1998).

Water quality assessment has always been an issue of debate at scientific, conservation policy level and socio-economic level. However, precise information on water quality in aspect such as physical, biological, chemical and bacteriological is very limited. Therefore, a comprehensive assessment of water quality would give an indispensable findings applicable not only to deal with the consequences of present and future threats of contamination but also, raise awareness among the people and provide a basis for future action at all levels.

Waste disposal mixing directly into the river can have an adverse impact on the flora and fauna of aquatic areas such as streams, ponds, and lakes. Biodiversity is measured in terms of the abundance and type of fauna, but both have declined sharply in the polluted sections of the Bagmati River and its tributaries (Pradhan 1998). Besides, rivers are considered sacred by Nepali people and have religious and cultural values. Misuses and overexploitations of water resources in some urban centre and industrial areas are causing problem of river water pollution. Activities such as disposal of untreated municipal sewages and industrial effluents, dumping of solid waste and sand mining are major human activities that have affected aesthetic value of rivers. However, extent and magnitude of depletion of water resources has not been determined yet. Water pollution is a serious public health issue in Nepal. There is a vital connection between water and health. Water is very important for all living beings, and is consumed by all and as such, it is essential that all should get pure and clean drinking water (Sharma 2000). The rivers are the main places for disposal of urban solid waste, domestic effluents, and industrial effluents, which are responsible for polluting the water and causing waterborne diseases. Yet, government policy has given little emphasis on this issue (UNICEF 1987). Besides, this study will also help to recognize the worst segments of the river and undertake necessary actions to stop further deterioration of the rivers.

Objectives

The main objective of this study was to investigate the water quality of the Hanumante River and develop a baseline data, which are given as follows:

examine the physico-chemical parameters of the river
examine the biological water quality based on benthic macro invertebrates, and
establish a relationship between physico-chemical and biological parameters

1.3 Research Hypothesis

Pollution level is increasing in downstream.
Increase in pollution leads to chemical and biological deterioration of water quality.

1.4 Rationale

The Hanumante river has not been explored ecologically much as compared to other tributaries of Bagmati it is regarded as the most holy as well as septic (mixing of drainage directly) river of Bhaktapur district. It is one of the important sources of water for domestic and agricultural purposes. For the last few decades, the water quality of the Hanumante river has been degrading drastically due to untreated sewage and industrial effluents mixing into it. Increase in pollution, heavy encroachment, decrease in species diversity and degrading water quality are major problems of this river. Banks of the river has been highly encroached due to uncontrolled urban population. It has become a major dumping location of domestic sewages, agricultural drainage, urban solid waste disposal and industrial effluents. These activities are deteriorating the river water quality and disturbing the aquatic ecosystem. Hanumante an important tributary of Bagmati river from Bhaktapur district, has not received any attention to save this river yet.

Therefore, the scientific study of water quality is necessary to determine the condition of water in different points and different time. This provides the information about the present condition of river and a change in trend in quality of river to concerned authorities. This study might help to suggest the correction measures that is causing the pollution of Hanumante river.

Literature Review

Biological Indicator of Pollution in River Bagmati

It is an well established fact that, certain species can be used to indicate certain type of environmental conditions. As some of the environmental requirements are essential for many species, their presence indicate something about the nature of the environment in which they are found. Thus, the concept of the presence of species to indicate certain condition is a practical approach and easily verifiable. It requires therefore a thorough investigation of most of the significant species under investigation. Supplementing this with physical and chemical analysis will provide comprehensive status to river water quality.

Shrestha (1980), investigated the biological indicators of pollution in Bagmati river. Bottino et al. (1990), carried out chemical and biological analysis of Bagmati river and its tributaries (with special references to pollution).

Cairns and Pratt (1993) studied the biological indicators in Bagmati river. The study reveals that diatoms and invertebrates can be considered as complimentary indicators Among them Trichoptera, Hydrachnida, Ephemeroptera and Diptera show a high affinities for most running water types. Plecoptera and Oligochaeta appear as useful indicators for some particular type of rivers (Rundle and Jetkins 1993). This trend is likely to be the consequence of multiple anthropogenic pressures. The study further suggests that the Trichoptera, Hydrachnida, Diptera, Ephemeroptera and Oligochaeta could be considered as best candidate groups for tiered-taxonomic resolution approach, where only taxa, which have narrow and specific ecological requirements, would be identified to finer levels (Macan 1974).

Benthic Invertebrates

According to Cairns and Pratt (1993), community-based studies of macro-invertebrates form the basis of most biological studies of water quality chiefly for three reasons: firstly, macro invertebrate community are easy to collect and identify; second, they are fish food and therefore explainable to the general public; and lastly, their analysis allows inferences to be drawn about the food base (algae, leaves etc), habitat quality and relative health of community.

Biological Water Quality of Bagmati river

Pradhan (1999), investigated the biological and physio-chemical parameters and studied its effect on the distribution of benthic macro invertebrates of tributaries of Bagmati. Using saprobic measures, water quality of Bagmati and its main tributaries was analyzed. Altogether 71 families, 136 genera and 157 species of macro zoobenthos along the Bagmati river were identified. Two new species *Aphelocheirus nepalensis* and *Aphelocheirus pradhanae* from family Aphelocheiridae had been identified. The number of family was found to be decreasing from upper Bagmati to the successive poorer quality water. For instance, the animals belonged to groups like Ephemeoptera, Plecoptera and Trichoptera were sensitive to poor water quality. Diptera group had shown a wide range of tolerance to water quality. From the bacteriological analysis, heterotrophic count showed *Escheria coli* feacal streptococcuss were most prevalent.

Regarding the chemical analysis, DO was highest in upper Bagmati and lowest in lower plains (settlement areas). In contrast, DO and BOD 5 was low in upper regions and gradually increased in lower areas indicating increasing organic pollution.

2.6 Relation of Macro Invertebrate with Nitrogen

Ingram et al. (1966) investigated that the mean value of individual taxa of lower consumer (Bivalve snail and caddisfly) tended to increase with increasing Human Population Density. It also suggested that human activities potentially induce changes in the N baseline of river food webs.Taxonomic composition of macro invertebrates community according to its stream gradient was deliberately studied by Turner et al. (2008). The study revealed that stream could be categorized into four different types according to gradients. Two of them were relatively pristine degree of benthic assemblages assesed by comparative longitudinal pattern between north flowing and south flowing. Both univariate and multivariate analyses indicate significant changes in macro invertebrate community functions with smaller closeness in taxonomic composition.

Relation between physical and biological parameters

Pradhan (2002), investigated pH, total dissolved solids, electronic conductivity, chlorine and flourides which showed high correlation with zooplanktons. It showed that the total dissolved solid wss directly related to hardness which affects aquatic biota.

Various studies (Yadav 1995, Shakya 2000) have analyzed the variance of aquatic biomass, DO, pH, total hardness, ammonia, nitrates, phosphates and benthic macro invertebrates in different habitat of pond and stream. It shows that benthic fauna was found to be higher in pond than in freshwater.

Pradhan and ICIMOD (2006), investigated the water quality of Bagmati . Her study shows diversity and abundance of benthic macro invertebrates representing the specific characteristic features of the river sites. The pristine or unpolluted river was generally characterized by certain types and abundance of aquatic organisms based on climate and stream hydrological features. While on the other hand, pollution occurred as a consequence of use of river water by human interferences for different purposes, which causes changes in both diversity and abundance of aquatic organisms. Generally, as the diversity of animal decreases sensitive organisms are replaced by pollution tolerant animals, and as their abundance increases the intensity of organic pollution increases (Nemerow 1974). The presence or dominance, or absence of certain species can be an indicator of certain water quality condition (Welch 1992).

Altogether 71 families, 136 genera and 157 species of macro zoobenthos along the Bagmati river had been identified. The number of families had decreased according to the decreasing quality of water classes. The animals belonging to the groups like Ephemeroptera, Plecoptera and Trichoptera were sensitive to poor water quality. Diptera group had a wide range of tolerance of water quality.

The tolerance level of benthic invertebrates was associated with chemical components, since each benthic macro invertebrate had particular requirements with respect to chemical condition of its habitat. Changes in chemical condition might result in reduction in species number, change in species dominance or total loss of sensitive species by death or migration. To exemplify, only a few taxa showed their different tolerance levels to the chemical parameters, The families of Plecoptera group was found in high oxygen saturation level, where as the families of groups

Ephemeroptera and Trichoptera have shown comparatively wider range. Some of the species of the family having a wider range of tolerance, and not being sensitive to the concentration of dissolved oxygen, such as Baetidae and Hydropsychidae, as in families Ephemeroptera and Trichoptera respectively. The Oligochaeta group showed high tolerance level to low oxygen saturation ranging from five to ninety percent.

3. Research Methods

3.1 Study Site

3.1.1 Bhaktapur District

Bhaktapur district is located in eastern part of the Kathmandu valley at the latitude of 27.66° and Longitude 85.41° E with elevation of 1330 meter from sea level. This small district is endowed with temperate climate zone. Average rainfall is 3220mm annually which is brought by south-east monsoon of June to September. But winter season is facilitated by occasional orographic rainfall. This district is most densely populated accommodating more than eight million people.

3.1.2 Climatic Condition of Bhaktapur

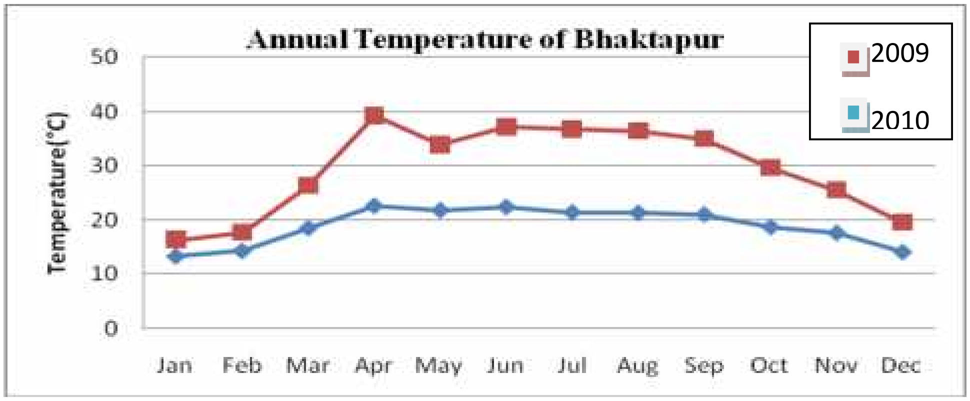


Figure 3.1 Annual temperature of Bhaktapur

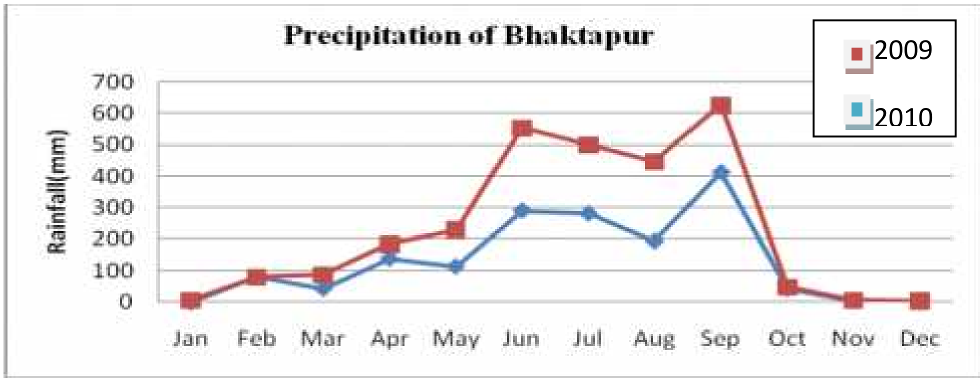


Figure 3.2 Annual precipitation of Bhaktapur

3.1.3 Hanumante River

Hanumante river is a holi river of Bhaktapur district. It originates from north-east slope of Nagarkot hill at an elevation of 1335 meters above sea level and drains into the Bagmati River as it's tributary and finally merges into the Ganges of India. It's total length is 6.7 km. This river can be divided into two major regions, i.e. Headwater and Valley segment. Hanumante River is very important from religious and social point of views. Hanumante river is accompanied by many other tributaries, such as Chakkhu khola, Tyabakhushi khola, Kalka khola, Ghatte khola, Khasyangkhusung khola, Gakhu khola and Charkandi Khola. Hanumante river is being used as drinking water source as well as irrigation and sewage dumping by Bhaktapur district. Besides, it is accounted to be the most polluted river as, it is misused for disposing effluents and dumping of solid waste, particularly in Bhaktapur district. Rocks, sand and gravel are extracted from every accessible river section. Though removing sand and gravel from river bed is considered an illegal activity by the Government of Nepal, at local level, it is still being practised regularly. No regular monitoring or surveillance has been done so far, on the impact brought about to the aquatic environment by such activities.

3.2 Research Design and Instrumentation

On the basis of information acquired from the preliminary survey, altogether seven study sites were selected along with the Hanumante river in different distance. Selection of sites was based on criterion such as nature of substratum, landscape and other polluting agents.

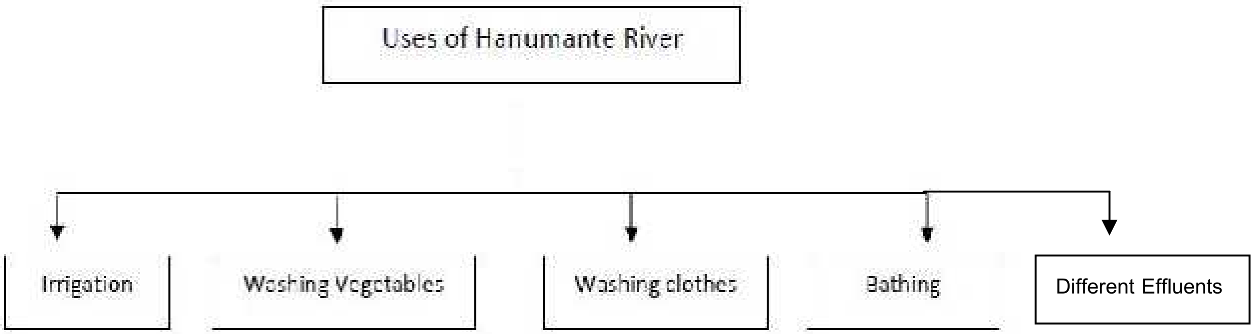
3.2.1 Study Sites:

Table 3.1 Description of Sites with Brief Physical Features

Sampling	Station	G.P.S	Elevation (m)	Substratum	Effluents
Station I	Hanumanghat	27040'11" 85026'15"	1312	B,P,Sd,St	Tw, Se.
Station II	Sallaghari	27040'25" 85024'33"	1308	C,P,Sd.St	Do,Sw, I
Station III	Thimi	27040'16" 85023'9"	1298	C,G.Sd,St	Ag,In,Sw
Station IV	Gatthaghar	27039'52" 85021'48"	1291	C,P,Sd,St	Ag,Sw,Se
Station V	Kaushaltar	27040'9" 85023'56"	1284	G,P,Sd,St	Se,Sw
Station VI	Balkot	27040'12" 85024'44448"	1278	G,P,Sd,St	Se,Sw
Station VII	Narephat	27040'3" 85021'9"	1265	C,Sd,St	Ag,Se

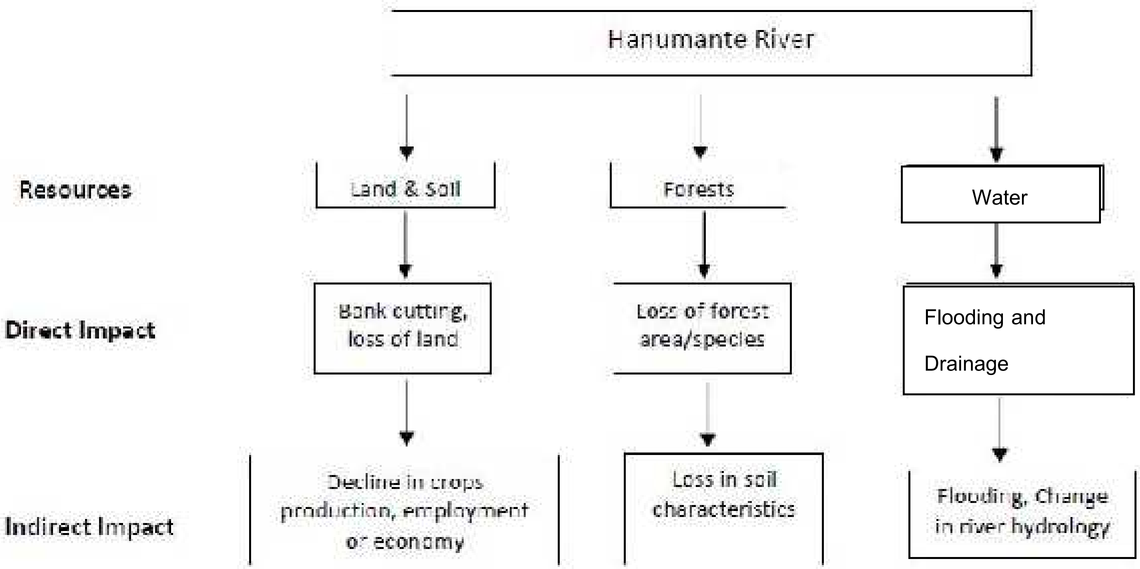
Note:B=Boulders, C=Coblers, G=Gravel, P=pebbles, Sd=Sand, St=SiltTw=Temple waste, Se=Sewage, Do=Domestic waste, In=Industrial waste,Ag=Agricultural waste, Sw=Solid waste

SCHEMATIC REPRESENTATION OF USE AND IMPACTS AT HANUMANTE RIVER



Utilization of Hanumante river for different purposes

Utilization of Hanumante river for different purposes



Schematic diagram on possible impacts of Hanumante river on the environment

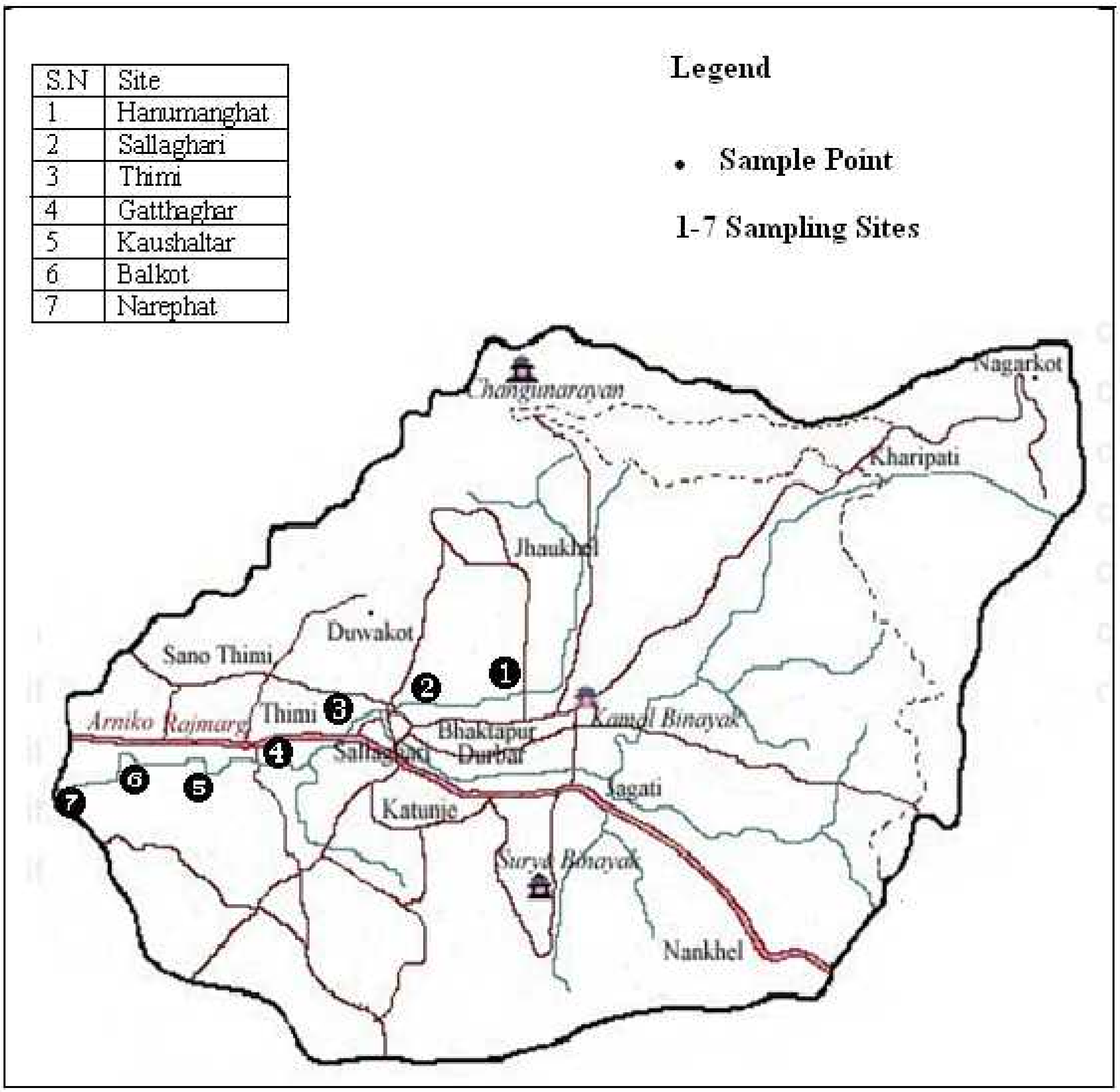


Figure 3.3 Sampling Sites along the Hanumante river

The selection of sample site was done in two different seasons. Pre-monsoon (February-May) and Post-monsoon (October-January) periods were considered for field data collection. Collection of benthic macro invertebrates was not possible during monsoon season due to heavy flow of current in the river.

3.3 Methods and Materials

3.3.1 Physico- Chemical Parameters of Water

S.N	Parameters	Materials/Method	Description of Method
1	Temperature	Hydrolab Instrument	3.3.1
2	Total Dissolved Solids	Hydrolab Instrument	3.3.1
3	Conductivity	Hydrolab Instrument	3.3.1
4	pH	Hydrolab Instrument	3.3.1
5	DO	Winkler's Method	3.3.2
6	Free CO_2	Titration method from Trivedi and Goel	3.3.3
7	BOD	APHA	3.3.4
8	Nitrate	Titration method from Trivedi and Goel	3.3.5
9	Phosphate	Titration method from Trivedi and Goel	3.3.6

3.3.1 Physical Parameters

The temperature of water in each sampling site was recorded with the help of Hydrolab instrument, a multi-probe with automatic data logging system. Water was taken in small cubet and kept in instrument, and data was recorded in Celsius degree (^{0}C).

Likewise, with the help of Hydrolab instrument , a multi-probe with automatic data logging system pH, Specific Conductivity (µs/cm) and Total dissolved solids (mg/lit) of water in each sampling site was recorded in triplet for better accuracy usually at a time before noon (12 o' clock).

3.3.2 Dissolved Oxygen

For the measurement of dissolved Oxygen, Winkler's Method was used in the laboratory. BOD bottle of 250 ml was filled with sample water upto its neck without any bubbles. Two ml of manganous sulphate ($MnSO_4$) and two ml of alkaline (KI) were added wih separate pipette .The stopper was then slightly fixed avoiding air bubbles and kept standstill for some moment until precipitation settled down. Afterwards, two ml of concentrated sulphuric acid (H_2SO_4) was added followed by shaking it until brown colour of precipitate ion disappeared completely. Then, hundred ml of BOD sample water was taken in a conical flask and titrated against Sodium thiosulphate ($Na_2S_2O_3$, 0.025N) using starch indicator. Then the consumed volume of Sodium thiosuphate was recorded from the end point. This value was converted into mg/lit by using the following equation.

$$DO(mg/lit) = \frac{(\mathrm{ml} \times \mathrm{N})\ \mathrm{of\ titrant} \times 8 \times 1000)}{\frac{V2(V1 - V)}{V1}}$$

Where, V=Volume of manganous sulphate + Potassium iodide

V1= Volume of sample bottle after placing the stopper

V2= Volume of part of content titrated

N= Normality of titrant

3.3.3 Free Carbondioxide

Hundred ml of sample water was taken in conical flask and kept in a cool place. Few drops of phenolphthalein indicators were added. If the sample remained colorless it indicated the presence of free carbondioxide. Then it was immediately titrated against Sodium Hydroxide (NaOH 0.05N) solution, stirring with a glass rod until pink colour appeared (for about one minute). The volume of Sodium hydroxide (NaOH) was consumed in getting the endpoint. This value was converted into mg/lit by using the following equation.

$$FreeCO2(mg/lit) = \frac{(\text{ml} \times \text{N}) \text{ of titrant(NaOH)} \times 1000 \times 44}{\text{Volume of sample consumed}}$$

Where, N= Normality of titrant

44= molecular weight of CO_2

3.3.4 Biological Oxygen Demand

Dissolved oxygen of water sample in situ with DO meter was recorded and incubated for five days at temperature of 40^0c. With the reference of APHA (1995) dilution was made from ranges of 25-100 % for polluted water. BOD was calculated using following formula:

$$BOD = \frac{D1 - D2}{P}$$

D1=DO of diluted sample before incubation

D2=DO of diluted sample after incubation

P =decimal volumetric fraction of sample used

3.3.5 Nitrate

Standard Nitrate solution was prepared by dissolving potassium nitrate (KNO_3) into distilled water in a standard amount. Standard calibration curve containing concentration and absorbance was prepared using the standard solution (Mackereth et al. 1978). Then the concentration of nirate in the water sample was measured by Phenol disulphonic method. Fifty ml of sample water was taken in conical flask and an equivalent amount of silver sulphate was added to it to remove chloride. The solution was heated slightly to filter the precipitate of AgCl. Then the filtrate was taken in a porcelain basin and evaporated to dryness on a steam bath. The residue was cooled, dissolved in 2ml Phenol disulphonic acid and the content was diluted to 50 ml with double distilled water. To this content, 6 ml of liquid ammonia was added to develop it into a yellow colour. A reagent blank was also made by adding phenol disulphonic acid and double distilled water and the volume was made to 50 ml. The absorbance of the sample and reagent blank was measured at 410nm by a spectrophotometer within 3 minutes of colour development. The concentration of nirate in the sample was determined by calibration in a graph of standard curve (Trivedi and Goel 1982).

3.3.6 Orthophosphate

Standard Phosphate solution was prepared by following Mackereth et.al. (1978) procedure. Stannous Cholride method was used to determine the concentration of Orthophosphate. Fifty ml of the filtered water sample was taken in a conical flask and few drops of phenolphthalein indicator were added. As soon as color appeared it was neutralized by dropwise addition of a strong acid solution. Two ml of Ammonium molybdate was added to the sample followed by five drops of Stannous Chloride solution. The sample was shaken well and kept in rest for five minutes until it developed into blue color. This was measured by the spectrophotometer at 690 nm against distilled water with same amount of calibration curve.

3.3.7 Benthic Macro invertebrate Data

Benthic macro invertebrates are the organisms attached or resting on the bottom or living in the bottom sediments of rivers, streams and lakes. They occupy consumer level of aquatic ecosystem.

Table 3.2 Commom Groups of Benthic Macro Invertebrates

Class	**Order**	**Class**	**Order**
Insecta	Ephemeroptera	**Crustacea**	Isopoda
	Plecoptera		Amphipoda
	Trichoptera		Decapoda
	Diptera	**Mollusca**	Bivalvia
	Odonata		Gastropoda
	Heteroptera	**Annelida**	Tricladida
	Coleoptera		Hirudinaria
	Megaloptera		Oligochaeta

3.4 Sample Collection and field study

This study was inspired by Pradhan's PhD dissertation, "Water Quality Assessment of the Bagmati River and Its Tributaries, Kathmandu Valley, Nepal" (Pradhan 1998). The following methods and tools were used for data collection in the field.

First, reconnaissance survey accompanied with colour toposheet maps (1:25,000) was carried out to acquaint with the study area and to determine the sample sites along the river. Three important factors such as terrain features, drainage system and locational attributes were taken into consideration for the selection of sample sites for water quality assessment. Altogether 7 sample sites along the Hanumante river were determined and located on toposheet.

Second, the structured preliminary field survey sheet containing components like general information, substrate composition, physical components, land use and type of influence, river's physical parameters and aquatic vegetation was used to gather information of each sample site.

Third, during the protocol survey, qualitative sampling of benthic invertebrates was collected from each sample site insitu within 1 kilometers along the river where all micro-habitats were taken into consideration. The samples of benthic invertebrates were identified at the laboratory at possible levels of genus or species with the help of existing keys. Water samples were collected from each sample point for chemical analysis.

For the qualitative data collection of the benthic macroinvertebrates following measures were used:

Micro-habitat of each sample area was considered in each sample site.

Net sampler of mesh size 100µm was used to collect macrofauna at muddy substratum. Other type of habitats such as under cobbler, rocks and woody debris were carefully observed and macro invertebrates were collected

Collected animals were sealed in small viles with 70% ethanol and sealed with cotton. Each vile was labeled with site number.

In the laboratory, identification and classification of those animals were instituted with the help of simple microscope.

On the basis of Extended Biotic Index water quality class of each sampling site was classified. Abundance of animal and biotic score were calculated.

Following Parameters of Benthic Macro Invertebrates were analysed

Abundance

Abundance is analytical character which expresses species of community quantitatively as well as qualitatively (Number and orders of species). Range of abundance also indicates the suitability of ecosystem for any species. Different species show their different limit of tolerance which highly affect their existence in that particular environment. As recommended by Schwerdtfeger (1975) abundance of fauna at different sampling site was estimated from 1 to 5 scales. Rank 1 was given for rare and rank 5 for frequent one. The value obtained from BI has been compared with the weight assigned to each SWQC and determined the water quality class of the sites. (Annex 7)

Equation for Biotic Index (Pradhan 1998)

$$BI = \sum_{i=1}^{n} \frac{Wi \times hi}{H}$$

Where, BI =Biotic Index

Wi=Score of ith taxon

hi=Number of ith taxon

H=Total number of taxa

n=Number

i=Position

3.5 Field Measurement, Water Sampling and Analytical Procedures

Hydrolab instrument was used for insitu measurements of some basic water quality parameters. Parameters measured using Hydrolab were Water temperature, Specific Conductivity (SPC), Total Dissolved Solids (TDS), pH, Dissolved Oxygen, BOD, nitrate and phosphates were also measured at laboratory.

For the parameters to be analyzed in the laboratory, water samples were collected by net sampling method and were preserved as per instruction in Standard Method (APHA 1995). In laboratory the parameters were analyzed through standard laboratory procedures (APHA 1995).

The parameters analyzed in the laboratory for Hanumante was Biological Oxygen Demand (BOD), Nitrates and Phosphates.

To analyze the extent of pollution, the parameters BOD and phosphates were compared with the risk threshold level (RTL) as provided by (APHA 1995) .The risk threshold level of BOD and phosphate were 10ppm and 0.25 ppm respectively.

Table 3.3 Water quality criteria and standards proposed for Bagmati river and its tributaries

Parameter	Drinking	Aquatic life	Bathing	Agriculture
PH	6.5-9.2	6.5-8.5	6.5-9.0	6.5-9.0
TDS(mg/l)	1500	1000	1500	500-3000
SS(mg/l)	-	25	50	-
DO (mg/l)	-	6	3	3
NO^{-3}(mg/l)	-	20	20	25
Total PO^{4}(mg/l)	0.1	0.1	0.2	0.2
BOD(mg/l)	4	4	6	10

Source: Pradhan 1998

4. Results

4.1 Physical Analysis

One of the features of river waters is that its chemical parameters are changing over time. So, if the parameters are regularly monitored for a certain period of time, the real tolerance range of particular taxa of benthos to particular chemical can be determined. Domestic effluents started right from the Hanumanghat. Being the temple area and place for funeral this site got maximum waste from temple and residential areas. While in the downstream river almost all sites received maximum effluents from industries, sewerages, solid wastes and agricultural effluents (Table 3.1).

4.2 Physico-Chemical Factor

Comparison of the water quality in pre and post monsoon by different physico-chemical and biological parameters showed that upstream was less polluted and following sites were gradually more polluted due to additions of different effluents. Trend of deterioration was not constant as there was found to be monthly variation in parameters. Physico-chemical parameters such as total dissolved solids, conductivity, pH, free CO_2, BOD, nitrate and phosphate increased gradually in downstream.

Table 4.1 Physico-Chemical Parameters of Hanumante river in Pre-monsoon

Sites	Temp(0c)	TDS (mg/lit)	Conductivity (µS/cm)	pH	DO (mg/l)	BOD	Free CO_2	Nitrate (mg/l)	Phosphate (mg/l)
Hanumanghat	17	0.345	0.35	7.61	6.4	16.83	8.955	8.0	7.1
Sallaghari	17	0.405	0.46	7.38	3.12	21.36	10.13	9.4	12.1
Thimi	18	0.62	0.75	7.63	5.52	27.54	10.92	10.7	14.6
Gatthaghar	19.5	0.355	0.31	7.48	4.39	42.23	11.725	12.4	15.2
Kaushaltar	19.5	0.525	0.56	7.54	4.02	50.24	14.28	12.8	15.9
Balkot	21.5	0.63	0.61	7.66	3.77	57.2	13.72	15.3	16.1
Narephat	21.5	0.7	0.84	7.855	3.7	69.41	15.86	16.7	16.8

Source: Field Survey 2009

Table 4.2 Physico-Chemical Parameters of Hanumante River in Post-monsoon

Sites	Temp (0c)	TDS (mg/lit)	Conduct (µS/cm)	pH	Free CO2	DO (mg/lit)	BOD	Nitrate (mg/lit)	Phosphate (mg/lit)
Hanumanghat	19	0.07	0.055	5.26	6.65	6.56	10.12	6.4	5.3
Sallaghari	18.5	0.155	0.23	6.13	8.02	6.36	16.43	7.7	8.7
Thimi	19	0.23	0.17	5.82	8.3	6.24	24.2	9.3	11.7
Gatthaghar	19.5	0.2	0.305	5.6	10.67	5.06	34.87	11.5	12.3
Kaushaltar	21	0.205	0.15	6.03	12.955	5.76	45.155	12.7	14.8
Balkot	20	0.29	0.355	6.14	14.22	5.76	55.17	14.5	16.0
Narephat	19.5	0.365	0.39	6.305	15.105	5.63	64.41	14.9	16.6

Source: Field Survey 2009

The average temperature was 18 ^{0}c and ranged from 17^{0}c to 21^{0}c with ±1.1 from headwater to downstream. Temperature of water shows less variation in pre-monsoon than in post-monsoon with standard deviation of ±3.5 (Table 4.1).

Mean TDS was 0.543 mg/lit and fluctuation ranged from 0.34mg/lit to 0.7 mg/lit. Total dissolved solid was gradually increased from upstream to downstream and correlation coefficient between elevation and TDS was -0.631. 500mg of TDS was preferable for 1 liter of water. TDS and Conductivity was relatively proportional with each other. Mean Conductivity was 0.592 µs/cm but fluctuation ranged from 0.35µs/cm to 0.84 µs/cm (Tables 4.1 and 4.5).

Value of pH was gradually trimmed down with accumulation of organic compound, therefore fluctuation ranged from 5.26 to 7.87. During the assessment, an average pH of water during pre-monsoon was 7.59, and during post-monsoon it was 5.85. The highest record of pH was 7.87, and the least record was 5.24 (Tables 4.1 and 4.2).

During the assessment average dissolved oxygen of water during pre-monsoon was 4.836 mg/lit while in post-monsoon the average DO was 5.84 mg/lit. The highest recorded DO was 6.59mig/lit at post-monsoon in Hanumanghat and least recorded was 3.27 mg/lit in Thimi Site at pre-monsoon (Tables 4.1 and 4.2).

Concentration of free carbondioxide increased with the increase in contamination of organic matters. Free carbondioxide was higher in pre-monsoon 16.59 mg/lit at Narephant Site than in post-monsoon. The value limit to 6.36 mg/lit in pre- monsoon at Hanumanghat Site.

During the Pre-monsoon period the average BOD of water was 40.69 while in Post-monsoon the average BOD was 35.77. The highest recorded BOD at Narephant was 77.16 in pre-monsoon and the least record of BOD at Hanumanghat was 9.86 at post-monsoon period. There was an inverse relationship between BOD and DO with r=-0.533126.

Most of the sites of the Hanumante river were used for irrigation and agricultural drainages therefore nitrates and phosphates were chosen to examine the agricultural as well as organic decomposition. During pre-monsoon, there was less phosphate in comparison to post-monsoon, while the nitrate was high in pre- monsoon. Phosphate was in high downstream where agricultural practices were done and nitrate was high in the most polluted areas such as Sallaghari, Thimi and Narephant.

4.2.1 Site Comparision

Null hypothesis were tested; physico-chemical qualities of all sites did not differ significantly. F-test at 95% confidence level rejected it concluding that there was significant difference between physico-chemical qualities at different sites (Tables 4.1, 4.2). Addition of different pollution effluents at different sites resulted in the differences in water quality. Null hypothesis

Source of variation	Sum of squares	Degree of freedom(d.f)	Mean(Mean sum of square)/d.f	Calculated Value of F-ratio	Tabulated Value (F-limit)(0.05%, df)
Between samples(ssc)	8502.986	6	1417.164	$= \frac{1417.164}{67.83929}$ = 20.89002439	2.34 rejected
Within samples(sse)	2374.375	49-7=42	67.83929		
Total	10877.36	48			

was rejected in both seasons.

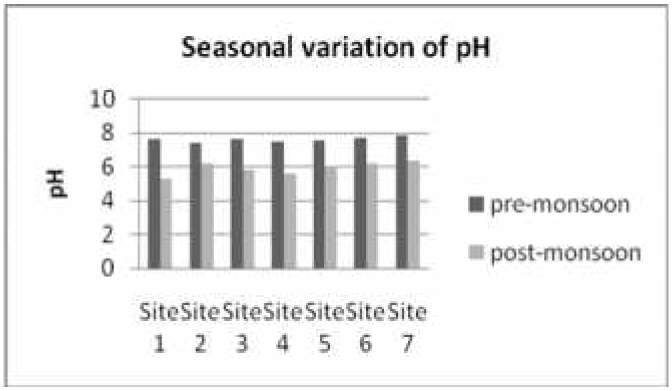
Table 4.3 Comparison between parameters in different sites in Pre-monsoon

Source of variation	Sum of squares	Degree of freedom(d.f)	Ms(sum of square)/d.f	F-ratio (ssc/sse)	5% f-limit (from table)

Source: From the analysis of variance table (Annex 6)

Between samples(ssc)	6774.339	6	1129.057	= $\frac{1129.057}{71.18551}$ =15.860762	2.34 rejected
Within samples(sse)	2491.493	49-7=42	71.18551		
Total	9265.832	48			

Table 4.4 Comparison between parameters in different sites in Post-monsoon



Source: From the analysis of variance table (Annex 7)

Figure 4.1 Seasonal Variation of pH

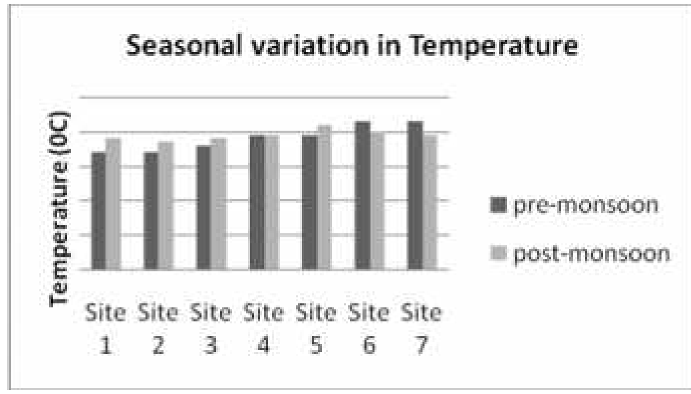


Figure 4.2 Seasonal Variation of Temperature

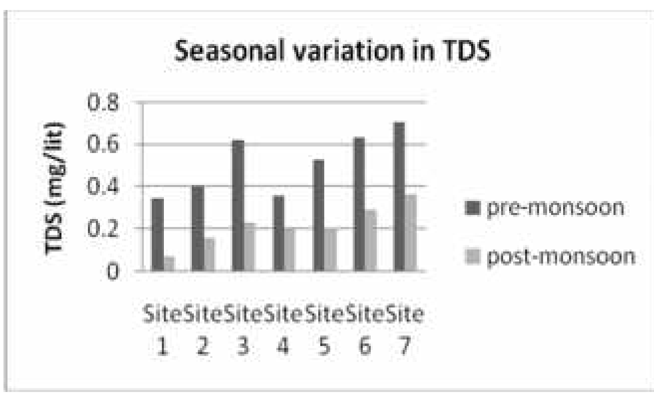


Figure 4.3 Seasonal Variation of TDS

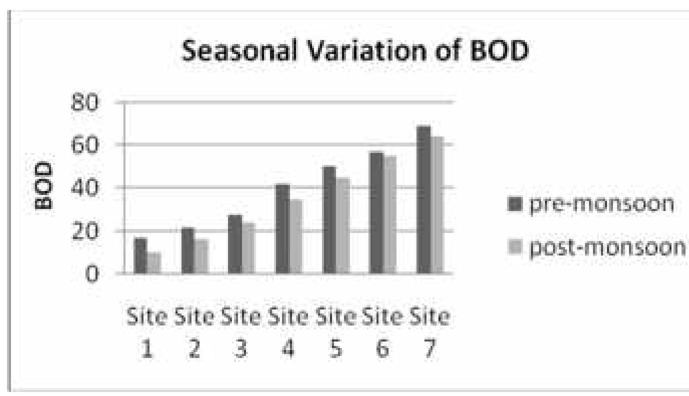


Figure 4.4 Seasonal Variation of BOD

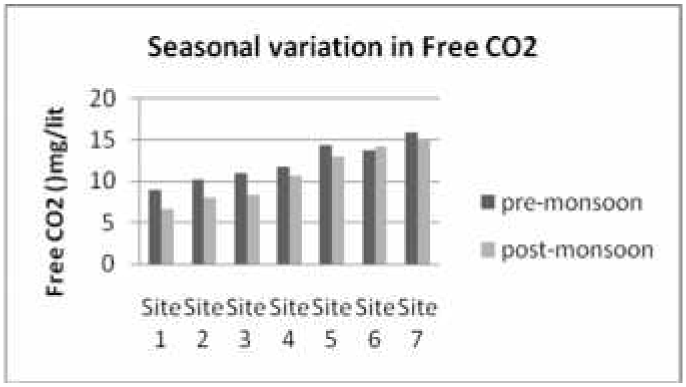


Figure 4.5 Seasonal Variation of Free CO2

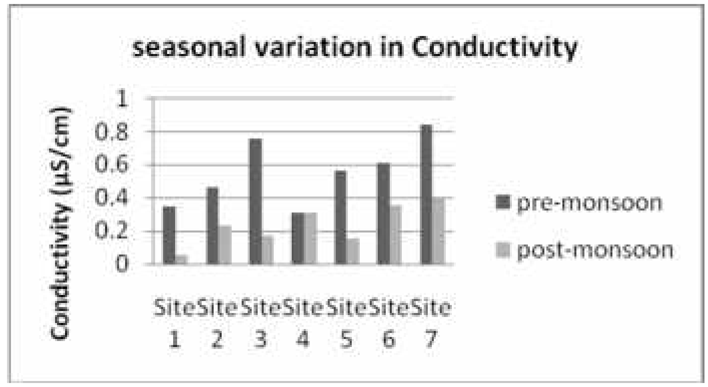


Figure 4.6 Seasonal Variation of Conductivity

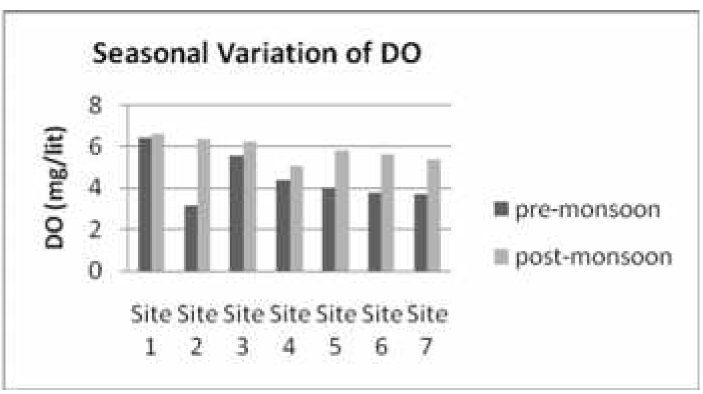


Figure 4.7 Seasonal Variation of DO

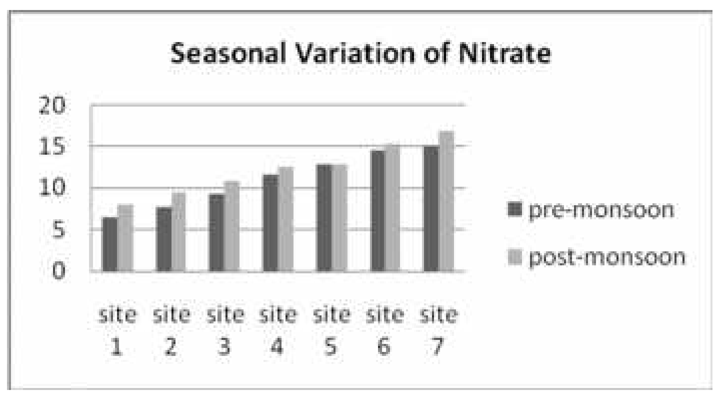


Figure 4.8 Seasonal Variation of Nitrate

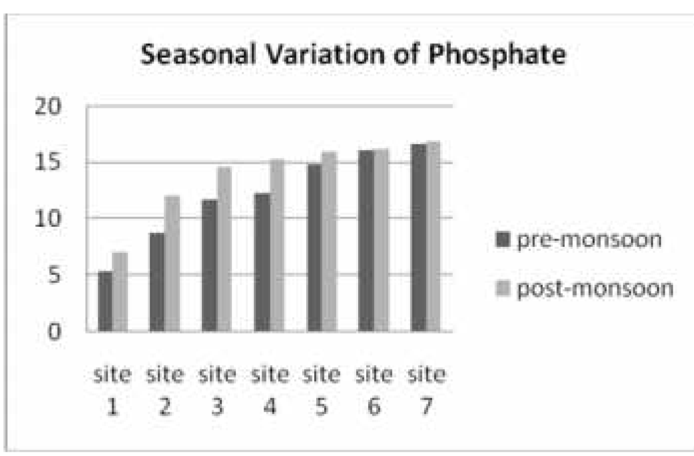


Figure 4.9 Seasonal Variation of Phosphate

Description from Graphical presentation

In the seasonal variation of pH along each sampling sites, value of pH was more or less same in all sites but pH value of post and pre monsoon was continuous in all sites.

In the seasonal variation of Temperature along each sampling sites slight increase in temperature was seen from site I Hanumanghat to site VII Narephant.

In the seasonal variation of Total Dissolved Solids there was marked fluctuation in all sites. There was high Total dissolved solids in Thimi, Narephant and balkot site. Gatthaghar and Hanumanghat sited show low Total Dissolved Solids. Same pattern was seen for the conductivity as in Total Dissolved solids

In the trend for BOD, Nitrate, Phosphate and Free Carbondioxide there was marked increase from Site I Hanumanghat to Site VII Narephant. This trend was same in both seasons but in post monsoon BOD and free carbondioxide was less in comparision to pre monsoon. Amount of nitrate and phosphate was seen more in post monsoon than in pre monsoon.

In the graphical presentation of Dissolved oxygen there was marked decrease of dissolved oxygen from Hanumanghat site to narephant site.

On the basis comparison on thresh hold values and obtained data (4.1 and 4.2), Hanumanghat site was less polluted than the other following sites. Trend of pollution was not uniform due to varieties of effluents mixed in the river. In comparison to other sites, water quality of Thimi and Narephant was highly deteriorated as shown in above graphs.

4.3 Biological Analysis

Biological abundance and EBI value (Annex 6) investigated the status of benthic macro invertebrate and some low tolerant species to pollution, such as Ephemeroptera and Trichoptera which were found to be rare. Chironomidae and Diptera, mostly mosquito larvae were high almost in all sites from upstream to downstream.

Degree of abundance changes with the change of organic pollution. Fluctuation of abundance of macro fauna was high in downstream with more pollution than in upstream. Pollution sensitive fauna were rare due to detoriation of water quality and high abundance of pollution tolerant species. Abundance of different species fluctuated in different season. (Figure 4.10).

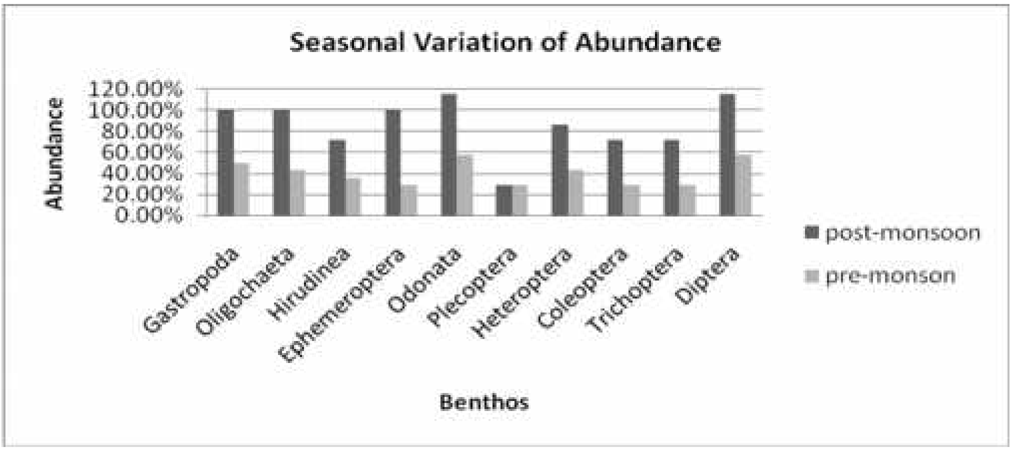


Figure 4.10 Seasonal Variation of Abundance of Benthic Macro Invertebrates

On the basis of EBI score (Annex 3,6,7), Hanumanghat site was less polluted than the other following sites. Trend of pollution was not uniform due to varieties of effluents mixed in the river. In comparison to other sites, water quality of Thimi and Narephant was highly deteriorated and showed Quality Class V (Annex 5).

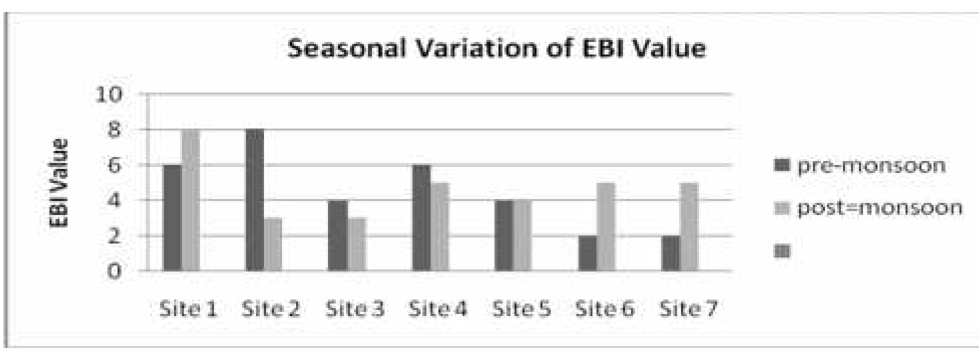
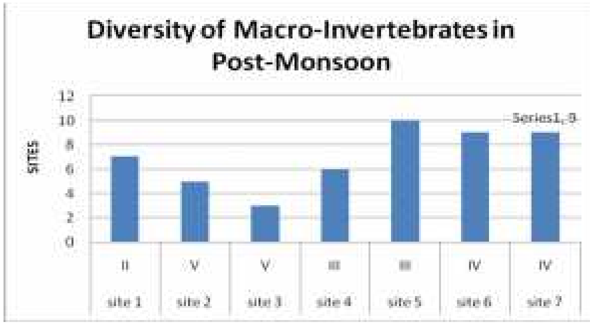


Figure 4.11 Seasonal Variation of EBI Value



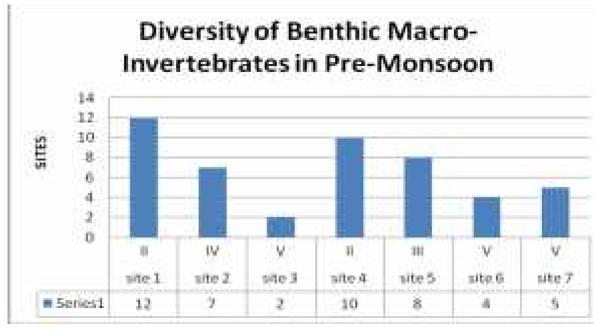


Figure 4.12 Diversity of macro invertebrates in post monsoon

Figure 4.13 Diversity of macro invertebrates in pre monsoon

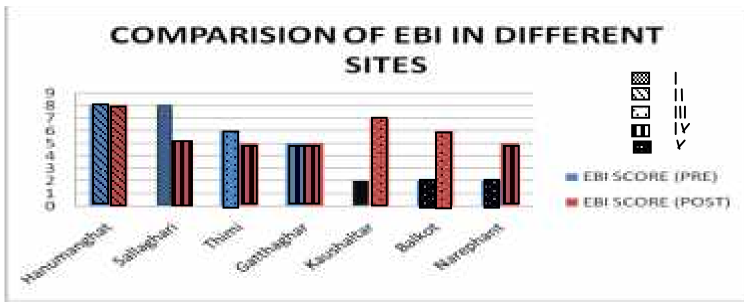


Figure 4,14 4. Site Comparision according to the EBI Score and EBI class

On the basis of diversity of macro invertebrates , Hanumanghat site was less polluted than the other following sites. Trend of pollution was not uniform due to varieties of effluents mixed in the river. In comparison to other sites, water quality of Thimi and Narephant was highly deteriorated and showed Quality Class V (Annex 5).

4.4 Relation between Physico-chemical and Biological Quality of Water

The correlation analysis between different parameters and occurrence showed the different positive and negative association (Table 4.5). Association between physico-chemical and biological parameters was the same in both pre-monsoon and post-monsoon seasons. Except for the dissolved oxygen, correlation coefficient of all parameters between occurrences showed negative value.

Table 4.5 Correlation between physico-chemical parameters and Occurrences of Benthos

Pre monsoon			Post monsoon		
Relation	Correlation (r)	Significance	Relation	Correlation (r)	Association
Temperature× Occurrence	-0.41	Negative	Temperature× Occurrence	-0.17	Negative

TDS ×Occurrence	-0.66	Negative	TDS ×Occurrence	-0.631	Negative
Conductivity ×Occurrence	-0.54	Negative	Conductivity ×Occurrence	-0.32	Negative
pH× Occurrence	-0.14	Negative	pH× Occurrence	-0.56	Negative
DO ×Occurrence	0.32	Positive	DO ×Occurrence	0.306	Positive
BOD ×Occurrence	-0.33	Negative	BOD ×Occurrence	-0.3379	Negative
Free CO_2 ×Occurrence	-0.34	Negative	Free CO_2 ×Occurrence	-0.35	Negative

Agriculture (Standard Values for Bagmati and it's tributaries)														
Sites	**pH (6.5-9.0) (pre/post)**		**TDS(mg/l) 1500 (pre/post)**		**DO(mg/l) 3 (pre/post)**		**NO_3(mg/l) 25 (pre/post)**		**PO_4(mg/l) 6 (pre/post)**		**BOD(mg/lit) 10 (pre/post)**		**Remarks**
I	7.6	5.26	0.345	0.07	6.4	6.56	8.0	6.4	7.1	5.3	16.83	10.12	**Not Apr**
II	7.3	6.13	0.405	0.155	3.12	6.36	9.4	7.7	12.1	8.7	21.36	16.43	**Not Apr**
III	7.6	5.82	0.62	0.23	5.5	6.24	10.7	9.3	14.6	11.7	27.54	24.2	**Not Apr**
IV	7.4	5.6	0.35	0.2	4.39	5.06	12.4	11.5	15.2	12.3	42.23	34.87	**Not Apr**

V	7.5	6.03	0.52	0.205	4.02	5.76	12.8	12.7	15.9	14.8	50.24	45.155	**Not Apr**
VI	7.6	6.14	0.63	0.29	3.77	5.76	15.3	14.5	16.1	16.0	57.2	55.17	**Not Apr**
VII	7.8	6.305	0.7	0.365	3.7	5.63	16.7	14.9	16.8	16.6	69.41	64.41	**Not Apr**

Aquatic Life (Standard Values for Bagmati and it's tributaries)													
Sites	**pH (6.5-8.5) Pre/Post**		**TDS (mg/lit) 1000 Pre/Post**		**DO (mg/lit) 6 Pre/Post**		**NO_3 (mg/lit) 20 Pre/Post**		**PO_4 (mg/lit) 0.1 Pre/Post**		**BOD (mg/lit) 4 Pre/Post**		**Remarks**
I	7.6	5.26	0.345	0.07	6.4	6.56	8.0	6.4	7.1	5.3	16.83	10.12	**Not Apr**
II	7.3	6.13	0.405	0.155	3.12	6.36	9.4	7.7	12.1	8.7	21.36	16.43	**Not Apr**
III	7.6	5.82	0.62	0.23	5.5	6.24	10.7	9.3	14.6	11.7	27.54	24.2	**Not Apr**
IV	7.4	5.6	0.35	0.2	4.39	5.06	12.4	11.5	15.2	12.3	42.23	34.87	**Not Apr**
V	7.5	6.03	0.52	0.205	4.02	5.76	12.8	12.7	15.9	14.8	50.24	45.155	**Not Apr**
VI	7.6	6.14	0.63	0.29	3.77	5.76	15.3	14.5	16.1	16.0	57.2	55.17	**Not Apr**
VII	7.8	6.305	0.7	0.365	3.7	5.63	16.7	14.9	16.8	16.6	69.41	64.41	**Not Apr**

Bathing (Standard Values for Bagmati and it's tributaries)													
Sites	**pH (6.5-9.2) Pre/Post**		**TDS (mg/lit) 1500 Pre/Post**		**DO (mg/lit) 3 Pre/Post**		**Nitrate (mg/lit) 20 Pre/Post**		**Phosphate (mg/lit) 0.2 Pre/Post**		**BOD (mg/lit) 6 Pre/Post**		**Remarks**
I	7.6	5.26	0.345	0.07	6.4	6.56	8.0	6.4	7.1	5.3	16.83	10.12	**Not Apr**
II	7.3	6.13	0.405	0.155	3.12	6.36	9.4	7.7	12.1	8.7	21.36	16.43	**Not Apr**

III	7.6	5.82	0.62	0.23	5.5	6.24	10.7	9.3	14.6	11.7	27.54	24.2	**Not Apr**
IV	7.4	5.6	0.35	0.2	4.39	5.06	12.4	11.5	15.2	12.3	42.23	34.87	**Not Apr**
V	7.5	6.03	0.52	0.205	4.02	5.76	12.8	12.7	15.9	14.8	50.24	45.155	**Not Apr**
VI	7.6	6.14	0.63	0.29	3.77	5.76	15.3	14.5	16.1	16.0	57.2	55.17	**Not Apr**
VII	7.8	6.305	0.7	0.365	3.7	5.63	16.7	14.9	16.8	16.6	69.41	64.41	**Not Apr**

Drinking (Standard Values for Bagmati and it's tributaries)													
Sites	**pH (6.5-9.2) (pre/post)**		**TDS(mg/l) 1500 (pre/post)**		**DO(mg/l) - (pre/post)**		**NO_3(mg/l) - (pre/post)**		**PO_4(mg/l) 0.1 (pre/post)**		**BOD(mg/l) 4 (pre/post)**		**Remarks (Appro/ Not Apr)**
I	7.6	5.26	0.345	0.07	6.4	6.56	8.0	6.4	7.1	5.3	16.83	10.12	**Not Apr**
II	7.3	6.13	0.405	0.155	3.12	6.36	9.4	7.7	12.1	8.7	21.36	16.43	**Not Apr**
III	7.6	5.82	0.62	0.23	5.5	6.24	10.7	9.3	14.6	11.7	27.54	24.2	**Not Apr**
IV	7.4	5.6	0.35	0.2	4.39	5.06	12.4	11.5	15.2	12.3	42.23	34.87	**Not Apr**
V	7.5	6.03	0.52	0.205	4.02	5.76	12.8	12.7	15.9	14.8	50.24	45.155	**Not Apr**
VI	7.6	6.14	0.63	0.29	3.77	5.76	15.3	14.5	16.1	16.0	57.2	55.17	**Not Apr**
VII	7.8	6.305	0.7	0.365	3.7	5.63	16.7	14.9	16.8	16.6	69.41	64.41	**Not Apr**

4.7 Site Comparison on the basis of Biological parameters

Sites	**Pre Monsoon**			**Post Monsoon**		
	Occurrence	EBI	Diversity	Occurrence	EBI	Diversity
I	4	8	8	6	8	8
II	4	8	6	4	5	5
III	4	6	8	2	5	5

IV	3	5	7	6	5	7
V	3	2	4	4	7	7
VI	5	2	5	4	6	7
VII	5	2	5	3	5	9

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Annexes

Annex 1. Field Protocol used to collect the data

Components	Parameters
Effluents	Agricultural, Sewages, Industrial, Solid Waste, Domestic
River Information	Site, River name, Locality name, Date, GPS information
Substrate Composition	Boulder, Cobblers, Pebbles, Gravel, Sand and Silt
Physico-chemical parameter	Temperature, pH, TDS, Conductivity, Nitrate, Phosphate, Free CO_2, BOD, DO
Biological features	Abundance, EBI Value, Map and Photo plates

Source: Data collection 2009/2010

Annex 2. Water quality classification by Extended Biotic Index (EBI)

Class	Genus	Total Number of Group Present									
		0-1	2-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
		Biotic Index									
Plecoptera	More than 1genus			8	9	10	11	12	13	14	15
	Only 1 genus			7	8	9	10	11	12	13	14
Ephemeroptera	More than 1genus			7	8	9	10	11	12		
	Only 1 genus			6	7	8	9	10	11		
Trichoptera	More than 1genus			6	7	8	9	10	11		
	Only 1 genus			5	6	7	8	9	10		
Gammarus	All above taxa absent			5	6	7	8	9	10		
Asellus	All above taxa absent			4	5	6	7	8	9	10	
Oligochaeta Chironomidae	All above taxa absent			3	4	5	6	7	8	9	10
All above type absent	Organism not requiring Oxygen			2							

Annex 3. EBI and its quality classes, diagnosis and color representation

EBI	Quality Classes	Diagnosis	Color Representation
10-15	I	Unpolluted	Blue
8-9	II	Slightly Polluted	Green
6-7	III	Polluted	Yellow
4-5	IV	Considerably Polluted	Orange

0-3	V	Extremely Polluted	Red

Annex 4. Description of Abundance of animals

Rank	% composition in the sample	Description
1	1	Very rare
2	1-2	Rare
3	2-5	Common
4	5-15	Abundant
5	More than 15	Highly Abundant

Annex 5. Periodic Data Table

PH

pre monsoon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
	7.61	7.385	7.63	7.48	7.54	7.665	7.855
post monsoon	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
	5.265	6.13	5.82	5.6	6.035	6.14	6.305

Temperature

year	season	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
2009	pre	17	17	18	19.5	19.5	21.5	21.5
2009	post	19	18.5	19	19.5	21	20	19.5

Tds

year	season	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
2009	pre	0.345	0.405	0.625	0.355	0.525	0.635	0.7
2009	post	0.07	0.155	0.23	0.2	0.205	0.29	0.365

Conductivity

year	season	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
2009	pre	0.35	0.46	0.75	0.31	0.56	0.61	0.84
2009	post	0.055	0.23	0.175	0.305	0.15	0.355	0.39

DO

year	season	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
2009	pre	6.4	3.12	5.52	4.395	4.02	3.775	3.7

2009	post	6.56	6.365	6.245	5.06	5.76	5.63	5.36

Free carbondioxide

year	season	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
2009	pre	8.955	10.13	10.92	11.725	14.285	13.725	15.86
2009	post	6.65	8.02	8.3	10.675	12.955	14.225	15.105

BOD

year	season	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
2009	pre	16.83	21.365	27.545	42.235	50.24	57.2	69.41
2009	post	10.125	16.43	24.265	34.87	45.155	55.175	64.415

Annex 6

For Benthic macro invertebrates

Abundance of Benthic Macro invertebrates in pre-monsoon (Early pre-monsoon)

S.N	Name of Benthos	Number of Sites							Total number of benthos occurance	Abundance	Class
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7			
1	Gastropoda	0	0	1	0	1	1	1	4	57.14%	C
2	Oligochaeta	0	1	0	1	0	0	1	3	42.85%	C
3	Hirudinea	0	0	1	0	1	1	1	4	57.14%	C
4	Ephemeroptera	1	1	0	0	0	0	0	2	28.57%	B
5	Odonata	1	0	1	0	0	0	0	2	28.57%	B
6	Plecoptera	1	1	0	0	0	0	0	2	28.57%	B
7	Heteroptera	0	0	0	1	0	1	1	3	42.85%	C
8	Coleoptera	0	0	1	0		1	0	2	28.57%	B
9	Trichoptera	1	1	0	0	0	0	0	2	28.57%	B
10	Diptera	0	0	0	1	1	1	1	4	57.14%	C

Abundance of Benthic Macro invertebrates in pre-monsoon (Late pre-monsoon)

S.N	Name of Benthos	Number of Sites							Total number of benthos occurance	Occurrence	Class
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7			
1	Gastropoda	1	0	1	1	1	0	0	4	57.14%	C
2	Oligochaeta	0	0	1	1	0	0	1	3	42.85%	C
3	Hirudinea	0	1	0	0	0	0	1	2	28.57%	B
4	Ephemeroptera	1	0	0	1	0	0	0	2	28.57%	B
5	Odonata	1	1	0	1	1	0	0	4	57.14%	C
6	Plecoptera	1	0	0	0	1	0	0	2	28.57%	B
7	Heteroptera	1	1	0	0	0	1	0	3	42.85%	C
8	Coleoptera	0	1	0	0	1	0	0	2	28.57%	B
9	Trichoptera	1	0	0	1	0	0	0	2	28.57%	B
10	Diptera	0	0	0	0	1	1	1	3	42.85%	C

Abundance of Benthic Macro invertebrates in Early post-monsoon

S.N	Name of Benthos	Number of Sites							Total number of benthos occurance	Occurrence	Class
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7			
1	Gastropoda	0	1	0	1	0	1	0	3	42.85%	C
2	Oligochaeta	0	0	0	1	1	0	1	3	42.85%	C
3	Hirudinea	0	0	0	1	0	1	0	2	28.57%	C
4	Ephemeroptera	1	0	1	0	1	0	0	3	42.85%	B
5	Odonata	1	1	0	0	1	0	1	4	57.14%	C
6	Plecoptera	1	0	0	0	0	0	0	1	14.28%	A
7	Heteroptera	1	1	0	1	0	0	0	3	42.85%	C
8	Coleoptera	1	1	0	1	0	0	0	3	42.85%	C
9	Trichoptera	1	0	1	0	0	1	0	3	42.85%	C
10	Diptera	0	0	0	1	1	1	1	4	57.14%	C

Abundance of Benthic Macro invertebrates in late post-monsoon

S.N	Name of Benthos	Number of Sites							Total number of benthos occurance	Occurrence	Class
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7			
1	Gastropoda	0	0	0	1	0	1	0	2	28.57%	B
2	Oligochaeta	0	1	0	1	1	0	1	4	57.14%	C
3	Hirudinea	0	1	0	0	0	0	0	1	14.28%	A
4	Ephemeroptera	1	0	0	1	1	0	1	4	57.14%	C
5	Odonata	1	1	0	0	1	1	0	4	57.14%	C
6	Plecoptera	1	0	0	0	0	0	0	1	14.28%	A
7	Heteroptera	1	1	0	0	1	0	0	3	42.85%	C
8	Coleoptera	1	0	1	0	0	0	0	2	28.57%	B
9	Trichoptera	1	1	0	0	0	0	0	2	28.57%	B
10	Diptera	0	0	0	1	1	1	1	4	57.14%	C

Diversity of Benthic Macro-Invertebrates along the Hanumante River in Early Pre-Monsoon

Benthos	Sampling Sites						
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Gastropoda	-	-	2	-	1	1	1
Oligochaeta	-	2	-	1	-	-	1
Hirudinea	-	-	1	-	1	1	1
Ephemeroptera	3	2	-	-	-	-	-
Odonata	1	-	3	-	-	-	-
Plecoptera	3	1	-	-	-	-	-
Heteroptera	-	-	-	2	-	1	1
Coleoptera	-	-	2	-	-	1	-
Trichoptera	1	1	-	-	-	-	-
Diptera	-	-	-	4	2	1	1
Total	8	6	8	7	4	5	5
EBI Score	8	8	6	5	2	2	2
EBI Class	II	II	III	IV	V	V	V

Diversity of Benthic Macro-Invertebrates along the Hanumante River in Late Pre-Monsoon

Benthos	Sampling Sites						
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Gastropoda	2	-	1	1	2	-	-
Oligochaeta	-	-	1	1	-	-	1
Hirudinea	-	2	-	-	-	-	2
Ephemeroptera	1	-	-	-	-	-	-
Odonata	1	-	-	2	1	-	-
Plecoptera	2	-	-	3	1	-	-
Heteroptera	1	2	-	-	-	1	-
Coleoptera	3	3	-	1	1	-	-
Trichoptera	2	-	-	-	-	-	-
Diptera	-	-	-	2	2	3	2
Total	12	7	2	10	8	4	5
EBI Score	9	5	2	8	6	2	2
EBI Class	II	IV	V	II	III	V	V

Diversity of Benthic Macro-Invertebrates along the Hanumante River in early Post-Monsoon

Benthos	Sampling Sites						
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Gastropoda	-	1	-	1	-	1	2
Oligochaeta	-	-	-	1	2	-	2
Hirudinea	-	-	-	1	-	2	1
Ephemeroptera	1	-	3	-	1	-	-
Odonata	2	2	-	-	1	-	1
Plecoptera	1	-	-	-	-	-	-
Heteroptera	2	1	-	1	-	-	-
Coleoptera	1	1	-	1	-	-	-
Trichoptera	1	-	2	-	-	2	-
Diptera	-	-	-	2	3	3	3
Total	8	5	5	7	7	7	9
EBI Score	8	5	5	5	7	6	5
EBI Class	II	IV	IV	IV	III	III	IV

Diversity of Benthic Macro-Invertebrates along the Hanumante River in late Post-Monsoon

Benthos	Sampling Sites						
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Gastropoda	-	-	-	1	-	2	2
Oligochaeta	-	2	-	1	1	-	1
Hirudinea	-	1	-	-	-	-	1
Ephemeroptera	1	-	-	1	2	-	-
Odonata	1	1	-	-	2	3	-
Plecoptera	1	-	-	-	-	-	-
Heteroptera	2	-	1	-	3	-	-
Coleoptera	1	-	2	-	-	-	-
Trichoptera	1	1	-	-	-	-	-
Diptera	-	-	-	3	2	4	5
Total	7	5	3	6	10	9	9
EBI Score	8	2	2	7	7	5	5
EBI Class	II	V	V	III	III	IV	IV

Annex 7

Description of Saprobic Water Quality Classes

SWQC	Features description of the Bagmati River and it's tributaries based on Protocol information
Class I	Uppermost headwater region location with straight channel course; forest coverage with above 80% and 70%; about 70% ±15 plant shading; about 20% detritus cover (wood and leaf); much of the water source tapped in reservoir for drinking purpose; channel width varies from 6 m ± 4 m to 15 m ±7; depth with 0.2 to 0.8 m; fully natural and stable bank; v-shaped channel; turbulent flow with velocity of over 1m/sec; substrate composition with overwhelmingly made up of boulder (>40 cm) with ≈50%; almost non-existent of silt; sand with below ≈5%; mean conductivity at ≈25μS/cm ±10; level of DO ≈10±2mg/litre.
Class II	Straight and meandering course stream; increasing human influence; few cases of natural influences such as bank erosion, flood and siltation; plant overhanging on the stream or shaded area (≈40%); medium water level; natural with semi-stable bank structure; medium flow velocity with over 0.5m/sec; variation in conductivity with 150 ±70 μS/cm; substrate composition with increasing amount of smaller and finer size materials in downward with boulder, cobble and pebble; domination of boulder with ≈25%; sand ≈25% together with silts (≈5%); DO with ±2.5 mg/litre; use of water for domestic purpose and agriculture; reductive feature at 20 ±18%; pebble collection and sand quarrying.
Class III	Flowing over the valley terrain at mature stage with meandering course; medium to low water level; increased in small particle materials; ≈35 ±25% sand amount, followed by small and large pebbles; 10 ±2% siltation coverage; decreasing large size boulder and cobble below ≈5%; stream channel width ranging from 6 ±3 m 3 ±1 m; mean depth with 2 meters ±1.5 at maximum and 0.3 meter at minimum; earthy with semi-hard bank structure; amount of DO at 6 ±2 mg/l; 220 ±65 conductivity; use of water in agriculture and for domestic uses; land use dominated by agriculture and then by settlement and fallow land; frequent flooding and siltation; increased sand quarrying and effluents of agriculture, domestic and industries.
Class IV	Terraced type channel; poorest water quality and spatially confined mainly to the urban core, where streams with medium to low and low water level flow slowly along the meandering course; use of water primarily for agriculture (>90%) and for washing vehicle, vegetables to sell and building construction; large amount of effluents of domestic and sewage (> ≈70%); substrate composition composed of sand and silt with >60%; decreasing large size materials (<5%); average stream width ranging from 8 ±6 m to 5 m. average stream depth ranging 0.7 to 0.3 m; earth bank structure except in some man-made stone staircases; meandering course; medium to low level water velocity of 0.3m/sec ±0.1; greater amount of human interference such as sand quarrying and pebble collection; frequent flash flood siltation and bank erosion; dominated by settlement and agriculture; low DO at 2 ±0.5; high conductivity at ≈500 ± 290; low runoff.

Source (Pradhan 2005)

Annex 8

ANALYSIS OF VARIANCE FOR THE PHYSICO-CHEMICAL PARAMETERS FOR DIFFERENT SAMPLING SITES OF HANUMANTE RIVER IN PRE-MONSOON SEASON

				PREMOSOON			
				PARAMETERS			
SITES	PH	TEMPERA	TDS	CONDUCTIVI	DO	FREE CO2	BOD
SITE 1	7.61	17	0.345	0.35	6.4	8.955	16.83
SITE2	7.38	17	0.405	0.46	3.12	10.13	21.36
SITE3	7.63	18	0.625	0.75	5.52	10.92	27.54
SITE4	7.48	19.5	0.355	0.31	4.395	11.72	42.23
SITE5	7.54	20	0.525	0.56	4.02	14.28	50.24
SITE6	7.66	21.5	0.635	0.61	3.77	13.72	57.2
SITE7	7.85	21.5	0.7	0.84	3.7	15.86	69.41

NULL HYPOTHESIS: There is no significant difference between physico-chemical parameters of Site 1 to Site 7 in the season of pre-monsoon.

ALTERNATIVE HYPOTHESIS: There is significant difference between physico-chemical parameters of Site 1 to Site 7 in the season of pre-monsoon

				PREMOSOON			
				PARAMETERS			
SITES	PH	TEMPERA	TDS	CONDUCTIVI	DO	FREE CO2	BOD
SITE 1	7.61	17	0.345	0.35	6.4	8.955	16.83
SITE2	7.38	17	0.405	0.46	3.12	10.13	21.36
SITE3	7.63	18	0.625	0.75	5.52	10.92	27.54
SITE4	7.48	19.5	0.355	0.31	4.395	11.72	42.23
SITE5	7.54	20	0.525	0.56	4.02	14.28	50.24
SITE6	7.66	21.5	0.635	0.61	3.77	13.72	57.2
SITE7	7.85	21.5	0.7	0.84	3.7	15.86	69.41
TOTAL	53.15	134.5	3.59	3.88	30.925	85.585	284.81
MEAN	7.592857	19.21429	0.512857	0.554285714	4.417857	12.22643	40.68714

GRAND MEAN =(MEAN PH+ MEAN TEMPERATURE+ MEAN TDS+ MEAN CONDUCTIVITY+ MEAN DO+ MEAN FREE CO_2+ MEAN BOD)

7

=12.17224

SUM OF SQUARE BETWEEN= N1(MEAN Ph-GRAND MEAN)^2+ N2(MEAN TEMPERATURE-GRAND MEAN)^2+ N3(MEAN TDS-GRAND MEAN)^2+ N4(MEAN CONDUCTIVITY-GRAND MEAN)^2+ N5(MEAN DO-GRAND MEAN)^2+ N6(MEAN FREE CO_2-GRAND MEAN)^2+ N7(MEAN BOD-GRAND MEAN)^2

N(MEAN OF PARAMETER-GRAND MEAN)2	**VALUE**
N1(MEAN Ph-GRAND MEAN)^2	146.7955
N2(MEAN TEMPERATURE-GRAND MEAN)^2	347.1324
N3(MEAN TDS-GRAND MEAN)^2	951.5893
N4(MEAN CONDUCTIVITY-GRAND MEAN)^2	944.8388
N5(MEAN DO-GRAND MEAN)^2	420.9137
N6(MEAN FREE CO_2-GRAND MEAN)^2	0.020551
N7(MEAN BOD-GRAND MEAN)^2	5691.696
SSC	8502.986

SUM OF SQUARE WITHIN=

∑(PH(SITE 1,2….7)-MEAN PH)^2+∑(TEMPERATURE(SITE 1,2….7)-MEAN TEMPERATURE)^2+∑(TDS(SITE 1,2….7)-MEAN TDS)^2+∑(CONDUCTIVITY(SITE 1,2….7)-MEAN CONDUCTIVITY)^2+∑(DO(SITE 1,2….7)-MEAN DO)^2+∑(FREE CO2(SITE 1,2….7)-MEAN FREE CO2)^2+∑ (BOD(SITE 1,2….7)-MEAN BOD)^2

SOURCE OF VARIATION	SUM OF SQUARES	DEGREE OF FREEDOM()D.F	MS(SUM OF SQUARE)/D.F	F-RATIO (SSC/SSE)	5% F-LIMIT (FROM

SS WITHIN							
SITES	PH	TEMPERAT	TDS	CONDUCTIVIT	DO	FREE CO2	BOD
SITE 1	0.000294	4.903061	0.028176	0.041732653	3.92889	10.70224	569.1633
SITE2	0.00138	4.903061	0.011633	0.008889796	1.684433	4.395013	373.5385
SITE3	0.00138	1.47449	0.012576	0.038304082	1.214719	1.706756	172.8474
SITE4	0.012737	0.081633	0.024919	0.05967551	0.000522	0.25647	2.380408
SITE5	0.002794	0.617347	0.000147	0.000036	0.15829	4.217156	91.25708
SITE6	0.004508	5.22449	0.014919	0.003104082	0.419719	2.230756	272.6745
SITE7	0.066122	5.22449	0.035022	0.081632653	0.515319	13.20284	825.0025
SUM	0.089214	22.42857	0.127393	0.233374776	7.921893	36.71124	2306.864
SSE				**2374.375225**			

Now we can set up ANOVA table for this problem

					TABLE)
BETWEEN SAMPLES(SSC)	8502.986	6	1417.164	= 1417.164 / 67.83929	2.34
WITHIN SAMPLES(SSE)	2374.375	49-7=42	67.83929	= 20.89002439	
TOTAL	10877.36	48			

Since the calculated valueof F is greater than that of tabulated value at 5% level of significance for degree of freedom (6, 42) therefore, Null Hypothesis is rejected.

Hence it is concluded that there is high fluctuation of physic-chemical parameter in different sites at the season of pre-monsoon.

Annex 9

ANALYSIS OF VARIANCE FOR THE PHYSICO-CHEMICAL PARAMETERS FOR DIFFERENT SAMPLING SITES OF HANUMANTE RIVER IN POST-MONSOON SEASON

				POST MONSOON			
				PARAMETERS			
SITES	PH	TEMPERA	TDS	CONDUCTIVI	DO	FREE CO2	BOD
SITE 1	5.265	19	0.07	0.055	6.56	8.955	10.125
SITE2	6.13	18.5	0.155	0.23	6.365	10.13	16.43
SITE3	5.82	19	0.23	0.175	6.245	10.92	24.265
SITE4	5.6	19.5	0.2	0.305	5.06	11.725	34.87
SITE5	6.035	19	0.205	0.15	5.76	14.285	45.155
SITE6	6.14	20	0.29	0.355	5.63	13.725	55.175
SITE7	6.305	20	0.365	0.39	5.36	15.86	64.415

NULL HYPOTHESIS: There is no significant difference between physico-chemical parameters of Site 1 to Site 7 in the season of post-monsoon.

ALTERNATIVE HYPOTHESIS: There is significant difference between physico-chemical parameters of Site 1 to Site 7 in the season of post-monsoon.

				POST MONSOON			
				PARAMETERS			
SITES	PH	TEMPERA	TDS	CONDUCTIVI	DO	FREE CO2	BOD
SITE 1	5.265	19	0.07	0.055	6.56	8.955	10.125
SITE2	6.13	18.5	0.155	0.23	6.365	10.13	16.43
SITE3	5.82	19	0.23	0.175	6.245	10.92	24.265
SITE4	5.6	19.5	0.2	0.305	5.06	11.725	34.87
SITE5	6.035	19	0.205	0.15	5.76	14.285	45.155
SITE6	6.14	20	0.29	0.355	5.63	13.725	55.175
SITE7	6.305	20	0.365	0.39	5.36	15.86	64.415
TOTAL	41.295	135	1.515	1.66	40.98	85.6	250.435
MEAN	5.899286	19.28571	0.216429	0.237142857	5.854286	12.22857	35.77643

GRAND MEAN =

$$\frac{\text{(MEAN PH+ MEAN TEMPERATURE+ MEAN TDS+ MEAN CONDUCTIVITY+ MEAN DO+ MEAN FREE } CO_2\text{+ MEAN BOD)}}{7}$$

= 11.35684

SUM OF SQUARE BETWEEN= N1(MEAN Ph-GRAND MEAN)^2+ N2(MEAN TEMPERATURE-GRAND MEAN)^2+ N3(MEAN TDS-GRAND MEAN)^2+ N4(MEAN CONDUCTIVITY-GRAND MEAN)^2+ N5(MEAN DO-GRAND MEAN)^2+ N6(MEAN FREE CO_2-GRAND MEAN)^2+ N7(MEAN BOD-GRAND MEAN)^2

N(MEAN OF PARAMETER-GRAND MEAN)2	**VALUE**
N1(MEAN Ph-GRAND MEAN)^2	208.4943
N2(MEAN TEMPERATURE-GRAND MEAN)^2	440.0693
N3(MEAN TDS-GRAND MEAN)^2	868.7614
N4(MEAN CONDUCTIVITY-GRAND MEAN)^2	865.5337
N5(MEAN DO-GRAND MEAN)^2	211.9467
N6(MEAN FREE CO_2-GRAND MEAN)^2	5.31941
N7(MEAN BOD-GRAND MEAN)^2	4174.214
SSC	**6774.339**

SUM OF SQUARE WITHIN

∑(PH(SITE 1,2….7)-MEAN PH)^2+∑(TEMPERATURE(SITE 1,2….7)-MEAN TEMPERATURE)^2+∑(TDS(SITE 1,2….7)-MEAN TDS)^2+∑(CONDUCTIVITY(SITE 1,2….7)-MEAN CONDUCTIVITY)^2+∑(DO(SITE 1,2….7)-MEAN DO)^2+∑(FREE CO2(SITE 1,2….7)-MEAN FREE CO2)^2+∑ (BOD(SITE 1,2….7)-MEAN BOD)^2

SOURCE OF VARIATION	SUM OF SQUARES	DEGREE OF FREEDOM()D.F	MS(SUM OF SQUARE)/D.F	F-RATIO (SSC/SSE)	5% F-LIMIT (FROM TABLE)

SS WITHIN							
SITES	PH	TEMPERAT	TDS	CONDUCTIVIT	DO	FREE CO2	BOD
SITE 1	0.402318	0.081633	0.021441	0.03317602	0.498033	10.71627	657.9958
SITE2	0.053229	0.617347	0.003773	0.00005102	0.260829	4.404002	374.2843
SITE3	0.006286	0.081633	0.000184	0.003861735	0.152658	1.712359	132.513
SITE4	0.089572	0.045918	0.00027	0.004604592	0.63089	0.253584	0.821613
SITE5	0.018418	0.081633	0.000131	0.007593878	0.00889	4.228898	87.9576
SITE6	0.057943	0.510204	0.005413	0.013890306	0.050304	2.239298	376.3046
SITE7	0.164604	0.510204	0.022073	0.023365306	0.244318	13.18727	820.1678
SUM	0.792371	1.928571	0.053286	0.086542857	1.845921	36.74169	2450.045
SSE			**2491.493**				

Now we can set up ANOVA table for this problem

BETWEEN SAMPLES(SSC)	6774.339	6	1129.057	$= \frac{1129.057}{71.18551}$ =15.860762	2.34
WITHIN SAMPLES(SSE)	2491.493	49-7=42	71.18551		
TOTAL	9265.832	48			

Since the calculated value of F is greater than that of tabulated value at 5% level of significance for degree of freedom (6, 42) therefore, Null Hypothesis is rejected.

Hence it is concluded that there is high fluctuation of physic-chemical parameter in different sites at the season of post-monsoon.