ASSESSMENT OF WATER QUALITY AND SOURCE OF POLLUTION FOR SOME SELECTED RIVERS IN SOUTHERN REGION OF BANGLADESH.

ZAHID HASAN KHAN

DEPARTMENT OF WATER RESOURCES ENGINEERING

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Dhaka-1000, Bangladesh

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Submitted by

ZAHID HASAN KHAN

(Roll No. 040516009 P)

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The project titled "Assessment of water quality and source of pollution for some selected rivers in Southern region of Bangladesh" Submitted by Zahid Hasan Khan Roll No. : 040516009P, Session : April, 2005 has accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Engineering in Water Resources on 21st September, 2010.

____
Dr. Umme Kulsum Navera
Associate Professor,
Department of Water Resources Engineering
BUET, Dhaka-1000, Bangladesh

Chairman
(Supervisor)

____
Dr. Md. Sabbir Mostafa Khan,
Associate Professor,
Department of Water Resources Engineering
BUET, Dhaka-1000, Bangladesh

Member

____
Dr. Md. Ataur Rahman
Associate Professor,
Department of Water Resources Engineering
BUET, Dhaka-1000, Bangladesh

Member

DECLEARATION

It is hereby declared that this thesis work or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Dr. Umme Kulsum Navera	Zahid Hasan Khan
Associate Professor	Roll No. 040516009 P
Department of WRE, BUET.	Session : April, 2005

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List of Abbreviations

APHA	American Public Health Association
BBS	Bangladesh Bureau of Statistics
BOD	Biochemical Oxygen Demand (5 day)
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CEE	Civil and Environmental Engineering
COD	Chemical Oxygen Demand 0C Degree Celsius
DoE	Department of Environment
DO	Dissolved Oxygen
DS	Dissolved Solids
ECR	Environmental Conservation Rule
EIA	Environmental Impact Assessment
GEMS	Global Environmental Monitoring System
NTU	Nephelometric Turbidity Unit
SS	Suspended Solids
SUST	Shahjalal University of Science and Technology
TS	Total Solids UN United Nations
TDS	Total Dissolved Solids
mg/l	Milligram per liter
m3/sec	Cubic meter per second
WQI	Water Quality Index
WHO	World Health Organization

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ABSTRACT

Rivers are important for mankind. They provide water for economic development and human consumption; they provide recreational facilities; they support a large variety of wildlife and they are part of our natural scenic heritage. Industrial development, improvements in living standards and change in agricultural practice have resulted in an increased demand for good quality water. However, such developments have produced increased amount of sewage, industrial wastewater, agricultural discharge and agricultural runoff. The rivers that flow through almost all of the world's cities shown an appreciable decline in water quality but these are often difficult to specify the exact cause of the deterioration.

Khulna division is situated in the south western part of Bangladesh, its area is about 22274 sq.km and the population is about 14.47 million. It has 10 districts and 28 municipalities in Khulna division. Khulna Formed with the silted alluvial soil. This division is fertile and produces a lot of coconut, paddy, jute, betel leaf, sugarcane, potato, turmeric, oil seeds, mulberry plant, vegetables, mango, jackfruit, banana, litchi, berry, palm and papaya. The world biggest mangrove forest is found in Sundarban. Khulna is also known as the city of Shrimps, because 75% of all shrimps exported from Bangladesh are cultivated in the Khulna zone.

This study was conducted depending on secondary data of some extensive laboratory tests which were performed by to DoE to determine the physical and chemical of some selected rivers (Bhairab , Kakshially, Garai, Rupsha, Poshur, Mouri, Mamundo, Kopotakha, Mathavanga) in Southern region of Bangladesh. The river water was found to be highly turbid and higher loading of BOD and COD in both Pre-monsoon and Monsoon period. This indicates that the bacteriological pollution load as compared to flow was very high in the both season. Also the pollutant load in downstream of the river and far away from the place of the major activities of the conveyor, were less. At the same time source of pollution were identified for the surrounding area.

Chapter 1
INTRODUCTION

1.1 Background of the study

Water is the most vital element among the natural resources and is crucial for the survival of all living organisms. The environment, economic growth and development of Bangladesh all are highly influenced by water - its regional and seasonal availability and by the quality of surface and groundwater. Spatial and seasonal availability of surface and groundwater is highly responsive to the monsoon (BBS, 1990) climate and physiography of the country. Availability of water also depends on upstream withdrawal for consumptive and non consumptive uses. In terms of quality, the surface water of the country is unprotected from untreated industrial effluents and municipal wastewater, runoff pollution from chemical fertilizers and pesticides and also oil and lube spillage in the rivers of southern region from the operation of sea ports and river ports. Water quality also depends on effluent types and discharge quantity from different type of industries, types of agrochemicals used in agriculture, and seasonal water flow and dilution capability by the river system.

Bangladesh is the lower riparian of three major river systems which are the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna (GBM), and constitutes about 8 per cent of the combined catchment area. Over 92 per cent of the annual runoff generated in the GBM catchment areas outside the countries flows through Bangladesh (Coleman, 1969). The combined flow of the Padma and Jamuna typically vary between less than 5000 m^3/s in the driest period (March-April) to 80,000-140,000 m^3/s in late August to early September (WARPO, 2000b).

The concerns over water quality relates not just to the water itself, but also to the danger of diffusion of toxic substances into other ecosystems. The aquatic environment for living organisms can be affected and bioaccumulation of harmful substances in the water-dependent food chain can occur both of which it turn harmful to human health. A variation of inland surface water quality is noticed due to seasonal variation of river flow, operation of industrial units and use of agrochemicals. The salinity intrusion in the Southwest region and pollution problems in industrial areas are significant.

The largest use of water is made for irrigation. Besides agriculture, some other uses are for domestic and municipal water supply, industry, fishery, forestry and navigation. In addition, water is of fundamental importance for ecology and the wider environment. Water stress occurs when the demand for water exceeds the amount available during a certain period or when poor quality restricts its use. This frequently occurs in areas with low rainfall and high population density or in areas where agricultural land or industrial activities are intense. Even where sufficient long-term freshwater resources do exist, seasonal or annual variations in the availability of freshwater may at times cause water qual ity degradation (EEA, 1999).

1.2 Causes of water pollution

The major causes of degradation of inland water quality are related to land based activities, when adequate regulatory measures are not incorporated and the stakeholders do not show proper concern. The underlying driving forces for this are poverty, an unhealthy national economy, lack of institutional strength, and lack of awareness and education. Pollutants that enter the surface water and coastal environment originate on land in the form of runoff from municipal, industrial and agricultural wastes, and from commercial seafaring activities.

1.2.1 Industrial effluent

In Bangladesh, industrial units are mostly located along the banks of the rivers. There are obvious reasons for this location such as provision of transportation of incoming raw materials and outgoing finished products. Unfortunately as a consequence, industrial units drain effluents directly into the rivers without any consideration of the environmental degradation which is not permitted based on environmental concern. The most problematic industries for the water sector are textiles, tanneries, pulp and paper mills, fertilizer, industrial chemical production and refineries. A complex mixture of hazardous chemicals, both organic and inorganic, are discharged into the water bodies from all these industries usually without treatment. organic components degrade water quality during decomposition by depleting dissolved oxygen. The non-biodegradable organic components persist in the water system for a long time and pass into the food chain (Ahmed and Reazuddin, 2000). Inorganic pollutants are mostly metallic salts, and basic and acidic compounds. These inorganic components undergo different chemical and biochemical interactions in the river system, and deteriorate water quality.

1.2.2 Agrochemical

The main suspected sources of agricultural runoff pollution are from the use of fertilizers and agrochemicals, including herbicides and pesticides. Urea, Triple Super Phosphate (TSP), Muriate of Potash (MP) and Gypsum are the major chemical fertilizers used in Bangladesh. The total amount of fertilizers used annually is about 2 million tons (BBS, 1998). With the increase of irrigated areas and cultivation of HYV rice, there was an increase of about 20 per cent fertilizer use in 1995. But the present growth in use has increased and fluctuates from plus minus 5 to 10 per cent. In 1995, the use of nitrogenous fertilizer accounted for about 88 per cent of the total fertilizer use, which was about 67 per cent in 1991 (BBS, 1994). The share of the market held by domestic production of Urea, TSP and Gypsum is currently about 90 per cent (BBS, 1985, 1990, 1994, 1998). Pesticide use was introduced in Bangladesh in around late fifties (BBS, 1979). Since 1981, the area covered by plant protection measures has actually decreased, though the trends have been erratic. Insecticide is commonly used for pest control, which accounts for about 90 per cent of the total consumed pesticide (BBS, 1985, 1998).

1.2.3 Fecal Pollution

Bangladesh has the highest rural population densities in the world and with an exception in some areas; the overall density is very high. Most of the rural areas have densities around 1,000 people per square km. The main water related problem is the lack of sanitation facilities in the rural areas and inadequate facilities for urban wastewater treatment. There is one sewage treatment plant in the whole country serving only a part of Dhaka. A major program for provision of sewerage is needed to arrest the increasing fecal pollution of open watercourses around all urban areas in Southern region of Bangladesh. Outside the urban areas, there is a problem with designing adequately sealed latrine systems at the household level. This will prevent fecal pollution more or less. Poor management of wellhead areas may be the most significant source of fecal contamination rather than direct aquifer pollution.

1.2.4 Oil and Lube Spillage

Chittagong and Mongla are the two seaports of the country, and on an average they deal with 1500 to 1600 vessels and 12,000 to 13,000 cargos annually (BBS, 1998). But the present growth in use has increased and fluctuates from plus minus 5 to 10 per of previously specified number. These ports, however, do not have facilities to receive and treat bilge and ballast water and thus ships throw wastewater into the territorial waters of Bangladesh (Majumder, 1999). Oil and lube spillage also happens during refueling of vessels and cargo handling. In addition, there are innumerable mechanized trawlers and boats engaged in fishing in the Bay of Bengal. The operators of these vessels dump waste including burnt oil into the water as they are ignorant about its adverse effect on environment. As the seaports and the harbors of Bangladesh are located near shallow water, large oil tankers carrying crude and refined oil cannot enter them. Therefore, oil spills also take place in outer anchorage during the transfer of crude and refined oil from large oil tankers to small tankers (Majumder, 1999). There have already been several environmental disasters due to heavy spillage from oil tankers in outer anchorage and along coastal areas of Bangladesh. Lube oil and heavy metals enter the coastal area water from the ship-breaking industries in Chittagong, and several accidents have occurred. However, there is no assessment available on the amount of lube oil discharged from ship-breaking industries. Concern over this pollution in the coastal area is emerging, and actions to prevent it are in the initial stage. Enforcement of the ECA and ECR, with institutional strengthening is essential to address this problem.

1.3 Rationale of the study

All major rivers running through cities or urban areas are subjected to some degree of pollution to some extent. This research work represents an attempt to show the various physical and chemical qualities of some river water in the Southern region of Bangladesh and also the source of their pollution. The As result, this type of study seems necessary to predict the current pollution status of based on the available data from Department of Environment. The nature of these pollutants and their sources are significant in this context are- The organic content of natural waters has for a long time has been recognized as the principal criterion of the quality assessment. Organic matter in natural waters can be of such diverse composition that it is almost impossible to characterize it chemically. The assessment is therefore made indirectly using the biochemical oxygen demand (BOD) test. DoE measures the amount of oxygen consumed during bacterial decomposition of the organic matter under standardized conditions. A chemical oxygen demand (COD) test of DoE is sometimes used for this purpose but gives the total organic content rather than the amount, which is bacterially degradable and gives no indication of the rate of oxygen consumption. All data which are used in this research work were originated by laboratory test conducted by Department of Environment (DoE).

1.4 Objective of the study

The objectives of the study are –

1. To study the existing pollution status of some rivers (Bhairab , Kakshially, G--orai, Rupsha, Poshur, Mouri, Mamundo, Kopotakha, Mathavanga) of South--ern zone of Bangladesh.
2. To compare the existing pollutant in the river water with International and National Standard comes from improper discharge of various industries.
3. To identify the source of pollution of corresponding river.

1.5 Organization of the thesis

Considering Literature review, location of the river basin, climate of the study area, sampling procedure, parameterization, data Analysis, results and discussions the thesis has been organized in six chapters; a brief description of the chapters is given below:

Chapter 1 contains introduction, and background of specific interest to conduct this research study, causes of water pollution (Industrial effluent Agrochemical Fecal Pollution Oil and Lube Spillage), rationale of the study, objective of the study, organization of the thesis.

Chapter 2 contains Literature review based on previous studies and environmental significance of pollutants, chemical surveillance, biological surveillance, water quality standards of Bangladesh and WHO.

Chapter 3 contains, location of the river basin , climate of the study area, justification of the study area selection, sampling, sampling frequency and collection of sample, analysis of various water quality parameter, source of pollution, laboratory techniques.

Chapter 4 contains Indicators and Parameters which includes indicators**,** parameters of concern.

Chapter 5 contains Data Analysis, results and discussions.

Chapter 6 includes conclusions and Recommendations of the study.

Chapter 2
LITERATURE REVIEW
AND
ENVIRONMENTAL SIGNIFICANCE OF POLLUTANTS

2.1 General

The aim of this chapter is to improve the knowledge of previous research work which is relevant to the present research study. This chapter is divided into two parts. First part deals with the previous work. Second part deals with the national as well as international water quality standards.

2.2 Literature review based on previous studies

There had not been so many studies related to the various physical and chemical qualities of river water of Bangladesh. A study was conducted by Hossain (2002) to determine the organic and inorganic pollutant loads of the selected industrial effluent of Chattak Pulp and Paper Mill on the water quality of Surma River. The water quality parameters determined were Metal ions, P^H, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Total Dissolved Solids (TDS). They found that 10 water samples out of 11 were having P^H ranges 6.5-7.2. Total dissolved solids of all water samples were far higher than the accepted level, which indicated that the sound growth of aquatic lives by decreasing the growth of phytoplankton due to the decreases of penetration of sunlight into water. DO of all the water samples at the site of the discharging zone was found zero. From the BOD value it was found that organic load of the river water being used by the industry was minimum.

Another study was conducted by Muyen and Mamun (2003) for prediction of pollution status of the Surma River (Chatak to Sunamganj) by simulation. The water quality parameters determined were DO, BOD, COD, P^H, TS, DS, Fecal Coliform, NH_3, Sulphate, Phenol, Atrazen. The recommendation was the general water quality of Surma river was designated as "slightly polluted", In order to use this water for public water supply, it needs a certain degree of treatment, such as sedimentation, disinfection, special treatment to reduce sulfide and phenol concentrations etc. The current state of water quality is acceptable for irrigation purposes. But in order to prevent further deterioration of the present quality, steps should be taken, so that if Chatak may need a water supply system based on the Surma River water, it could be done so with the least amount of cost.

Another study was conducted by Reza and Rahman (2005) to predict Risk assessment and management of effluent from a textile industry at Naraynganj. This research represented an attempt to show the various physical and chemical qualities of the raw composite textile industrial effluent from some selected mills of Naraynganj the discharges this effluent into the river without proper treatment. Laboratory test were performed to determine P^H, Colour, Turbidity, Hardness as $CaCO_3$, TS, SS, TDS, BOD_5, COD, Phenol, Chloride, Sulphate and some other heavy metals.

Table 2.2.1: Test result of effluent from textile industries of Narayanganj.

Sl. No.	Properties of water	Unit	Quantity
1	P^H	-	6.9
2	Total Solid	Mg/l	84250
3	BOD	Mg/l	5723
4	COD	Mg/l	13221
5	Phenol	Mg/l	0.06
6	Chloride	Mg/l	40328
7	Hg	Mg/l	0.08
8	Zn	Mg/l	0.04
9	Cr	Mg/l	0.00
10	Cd	Mg/l	0.02

(Source: Reza and Rahman, 2005)

To determine the dermal effect of the pollutants on human a CDI (Chronic daily Intake) value was evaluated for different pollutants. For Phenol CDI value of 0.018 mg/kg-day, Hg 0.00077 mg/kg-day, for Zn 0.0042 mg/kg-day and for Cd 0.000215 mg/kg-day were found using 30 years of exposure duration with 1 hour of daily exposure time. The HQ (Hazard Quotient) for Phenol, Hg, Zn, and Cd were found 0.45 mg/kg-day, 7.73 mg/kg-day, 1.04 mg/kg-day and 0.43 mg/kg-day respectively. The HQ over 1 for Hg and Zn shows that the chemical specific risk based concern has exceeded the limit of non-carcinogenic health hazard. The recommendation of this research work was as follows:

i. Regular practice of wastewater treatment before discharging it to the receiving water bodies should be ensured first.
ii. In a selected industrial zone where large number of textile industries is situated can develop a combined wastewater treatment plant to minimize the treatment cost.
iii. The treated combined textile wastewater should be disposed off to the water bodies (rivers) away from the estuaries and the places where different kinds of human activities are involved.
iv. The environmental standard regulatory commission or the DOE should take a firm footstep to ensure the safe disposal of the textile effluent.
v. Low cost treatment alternatives like (Aerated Lagoons, oxidization ponds) should be encouraged to enlarge the cost benefit margin of the textile industries.
vi. Research and Development should be geared to develop low pollution technologies in the textile mills.
vii. Last but not the least there should be a continuous monitoring, at strategic points, at regular intervals to quantitatively determine the pollution load.

Another study was conducted by Alam, *et al.,* 2007 to predict Risk and water quality assessment over view of River Sitalakhya in Bangladesh. This investigation was conducted with seasonal variation of water quality of Sitalakhya River of Narayanganj district during the year 1980 to 2000 due to Industrial discharges and agrochemicals came from point and non – point sources. The study area of Sitalakhya River was located between 23^0 36' 24" N to 23^0 45' 15" N latitudes and 90^0 30' 30" E to 90^0 30' 50" E longitudes. The study area was also interconnected with the river Brahmaputra, Lakhya, Balu, and Turag on the northeast. This investigation (2001-2007) to previous works (1980-2000) on Sitalakhya River, the physico – chemical variables, namely temperature, transparency, total dissolve solids, suspended solids, electrical conductivity, hardness, P^H, dissolve oxygen, biochemical oxygen demand, chemical oxygen demand, nitrate, ammonium, phosphate were significantly differs in the spatial (pollution source) and temporal (seasonal) sources of variation affecting and consideration measures to be taken for the safe aquatic lives as well as human health. The recommendation of this research work was to make relevant estimation of the total pollution loads to water by all the industrial sectors of Bangladesh using the Industrial Pollution Protocol System (IPPS) method developed by the World Bank. In terms of pollution, the most polluting sector was the food industry, where the sugar mills and oil/fat factories cause most of the pollution. Pulp and paper industry was the worst water polluter. Metal industries (ferrous and nonferrous) rank first in terms of toxic metals emission. The largest amounts of toxic chemicals are released by the tanneries and leather industries (raw and processed). In terms of the total emission to air, water, and land, the top three most polluting industries are pulp and paper, food industry and tanneries/leather. These industries were large in size or located in large clusters (tanneries), which can be identified and managed as point sources of pollution. The other significant polluters include the metal and textile industries. These are dispersed all over the country and will be more difficult to manage from pollution control point of view. Due to lack of resources, modern technology and awareness not much was being done to trap the harmful pollutants and reuse/recycle these chemicals. Recycling is practiced only when it is part of the production process, and not as a part of pollution mitigation activity. If strict environmental monitoring is enforced as per the Environmental Conservation Rules of 1997 and other relevant environmental laws, many of the industries of Bangladesh will be found in violation of the emission limits.

Another study was conducted by Kamal *et al*. (2007) titled "Study on the Physico Chemical Properties of Water of Mouri River, Khulna, Bangladesh". In that study Water sample were collected from six different point of the Mouri River, with a regular intervals in the months of January-March 2002 for the analyzing different physicochemical parameters of the water. Total 21 different physicochemical parameters were investigated. Correlation and the value among the parameters were also determined. In the present investigation the minimum and maximum value of water temperature, Transparency, Turbidity, TSS, TDS, Electric Conductivity, water P^H, dissolve oxygen, free Carbon dioxide, Alkalinity, Acidity, Hardness, BOD, COD, Sulphate, Phosphate, Nitrite, Sodium, Calcium, Potassium, Manganese and Iron were noted are shown in table 2.2.2.

River water did not show any significant pollution during the study. During the study period dissolved oxygen show direct relation with water temperature but inverse with BOD and COD.

A study was conducted by Masud, *et al*., 2007 to determine the major physicochemical parameters of the Mouri River to assess the status of pollution of this rive. They collected samples from six different stations at morning (8-9 am). Water samples were kept and preserved in 250 ml plastic and glass bottles after collection. Samples were collected and analyzed for a period of 6 months from February to July. The measured and analyzed water quality parameters involved both the physical and chemical parameters. Physical parameters were temperature, turbidity, total suspended solids (TSS) and total dissolved solids (TDS). Chemical parameters involved pH, dissolved oxygen (DO), free CO2, alkalinity, acidity, hardness, biological oxygen demand (BOD), chemical oxygen demand (COD) and nitrite nitrogen. The average value of water temperature, turbidity, TSS and TDS were 27.61°C, 18.56 cm (secchi depth), 473.17 mg/L and 2560 mg/L respectively.The range of different physical water quality parameters showed a higher rate of differences with respect to different months. The highest value of temperature was observed in the month of April because of dry season indicating high atmospheric temperature and the lowest in February due to cold season. The range of temperature of the Mouri River's water was found suitable as the national standard range of water temperature for aquatic organisms is 20-30°C (Bhaumik, *et al.*, 2006).

Table 2.2.2: Test result of Physico Chemical Properties of Water of Mouri River.

Sl. No.	**Properties of water**	**Unit**	**Quantity**
1	temperature	C	21.6 and 32.2 degrees
2	Transparency	cm	15 and 66
3	Turbidity	NTU	16 and 22
4	TSS	Mg/l	74 and 125
5	TDS	Mg/l	255 and 305
6	Electric Conductivity	µmho/cm	159 and 275
7	P^H	-	7.5 and 8.3
8	DO	Mg/l	1.1 and 8.3
9	Free CO_2	Mg/l	27.5 and 35.5
10	Alkalinity	Mg/l	350 and 610
11	Acidity	Mg/l	32.4 and 171
12	Hardness	Mg/l	310 and 529
13	BOD	Mg/l	13 and 31
14	COD	Mg/l	290 and 365
15	Sulphate	Mg/l	42 and 57.35
16	Phosphate	Mg/l	4.89 and 11.46
17	Nitrite	Mg/l	0.54 and 1.82
18	Sodium	Mg/l	16.8 and 33.9
19	Calcium	Mg/l	1.5 and 6.9
20	Potassium	Mg/l	49 and 94
21	Manganese	Mg/l	31 and 59

(Source: Kamal , *et al.*, 2007)

The range and mean value of water turbidity of the Mouri River clearly indicates highly turbid water throughout the experimental period. The standard values of TSS and TDS are 150 mg/L and 1000 mg/L for the inland surface water of Bangladesh (Alam, *et al.*, 2007). The amount of TSS and TDS were also considerably high in the unit volume of water. Thus, the results of the present experiment clearly indicate that the water of Mouri river is highly turbid and not suitable for maintaining the normal functioning of aquatic organisms. The mean value of water P^H at different stations of the river was found as 5.5-9. The value of pH was highly deviated from the standard level as the optimum value of water P^H is 7 or around 7 for the aquatic organisms and the tolerable range is between 6 and 8.5 (Azher, *et al.*, 2006). The deviation of P^H from standard level is due to the difference of the rate of dumping at various sites in the river. The lower values of P^H were observed at dry seasons when there was a little water in the river. The higher values of P^H were also observed at the same times but at different locations. Excess high and low values were observed at those sampling stations where dumping rate were high. The values of P^H tended to be around the optimum level where there was no dumping and there was a flow of water due to mixing with tidal waters near the sluice gate. Different aspects of water quality parameters of the Mouri river were determined successfully in the present study. This river acts as the main dumping site of wastage of Khulna city and this made the environment of the river totally degraded and unsuitable. Reversal of environmental degradation by water treatment, sanitation and hygiene interventions has number of positive impacts on the total environment. In the context of the scarcity of freshwater resources in urban areas, the ever-increasing cost of water treatment and infrastructure, and the rapidly growing urban population, unrestricted supply of water to consumers no longer makes sense in present day water management strategies. Water loss/wastage must be minimized at the household and industry level and grey water recycling should be implemented to reduce demand for water. Creating public awareness, developing widely accepted water reuse standards/criteria, developing and testing low cost treatment technology for grey water recycling, and getting political support for grey water reuse are the major obstacles that need to be overcome for successful water treatment and management. Appropriate water sector development entails interdisciplinary analysis and planning, and this could be strengthened by international endorsement of the sustainable development approach. Hence proper steps must be taken. The ranges of dissolve oxygen (DO) and free CO_2 were 0.4-8.2 mg/L and 21-35.5 mg/L at various stations throughout the experimental period. Sampling at the first four stations revealed that the values of DO were very low and totally unsuitable for most of the aquatic organisms except those of anaerobic as 4-8 mg/L DO is optimum for the aquatic organisms (Bhaumik, *et al.*, 2006). The values of free CO_2 was found comparatively higher indicating in an excess amount for photosynthesis by the aquatic plants. These two parameters are very important for identifying a suitable aquatic body and also to estimate productivity of an aquatic system (Romesh and Anbu, 1996; Davies, *et al.*, 2008). The low oxygen and high free CO_2 of this river water was due to the excess dumping (domestic and urban sewage, industrial effluents, agricultural wastes etc.). The major effect of sewage in water is that it reduces oxygen content of water as the organic matter content of sewage is higher (Ragothaman and Trivedy, 2002). The abundance of CO_2 also exerts certain specific effects on animals of aquatic environment. The increased CO_2 level brings stress and it enhances respiratory activity in most of the aquatic animals (Hosetti and Kumar, 2002). The results of the present experiment clearly indicated that the upstream portion of the river was unproductive and totally unsuitable for the most of the fisheries organisms.

The ranges of alkalinity, acidity and hardness at different sampling stations were observed as 350-610 mg/L, 32.4-171.23 mg/L and 310-510 mg/L respectively. The range and mean values of alkalinity in the water of the Mouri river was comparatively high due to the degradation of various waste materials. Acidity of the Mouri river water was also higher than the standard level indicating unfavorable for the normal functioning of the fisheries organisms. Hardness is the property of water which prevents the lather formation with soap and increases the boiling point of water. The major cations imparting hardness are calcium and magnesium. The responsible anions are bicarbonate, carbonate, sulfate and chlorides. Hardness of the water of this river is very high indicating abundance of various heavy particles originated from various organic effluents. These unsuitable chemical parameters probably reduced the abundance of various fisheries species from the river.

The range of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) at different sampling stations were 23-42.35 mg/L and 290-406 mg/L respectively. BOD and COD levels were observed higher at the upstream stations where dumping rate was very high and water availability was also lower. On the other hand, lower values of BOD and COD were recorded at the downstream stations where water availability was higher and there was a mixing with the tidal waters.

The estimation of BOD gives an indication of the amount of pollution in a body of water. The high amount of BOD indicates large bacterial and fungal population. Owing to metabolic activities of these organisms, the dissolved oxygen gets reduced and the area is found without oxygen. Aquatic organisms such as fishes either evade this area or are killed (Khatri, 1985). The range of the values of nitrite nitrogen (NOs-N) was 0.54-1.88 mg/L at different stations throughout the experimental period. The standard value of NOs-N for the aquatic organisms is <0.25 mg/L (Hoq, 2008) and for bathing is 0.2-0.9 mg/L (Jalil and Njiru, 2010). Abundance of NO3-N was very high and made the environment almost toxic for aquatic nektonic organisms due to excess dumping. These dumped materials produced the nitrite nitrogen in an excess amount in the river.

A study was conducted in our neighboring country, India to determine water quality of the Chhoti Gandak River using principal component analysis, Ganga Plain, India by Bhardwaj, *et al.*, 2009. Chhoti Gandak is a meandering river which originates in the terai area of the Ganga Plain and serves as a lifeline for the people of Deoria district, Uttar Pradesh. It travels a distance of about 250 km and drains into Ghaghara near Gothani, Siwan district of Bihar. It has been observed that people of this region suffer from water-borne health problems; therefore water samples were collected to analyse its quality along the entire length of Chhoti Gandak River. The principal components of water quality are controlled by litho logy, gentle slope gradient, poor drainage, long residence of water, ion exchange, weathering of minerals, heavy use of fertilizers, and domestic wastes. At some stations water is hard with an excess alkalinity and is not suitable for drinking and irrigation purposes. The variation in the local and regional hydro geochemical processes distinguished the geogenic sources from the anthropogenic one. Ganga Plain is one of the most densely populated regions of the world due to its availability of water, fertile soil, and suitable landscape. Density of the river is high in eastern Uttar Pradesh and Bihar. Rivers are considered as a lifeline but are now adversely affecting the population by fluvial hazards (Singh, 2007). India is water-stressed and is likely to be water-scarce by 2050 due to the continuous and increasing demand for water (Gupta and Deshpande, 2004). Water resources and water quality affect the economic, social, and political development of the society. It has been observed in the field that people of the Deoria district are suffering from water-borne health problems mainly related to throat, skin, and stomach. The hydro geochemistry of ground water and anthropogenic control over dolomatization reaction in the alluvial sediments of the Deoria district located within the Chhoti Gandak River Basin have been analysed (Bhardwaj, *et al*, 2009). However, no attempt has been made to analyze the water quality and water chemistry of this river. The hydro geochemical process reveals the zones and quality of water. This process also helps us to understand the changes in water quality due to sediment–water interaction and anthropogenic influence. The impact of land use on the quality of water is an important aspect to develop a suitable policy and legislative or regulatory mechanisms. Lack of such efforts results in the deterioration of water quality which causes health problems and also damages the industrial sector. Therefore, it is essential to evaluate the relationship between chemical variables and to identify local and regional processes which influence quality of water, using principal component analysis for proper planning, water resource management, and sustainable development. Domestic and industrial wastewater constitutes a constant polluting source, whereas surface runoff is a seasonal phenomena mainly controlled by climate within the basin (Singh, *et al*, 2004). Weathering of primary and secondary minerals contributes to cations and silica in the system (Jacks, 1973 and Bartarya, 1993). In the present study, a detailed investigation has been made to identify the hydro geochemical processes and their relation with water quality, hydro chemical evolution of water system through principal component analysis, and spatial variation in the water quality. Assessment of water quality is important to determine its suitability for consumption in the domestic, agricultural, and industrial sectors. Chhoti Gandak River originates near Dhesopool in Mahrajganj district of Uttar Pradesh and after traveling a distance of about 250 km towards south, joins the Ghaghara near Gothani in Siwan district of Bihar. Chhoti Gandak River with its tributaries along with Rapti and Ghaghara are the main drainage of the Deoria district. The drainage pattern is subdendritic to dendritic and the streams are perennial to ephemeral in nature. Deoria district is located between $26^{\circ}06^{'}$–$26^{\circ}44^{'}$ N latitude and $83^{\circ}30^{'}$–$84^{\circ}12^{'}$E longitude in Uttar Pradesh. Basic information of Chhoti Gandak River and Deoria district is given in table Geologically, the area is made up of Quaternary alluvium of different ages consisting of clay, silt, sand, and gravel mixed in different proportions. The valley and channel width, cliff pattern, point bars and discharge of the river are controlled by climate, the migration and tilting is controlled by tectonics, and river terraces are evolved under the control of both tectonics and climate (Singh, *et al*, 2009). Older alluvium (Bhangar) and newer alluvium (Khadar) are the two morphostratigraphic units as described in the classical literature of the Ganga Plain (Pascoe, 1917). Upland terrace surface, river valley terrace surface, and present day river channel made up of older alluvium and newer alluvium are the main geomorphic units which are depositional in nature (Singh, 1996). Two main depositional areas, identified in the Ganga Plain are (a) channel areas and (b) interchannel areas. Sedimentation in the interchannel areas takes place mainly by sheet flow (Kumar, *et al*, 1995), and interfluve deposits (Singh, *et al*, 1999). Whereas river deposit sediments in the channel areas are in the form of channel-bar deposits (Singh and Singh, 2005). Water samples were collected in two sets from different stations at regular intervals along the entire length of Chhoti Gandak River during summer (June), 2006. The collected samples were stored in acid-cleaned, high-density polyethylene (HDPE) bottles (1000ml) which were carefully rinsed three times before use. The use of HDPE bottles minimizes container pollution and promotes the sample preservation (Hall, 1998). Analyses of water samples were carried out immediately after collection. Samples were stored in a refrigerator at 4°C prior to analysis. Temperature, P^H, conductivity, total dissolved solids were determined in the field by Cyber Scan 510. Potassium and sodium by Systronics Flame photometer 128, nitrate by Perkin Elmer, UV/VIS spectrometer, Lambda 40. Other parameters were measured using standard water quality procedures (American Public Health Association 1992, 1998). The reproducibility of the analytical procedures was checked by carrying out duplicate analysis. The variation in result was less than 5% of the mean. Ability to replicate samples was determined by collecting two samples at every station. Chemical data were analyzed by the principal component analysis, which quantifies relationship between the variables by computing the matrix of correlations for the entire dataset. In the present study results of the first three principal components were selected following Kaiser (1958) to explain the hydro-geochemical processes that control the ion concentrations of water, which account for most of the total variance in the dataset.

Analysis of the chemical constituents of the Chhoti Gandak River at different stations. The tables indicate that the concentration of P^H ranges from 6.24 to 8.61 and total dissolved solid (TDS), which is a measure of the degree of quality, varies from 60–192.6mg/L, with a mean of 103.56mg/L. As per the classification of TDS (Fetter 1990), all the water samples come under fresh type (TDS <1000mg/L). The total hardness (TH) in the water is in the range of 45– 370mg/L which indicates that the water of some sampling stations belongs to a very hard category (>300mg/L; Twort et al 1974). Cation and anion analysis shows that the content of Ca^{2+} is between 6 and 36mg/L; Mg^{2+} is between 4.8 and 42mg/L, Na^{+} is between 12 and 86mg/L, K^{+} is between 2.1 and 116mg/L; HCO^{-3} is between 98 and 451mg/L; Cl^{-} is between 3.5 and 121mg/L; SO_4^{2-} is between 88 and 186mg/L; NO^{-3} is between 14 and 38mg/L; and F^{-} is between 0.4 and 0.59mg/L, with mean values of 20.6, 18.2, 35.4, 21.2, 195.6, 38.1, 134.5, 24.5, and 0.45mg/L, respectively. Water is characterized by $Na^{+} > Ca^{2+} > Mg^{2+}$: $HCO^{-3} > SO_4^{2-} > Cl^{-} > NO^{-3}$ facies. The P^H and concentration of TH and Ca^{2+} in 40, 80 and 10% respectively of the water samples are more than the safe permissible limits proposed by Indian Standard Institute (1983) and World Health Organization (1984) (7–8.5 for P^H, 100mg/L for TH and 30mg/L for Ca^{2+}). So it can have an adverse affect on human health (Holden 1970; Maiti 1982). The values are shown in Table 2.2.3.

Another study was conducted by Karikari, *et al*., (1999) on An Assessment of Water Quality of Angaw River in Southeastern coastal Plains of Ghana. Rivers are the most important freshwater resource for man. Social, economic and political development has been largely related to the availability and distribution of freshwaters contained in riverine systems. Water quality problems have intensified through the ages in response to the increased growth and concentration of populations and industrial centers.

Table 2.2.3. Descriptive statistics of the analyzed chemical components

Sl no.	Parameter	Minimum	Maximum	Mean	St. Deviation	Coefficient Of Variation
1	Temperature	29.2	38.7	33.05	2.98673	8.9206
2	PH	6.24	8.61	7.386	0.75424	0.5689
3	Conductivity	120.7	310	198.52	67.76903	4292.6418
4	TDS	60.1	192.6	103.56	43.59916	1900.8871
5	K+	2.1	116	21.21	36.46622	1329.7854
6	Na+	12	86	35.45	24.68293	604.2472
7	Ca2+	6	36	20.65	11.97231	143.3361
8	Mg2+	4.8	42	18.205	14.16773	200.7247
9	Cl−	3.5	121	38.16	38.44448	1477.9782
10	F−	0.4	0.59	0.458	0.05978	0.03573
11	NO−3	14	38	24.5	7.47217	55.8333
12	SO42−	88	186	134.5	29.7069	882.5000
13	HCO−3	98	451	195.6	97.80161	9565.1556
14	SO4	10	28	15.2	5.59365	31.2889
15	T- Hardness	45	370	143.5	88.35063	7805.8333

(Source: Bhardwaj, *et al.*,2009)

Polluted water is an important vehicle for the spread of diseases. In developing countries 1.8 million people, mostly children, die every year as a result of water-related diseases (WHO, 2004). Ghana's water resources have been under increasing threat of pollution in recent years due to rapid demographic changes, which have coincided with the establishment of human settlements lacking appropriate sanitary infrastructure. This applies especially to peri-urban areas, which surround the larger metropolitan towns in the country. Many such settlements have developed with no proper water supply and sanitation services.

Table 2.2.4. Compliance of river water quality of water samples (%) to drinking and irrigation standar.

Sl No	**Parameter**	**WHO (1984)**	**ISI (1983)**	**Samples (%) exceed the safety limits**
1	P^H	7– 8.5	7–8.5	40
2	TDS	500	500	Within the range
3	TH	100	300	80
4	Ca^{2+}	75	75	Within the range
5	Mg^{2+}	30	30	10
6	Na^+	200	–	Within the range
7	HCO_3^-	–	300	Within the range
8	Cl^-	200	250	Within the range
9	SO_4^{2-}	200	150	Within the range
10	NO_3^-	45	45	Within the range
11	F^-	1.5	0.6–1.2	

(Source: Bhardwaj, *et al.*, 2009)

People living in these areas, as well as downstream users, often utilize the contaminated surface water for drinking, recreation and irrigation, which creates a situation that poses a serious health risk to the people (Verma and Srivastava, 1990). The River Angaw runs through farmlands and rural communities before its confluence with River Volta. Not much studies have, however, been done on the water quality of the river. This would be of importance since water supply treatment was being planned to supply water to the entire community at the time of the study. A number of factors influence water chemistry. Gibbs (1970) proposed that rock weathering, atmospheric precipitation, evaporation and crystallisation control the chemistry of surface water. The influence of geology on chemical water quality is widely recognised (Gibbs, 1970; Langmuir, 1997; Lester and Birkett, 1999). The influence of soils on water quality is very complex and can be ascribed to the processes controlling the exchange of chemicals between the soil and water (Hesterberg, 1998). Apart from natural factors influencing water quality, human activities such as domestic and agricultural practices impact negatively on river water quality. It is, therefore, important to carry out water quality assessments for sustainable management of water bodies. The study serves to determine the water quality of River Angaw. It provides the physicochemical and bacteriological characteristics of the water and, finally, contributes towards the limnological knowledge of the river. River Angaw is situated few kilometers from Ada Foah, a town noted for its beautiful beach and holiday resort. The river is located between latitude 5o 45'–5o 50' N and longitude 0o 34'–0o 38' E. River Angaw follows a course of about 19.48 km to join the Volta Lake. There is virtually no industrial development in the area. Pollution within the area may come from human waste. The use of agro-chemicals is a potential problem, though the amounts in use are currently limited by high cost. The main economic activities in the catchment area are fishing, basket weaving and crop farming along the banks of the river. Major crops include vegetables, maize and cassava. The study area experiences two seasons; a dry season from November to March and a two maxima rainfall. According to data from the Ghana Meteorological Agency at the Ada synoptic station, the major rains occur between April and June with a break in July while the minor rains occur between August and October. Meteorological data (1994–2004) at the Ada synoptic station revealed that the annual rainfall for the study area was 796.3 mm with mean daily temperatures ranging between 25.9 in August and 30.0 in March.

Three sites on River Angaw were selected and monitored once a month over a period of one year, from September 1997 to August 1998. The first site was located near the proposed water treatment plant known as selected site (SS) at Keseve. The other two sampling sites were located about 2 km upstream (US) and downstream (DS) of the proposed water supply treatment plant. Surface water samples for physico-chemical analyses were collected mid-stream at depth 20-30 cm directly into clean 1-litre plastic bottles. Temperature and pH were measured in situ, using a temperature probe and portable pH meter, respectively. For dissolved oxygen (DO) determinations, samples were collected into 300-ml plain glass bottles and the DO fixed using the azide modification of the Winkler's method. Samples for bacteriological analyses were collected into sterilized plain glass bottles. All samples were stored in an icebox and transported to the CSIR-Water Research Institute's Laboratory in Accra for analyses.

The methods outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998) were followed for the analyses of all the physico-chemical parameters. Conductivity was measured with Jenway model 4020 conductivity meter, and turbidity with a Partech model DRT 100B Turbidimeter. Sodium and potassium were measured by flame emission photometry; calcium and magnesium by EDTA titration; sulphate by the turbidimetric method; colour by colour comparator and chloride by argentometric titration. Other analyses included alkalinity by strong acid titration method. Nitrate-nitrogen was analysed by hydrazine reduction and spectrometric determination at 520 nm, nitrite-nitrogen by diazotization and spectrophotometric determination at 540 nm, phosphate by reaction with ammonium molybdate and ascorbic acid, and measured at 880 nm, and ammonium by direct nesslerisation and spectrophotometric determination at 410 nm. Fluoride by SPADNS method and total dissolved solids, and suspended solids were measured gravimetrically after drying in an oven to a constant weight at 105 ^{o}C. Total and faecal coliforms were determined by membrane filtration method using M-Endo-Agar Les (Difco) at 37 ^{o}C and on MFC Agar at 44 ^{o}C, respectively. Pearson's rank correlation was used to establish relations between parameters. All tests were two-tailed. The analyses were executed by SPSS (version 12 for Windows, year 2003).

The mean pH of the river water was neutral at all stations for the study period with a range of 7.2–7.3. The pH fell within the range associated with most natural waters which is between 6.0 and 8.5 (Chapman, 1992), stipulated for drinking and domestic purposes. The mean conductivity of the river ranged between 608 and 947 μS/cm in this order of increasing magnitude: downstream < selected site < upstream. This order prevailed most of the time throughout the study period. The downstream recorded relatively low conductivity throughout the monitoring, due to dilution from River Volta which has much lower conductivity (62–77.5 μS/cm) (Antwi and Ofori-Danson, 1993). The upstream level was always high probably due to the nature of the soil at the water source. Mean values of turbidity were 2.96 NTU, 2.28 NTU and 1.75 NTU for the upstream, selected site and downstream, respectively. The levels of turbidity recorded in this study were comparable to those reported for River Volta at Akuse (mean range 2.8–3.2 NTU) by Water Research Institute (1999). However, average turbidity recorded in Birim basin (37.5 NTU) by Ansa-Asare and Asante (2000) were much higher than those observed in the study. The low turbidity throughout the sampling period suggests that discharges from domestic effluents and run-offs from agricultural activities that reach the river may be minimal or large particulates that readily settled to the bottom. The low turbidity of the river will facilitate water purification processes such as flocculation and filtration, which could reduce treatment cost. The hardness of the river reduced from upstream to the downstream. The US, SS and DS recorded average hardness levels of 133, 107 and 89 mgl-1 CaCO3, respectively. The relatively lower levels downstream may be attributed to the influence of River Volta which has very low levels of hardness (19–38 mgl-1 CaCO3) (Antwi and Ofori-Danson, 1993). Alkalinity followed a similar trend as hardness. Dissolved oxygen (DO) mean levels varied between 6.15 and 6.87 mgl-1. The downstream had relatively higher oxygen throughout the study. This might be due to the windy nature of the area and the regular mixing of the water with the Volta Lake which has higher DO content. Pristine surface waters are normally saturated with

DO, but such DO can be rapidly removed by oxygen demand of organic wastes. The measurement of DO provides a broad indicator of water quality (DFID, 1999). DO concentra-tions in unpolluted water are normally about 8.0–10 mg/l (at 25 oC) (DFID, 1999). Concentrations below 5.0 mgl-1 adversely affect aquatic life. The concentration of DO in the Angaw river were above 5.0 mgl-1 and, therefore, the river water would be suitable for use of the aquatic ecosystem.

NH4-N, NO3-N and NO2-N are considered to be non-cumulative toxins (Dallas and Day, 1993). High concentra-tions of NO3-N and NO2-N may give rise to potential health risks particularly in pregnant women and bottle-fed infants (Kempster, *et al.*, 1997; Kelter, *et al.*, 1997). NO3-N at elevated concentra-tions is known to result in cyanosis in infants. Ammonia is naturally present in surface water and groundwater and can be produced by the deamination of organic nitrogen containing compounds and by the hydrolysis of urea. The problem of taste and odour may, however, arise when the NH4-N level is greater than 2 mgl-1. Above 10 mgl-1, appreciable amounts of NO3-N may be produced from NH4-N under suitable anaerobic conditions (WHO, 1993; Kempster, *et al.*, 1997). The mean concentrations of nutrients are presented . Nitrate levels averaged 0.880 mgl-1 as N at the upstream; 0.321 mgl-1 at the selected site and 0.304 mgl-1 at the downstream. The average NO3-N concentration of Angaw river was much higher than the 0.1 mgl-1 for unpolluted world rivers (Webb and Walling, 1992). The WHO safe limit for nitrate for lifetime use is 10 mgl-1 as N (WHO, 1984). This limit was not exceeded in the river water; thus, nitrate is not considered to pose a problem for the domestic use of water from the river. However, nitrate could be a problem for other uses because of eutrophication (Rast and Thornton, 1996). Mean levels of ammonia were 0.191 mgl-1; 0.144 mgl-1 and 0.113 mgl-1 for upstream, selected site and downstream, respectively. Low ammonia concentrations were also observed in the Kpong Reservoir by Antwi and Ofori-Danson (1993) with a mean of 0.02 mgl-1 and a range of < 0.001– 0.12 mgl-1. At Akuse on the Volta river, Water Research Institute (1999) recorded a mean level of 0.21 mgl-1 ammonia and a range of 0.193–0.227 mgl-1. Unpolluted waters contain small amounts of ammonia, usually less than 0.1 mgl-1 (Chapman, 1992). The concentrations of ammonia in the Angaw river for the duration of the study were not alarming due to low anthropogenic activities reaching the river. Phosphurous is the limiting nutrient for algal growth and, therefore, controls the primary productivity of a water body. In most natural surface waters, phosphorous ranges from 0.005 to 0.020 mgl-1 PO4-P (Chapman, 1992). In some pristine waters concentra-tions as low as 0.001 mgl-1 may be found. Mean levels of phosphates were 0.030 mgl-1 as P at the US; 0.050 mgl-1 at the SS; and 0.030 mgl-1 at the DS. High concen-trations of phosphate can indicate the presence of pollution and are largely responsible for eutrophic conditions. Eutrophication-related problems in warm-water systems begin at P concentrations of the order 0.34–0.70 mg P/l (Rast and Thornton, 1996). The associated N concentrations would be of the order 0.34–0.70 mg N/l. It is accepted that these represent nutrient threshold levels, beyond which there will be a corresponding increase in the risk and intensity of plant-related water quality problems (OECD, 1982). River Angaw was not observed to be eutrophic, nevertheless, care must be taken so that eutrophication would not be a problem in the river. The river is being abstracted and treated to supply water to Ada Foah, Kasseh and its environs and eutrophication could increase its treatment cost through filter clogging in water treatment works (Murray, *et al.*, 2000). Silica is an essential element for aquatic plants (e.g. diatom). It is taken up during cell growth and released during decomposi-tion and decay giving rise to fluctuations. The mean silica values (between 11 and 14.2 mgl-1) observed in the river was higher than the world average of 9 mgl-1 in rivers (Horne and Goldman, 1995) but fell within 1-30 mgl-1 which is the range for most rivers and lakes (Chapman, 1992).

The results indicated that most of the physico-chemical quality parameters of River Angaw were within the WHO limits for drinking water and, therefore, may be suitable for domestic purposes. In contrast, however, the bacteriological quality of the water points, as suggested by the total and faecal coliform counts, exceeded the standard (0 cfu/ 100 ml) for potable water. In general, the bacteriological quality of the water was unacceptable, and would pose a serious risk to consumers without treatment. The poor bacteriological quality was due to direct contamination by animal and human wastes. The striking characteristic of River Angaw is its high ionic content which is reflected in high conductivity, total dissolved solids and sodium levels. Relatively higher levels of most physicochemical constituents occurred at the upstream while lower concentrations were observed downstream due to the influence of River Volta which has lower ionic content. Conductivity, TDS and most major ions varied seasonally with elevated levels in the rainy season. However, nutrient levels were low during the study period and did not give any clear seasonal variation. Even though the nutrient concen-trations were low, care must be taken by the inhabitants and the District Assembly to avoid eutrophication in the river since it is being abstracted and treated for water supply.

2.3 Catagories of pollutants

Water quality is important because it decides for what purpose it should and it should not be used for. There are three systems used for assessing the quality of river water (i) chemical analysis, where samples of the water are tested in a laboratory for a range of parameters. Chemical analysis can identify specific pollutants and they show conditions in the river at the time the same is taken. (ii) The physical assessment that involves measure the changes of physical properties in water. (iii) Biological assessment however, shows the effects of pollutants on the aquatic organisms at the time of sampling and it also reveals the longer-term effects of changing water quality (Metcalf and Eddy, 2003).

2.3.1 Chemical

Generally chemical properties of water involve P^H , chloride, alkalinity or T-alkalinity, hardness, N-nitrogen, phosphorus, sulfur, gases, ammonia, nitrate and nitrite, DO, BOD, COD, metallic constituents (Metcalf and Eddy, 2003). Among all type of chemical properties DoE measure P^H , chloride, alkalinity or T-alkalinity, hardness, DO, BOD, COD.

2.3.2 Physical

The most important physical properties of water are color, odor, temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid (Metcalf and Eddy, 2003). Among all physical properties DoE measure temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid.

2.3.3 Biological

Biological properties of water involve all type micro organisms including bacteria, fungi, algae, protozoa,plants, animals, fungi, algae (Metcalf and Eddy, 2003). Our supplied data did not contain any biological properties.

2.4 Water Quality Standards of Bangladesh and World Health Organization

Water quality standards set limits on the concentrations of impurities allowed in water. Standards also affect the selection of raw water sources and the choice of treatment processes required. The development of water quality standards began in the United States in the early 20th century. Since that time, the total number of regulated contaminants has increased as toxicological knowledge and analytical measurement techniques have improved. Modern testing methods now allow the detection of contaminants in extremely low concentrations. Water quality standards are continually evolving, usually becoming more stringent. As a result, the number of regulated contaminants increased over time, and their allowable concentrations in water are lowered. Table 2.4.1 Shows the water quality standards for Bangladesh and WHO.

Table 2.4.1 Drinking Water Quality Standards

Water quality parameter	Unit	Bangladesh Standards ECR, 1997	WHO Guideline Values (1996)
Aluminium	mg/l	0.2	0.2
Ammonia	mg/l	0.5	1.5
Arsenic	mg/l	0.05	0.01
Barium	mg/l	0.01	0.7
Benzene	mg/l	0.01	0.01
BOD	mg/l	0.2	-
Boron	mg/l	1	-
Cadmium	mg/l	0.005	0.005
Calcium	mg/l	75	-
Chloride	mg/l	150-600	250
Carbon-tetrachloride	mg/l	0.01	0.002
Chlorinated Phenols	mg/l	0.03	-
Chlorine	mg/l	0.2	0.5
Chloroform	mg/l	0.09	0.2
Chromium	mg/l	0.05	-
Chromium (Total)	mg/l	0.05	0.05
COD	mg/l	4	-
Coliform(Fecal)	No./100ml	0	0
Coliform(Total)	No./100ml	0	0
Color	PL-Co Unit	15	15
Copper	mg/l	1	2
Cyanide	mg/l	0.1	0.07
Detergents	mg/l	0.2	-

Table 2.4.1 (Continued)

Water quality parameter	**Unit**	**Bangladesh Standards ECR, 1997**	**WHO Guideline Values (1996)**
DO	mg/l	6	-
Fluoride	mg/l	1	1.5
Hardness(CaCO3)	mg/l	200-500	500
Iron	mg/l	0.3-1	0.3
Nitrogen	mg/l	1	-
Lead	mg/l	0.05	0.01
Magnesium	mg/l	30	-
Manganese	mg/l	0.1	0.5
Mercury	mg/l	0.001	0.001
Nickel	mg/l	0.1	0.02
Nitrate	mg/l	10	50
Nitrite	mg/l	<1	3
Odor		Odorless	Odorless
Oil and grease	mg/l	0.01	-
pH		6.5-8.5	6.5-8.5
Phenolic compounds	mg/l	0.002	-
Phosphate	mg/l	6	-
Phosphorus	mg/l	0	-
Potassium	mg/l	12	-
Total Alfa Radio Active Substance	Bq/l	0.01	0.1
Selenium	mg/l	0.01	0.01
Silver	mg/l	0.02	-
Sodium	mg/l	200	200
Suspended Solids	mg/l	10	-

Table 2.4.1 (Continued)

Water quality parameter	**Unit**	**Bangladesh Standards ECR, 1997**	**WHO Guideline Values (1996)**
Sulfide	mg/l	0	-
TDS	mg/l	1000	1000
Temperature	ºC	20-30	-
Tin	mg/l	2	-
Turbidity	NTU	10	5
Zinc	mg/l	5	3
Sulfate	mg/l	400	250

(Source: ECR, 1997)

Table2.4.2 Bangladesh standards for surface water quality

Water quality parameter	**Unit**	**Disinfections only**	**Conventional treatment**
P^H	-	6.5-8.5	6.5-8.5
BOD	mg/l	<2	<3
DO	mg/l	>6	>6
Total coliform	No./100ml	<50	<5000

(Source: ECR, 1997)

2.5 Summary

Every researcher suggested some specific way depending on type and concentration of parameters. But commonly they suggested that regular practice of wastewater treatment before discharging it to the receiving water bodies should be ensured first, the environmental standard regulatory commission or the DOE should take a firm footstep to ensure the safe disposal of the effluent, continuous monitoring, at strategic points, at regular intervals to quantitatively determine the pollution load.

Chapter 3

THEORY AND METHODOLOGY

3.1 General

This chapter has been arranged to give a clear concept to reader about give the geographical information of the study area. This chapter will cover the step to step procedure of DoE from field work to produce raw data including sample collection to laboratory procedure. This chapter will also give the information to reader about the source of pollution.

3.2 Location of the study area

Khulna Division with an area of 22273.21 sq km, is bounded by Rajshahi division on the north, Bay of Bengal on the south, Dhaka and Barishal divisions on the east, West Bengal on the west. Khulna division consists of one city corporation, 10 districts, 28 municipalities, 5 thanas, 59 upazilas, 569 union parishads, 6093 mouzas, 256 wards, 709 mahallas and 9277 villages. The districts are Khulna, Shathkhira, Bagerhat, Jessore, Jhenaidha, Magura, Narail, Kushtia, Chuadanga, Meherpur.

River Bhairab enter in to Bangladesh from Meherpur district and merged with Rupsha River in Khulna district. It passes over Chuadanga, Jassore and Khulna districts. Its catchment area is 905 Square meter.

The offtake of Kakshially River started from Ichamoty River and passes over Shathkhira District. Its catchment area is 60 Square meter.

The offtake of River Gorai starts from Padma River and passes through Kustia, Magura, Rajbari and Faridpur District. Its catchment area is 4568 Square meter.

Figure 3.2.1: Khulna Division (Source: WARPO, 2004 and CEGIS, 2004).

The offtake of Rupsha River starts from Bhairab River and passes through Khulna District. Out fall of Rupsha River is Kazibacha River. The catchments area of Rupsha River is 2935 Square meter.

The Pasur River is a river in southwestern Bangladesh. The Pashur river is a continuation of the Rupsa, which is formed of the union of the Bhairab and Atrai rivers.The offtake of Mathavanga River starts from Ganges River and passes through Kustia District. Out fall of Mathavanga River is Churnee River.

The catchments area of Rupsha River is 500 Square meter. Offtake of Kapotakhkho River starts from Bhairab River and passes through Jassore, Jhinaidah, Shathkira and Khulna Districts.

The out fall of Kapotakhkho River is Kholpetua River. The catchments area of Kapotakhkho River is 800 Square meter.

The Mouri River flows at the north side of Khulna city and separates the Dumuria thana from Khulna City. The river is about 9.5 Km long and falls into Rupsha River near Badamtala Khulna.

3.3 Climate of the study area

3.3.1 Season and rainfall

The climate of the said region is greatly influenced by the onset and withdrawal of the annual monsoon. Four distinct seasons are recognized. These are as follows:

(i) Pre-monsoon season: It extends from April to May and is characterized by increasing rainfall and sometimes-intense rainfall of short duration.

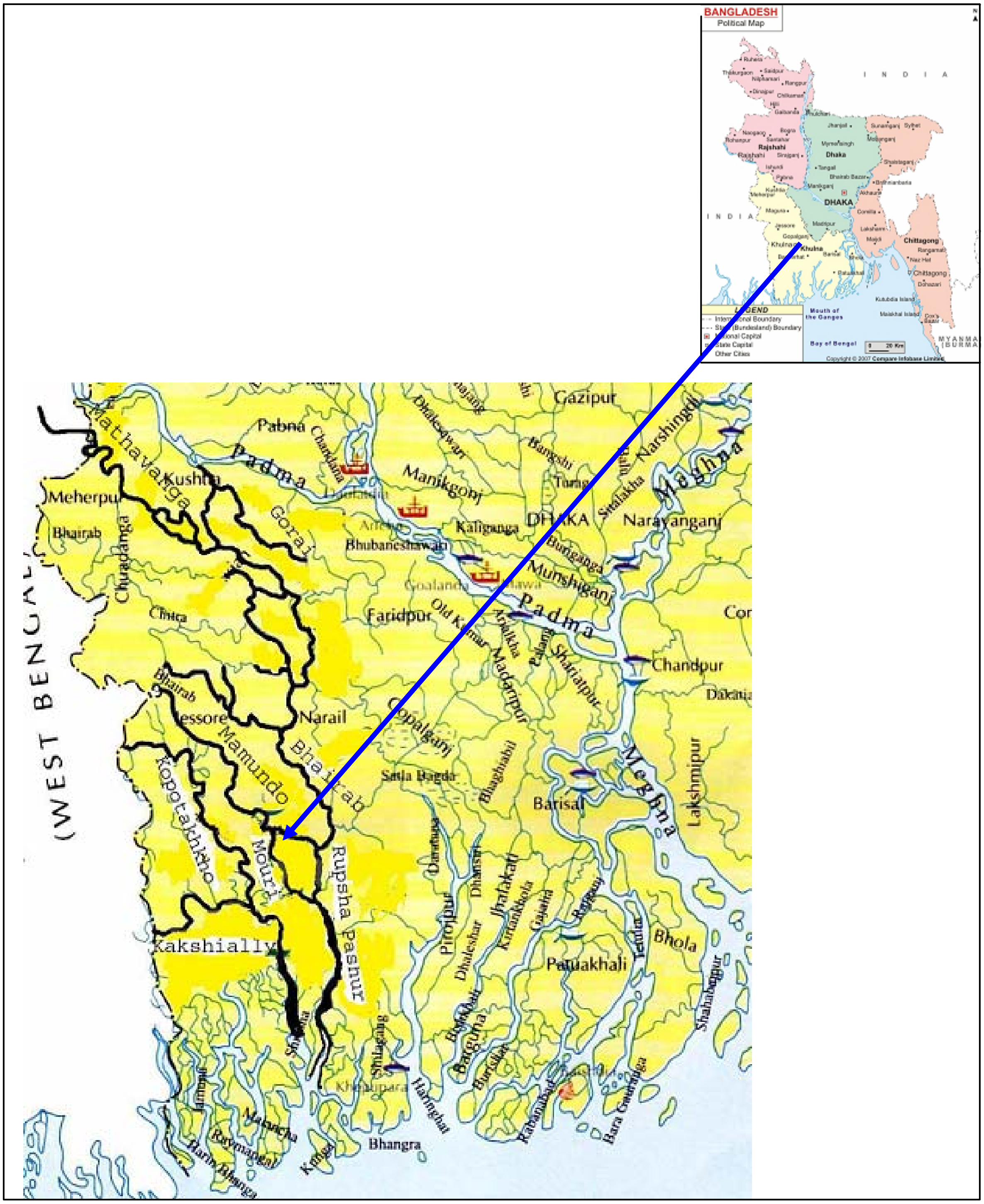

Figure 3.2.2: Rivers of Bangladesh (Source: WARPO, 2004 and CEGIS, 2004)

(ii) Monsoon season: It spreads over from the period June to September and is characterized by heavy rainfall occurring over longer duration. About 65 to 69% of the total rainfall occurs during the monsoon.

(iii) Post-monsoon season: It extends from October to November and characterized by decreasing rainfall. About 6 to 8% of the total rainfall occurs during the season.

(iv) Dry season: It extends from December to March, characterized by little or no rainfall. Only 3 to 4% of the total occurs in this season.

3.3.2 Floods

The annual flooding pattern in southern part of Bangladesh is easily distinguished into two types:

(i) Flash Floods

Flash floods occur in the pre-monsoon months of April and May in the piedmont rivers of the basin as a result of intense rainfall over short durations when the water levels in the rivers and beels are relatively low. The rapidly rising flood spills over banks and eventually flows into the lowland flood plains and in haors through khals. Rapid rise in river stage and consequent flow velocity cause extensive damages. As the water level in the river is relatively low, the flood stage in the piedmont rivers recedes very quickly.

(ii) River Floods

River floods occur in the monsoon season when the rivers flow very high causing over bank flow, which is aggravated by the backing up of water by the Meghna River and other rivers resulting in deep flooding through out the souther part of Bangladesh. The high flood levels persist throughout the monsoon and recedes as monsoon ends. During

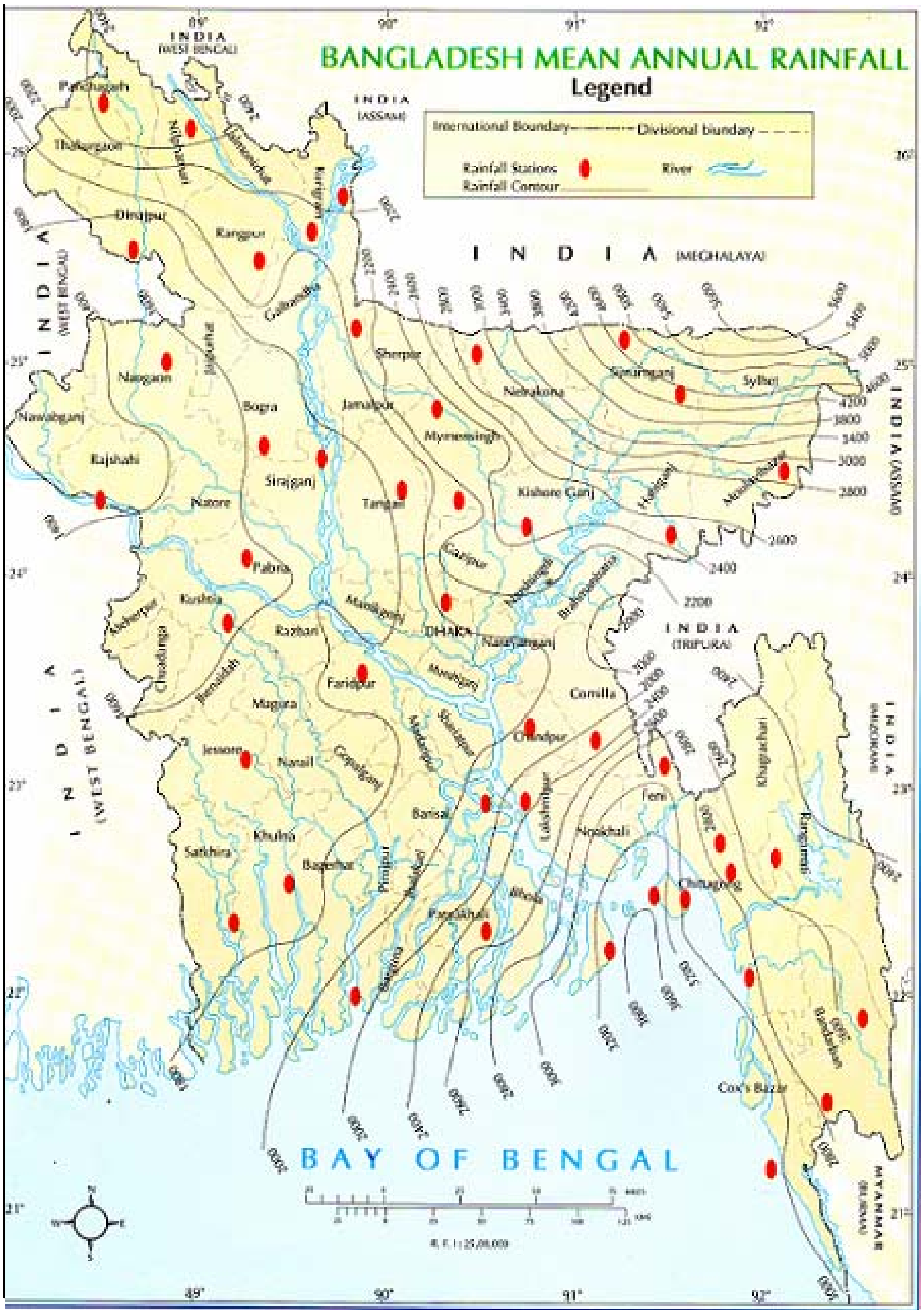

Figure 3.3.1: Average annual rainfall of Bangladesh (Source: BMD, 2003)

the monsoon season, all rivers overflow laterally into adjacent flood plains, except for those portions of the rivers which have full flood embankment.

3.4 Justification of the study area selection

The location of the study area was selected on the basis of the following environmental significance:

i. Sites of industrial complexes and local factories and restaurants along the stretch the river.
ii. Development of new industry.
iii. Discharge of industrial along with municipal waste.
iv. Effects on the downstream consumers.
v. Vehicular traffic traverses around the particular site emitting considerable exhaust of particulates, fuel and gases from automobiles and boats.

3.5 Sampling

The signification of a chemical analysis depends to a large extent on the sites of sample collection. An ideal sample should be one, which is both valid and representative. These conditions were met by DoE while collecting the samples through a process of appropriate location selection. This ensures that the composition of the sample was identical to that of the water body from which it was collected and the sample shared the same physico-chemical characteristics with the sampled water at the time and site of sampling.

3.5.1 Sampling program

The most important task of water quality analysis is sampling. One of the common causes of error in water quality analysis is improper sampling. So sampling of water should be accomplished with proper precaution to secure a representative sample. The sample must also be kept in such a manner that the concentration of the species to be analyzed remains unchanged during handling, transportation and possible storage. Meaningful and reliable sampling assures the validity of analytical findings. The goal of

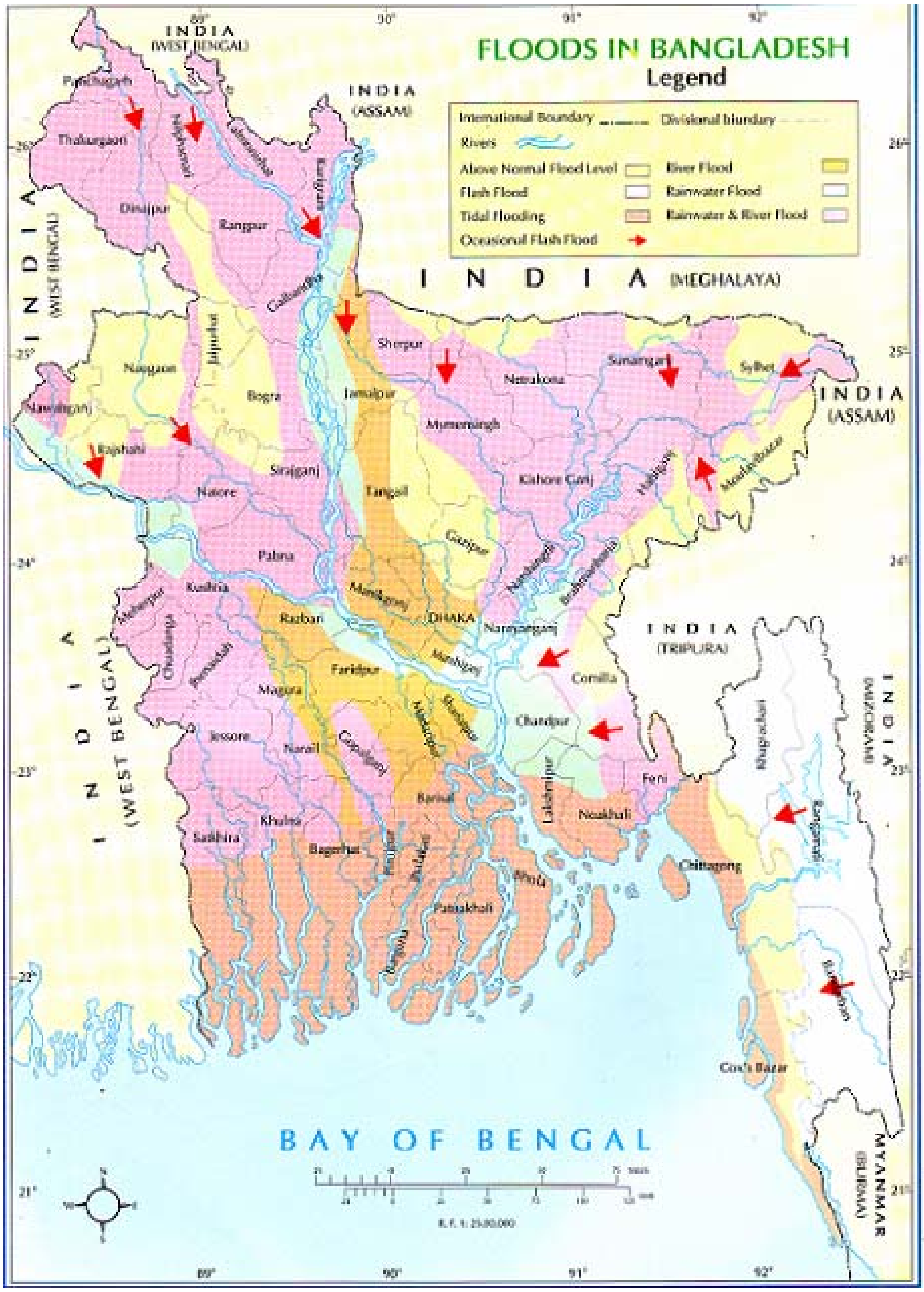

Figure 3.3.2: Types of flood in Bangladesh (Source: BMD, 2003)

sampling is to obtain for analysis a portion of the main body of water that is fully representative. All of these criteria about collecting the samples were assumed to be met by DoE more or less. The critical factors were-

i. Sampling point
ii. Sampling time
iii. Sampling frequency
iv. Maintenance of integrity of sample prior to analysis.

3.5.2 Standard sampling rule

The following general rules are followed by DoE to all sampling procedure:

i. The samples must represent the conditions existing at the point taken.
ii. The samples must be of sufficient volume and must be taken frequently enough to permit reproducibility of testing requisite for the desired objective as conditioned by the method of analysis to be employed.
iii. The samples must be collected, packed and manipulated prior to analysis in a manner that safeguards against change in the particular constituents or properties to be examined.

3.5.3 Sampling procedure

The sampling methods are-

i. Grab Samples
ii. Composite Samples
iii. Continual Samples

A grab sample represents the conditions existing only at the point and time of sampling water from sources such as wells, rivers, streams, lakes, oceans, reservoirs, pipelines etc.

i. Volume of sample: For physical and chemical analysis, a minimum volume of 2 liters should be collected, 4 liters is preferable.
ii. Point of sampling: Because of a wide variety of conditions found in streams, lakes, reservoirs, and other bodies of water, it is not possible to prescribe the exact point of sampling. The point of sampling should be chosen with extreme care so that a representative sample of water to be tested is obtained.
iii. Preparation of sample containers: The bottle may be borosilicate glass or other material resistant to the solvent action of water. It is to be cleaned the sample bottles with hot cleaning solution, pre added by soap or biodegradable detergent washing if necessary. Residual cleaning solution should be rinsed out with reagent water and dry by draining.
iv. Samples collection: Before taking sample, the sample container should be rinsed at least three times by filling it to one-fourth of its capacity with water to be sampled, shaking, and then emptying. Contact with air can change the concentration or characteristics of a constituent to be determined. So the sample should be secured against contact with air and containers should be completely filled with sample water. Collect the water by upward displacement through a tube extending to the bottom of the container and allowed the container with a stopper previously rinsed with the sample water.
v. Time interval between collection and analysis of samples: In general, allowing as short a time as possible to elapse between the collection of a sample and its analysis. Under some conditions, analysis in the field is necessary to secure reliable results. It is difficult to state exactly how much time can be allowed between the collection of a sample and its analysis. The following maximum limits in Table 3.1 are suggested for standard methods (APHA,1998) as reasonable for physical and chemical analysis:

Composite samples may be made by mutual agreement of the interested parties by combining individual (grab) samples taken at frequent intervals or by means of automatic samples. At the end of a definite period, samples are thoroughly mixed. Conti-

-nual samples stands for sampling water from sources such as wells, rivers, streams, lakes, pipelines, etc. on a continual basis.

Table 3.5.1 Time interval between collection and analysis of water sample.

Sample water	Time interval (hours)
Unpolluted waters	72
Slightly polluted waters	48
Polluted waters	12

(Source: APHA, 1998)

3.5.4 Procedure applied

Grab samples procedure was applied in the sampling from the said rivers of by DoE.

i. Volume of samples: 2 liters of each sample in each location.
ii. Point of sampling: A number of points at the surface across the entire width and at a number of depths at each point were selected to collect the sample.
iii. Preparation of sample containers: Plastic containers of capacity greater than 2 liters were used and prepared as mentioned before.
iv. Sample collection: Sample was collected according to the standard procedure as described before.

3.6 Sampling frequency & collection of sample

(i) Bhairab River: Samples were collected by DoE according to standard sampling procedure from following points , Table: 3.6.1 Sampling points of Bhairab River.

Sl. no.	Sampling points	Identification in figure
1	Noapara Ghat (Jassore , Side Point)	(1)
2	Noapara Ghat (Jassore, Middle Point)	(2)
3	Noapara Ghat (Jassore, Opposite Point)	(3)
4	Phultala Ghat (Khulna, Side Point)	(4)
5	Phultala Ghat (Khulna, Middle Point)	(5)
6	Phultala Ghat (Khulna, Opposite Point)	(6)
7	Labanchara Ghat (Khulna, Side Point)	(7)
8	Labanchara Ghat (Khulna, Middle Point)	(8)
9	Labanchara Ghat (Khulna, Opposite Point)	(9)
10	Charerhat Ghat (Khulna, Side Point)	(10)
11	Charerhat Ghat (Khulna, Middle Point)	(11)
12	Charerhat Ghat (Khulna, Opposite Point)	(12)

Samples were collected by DoE during the month April, May and August of 2007 during high tide and low tide.

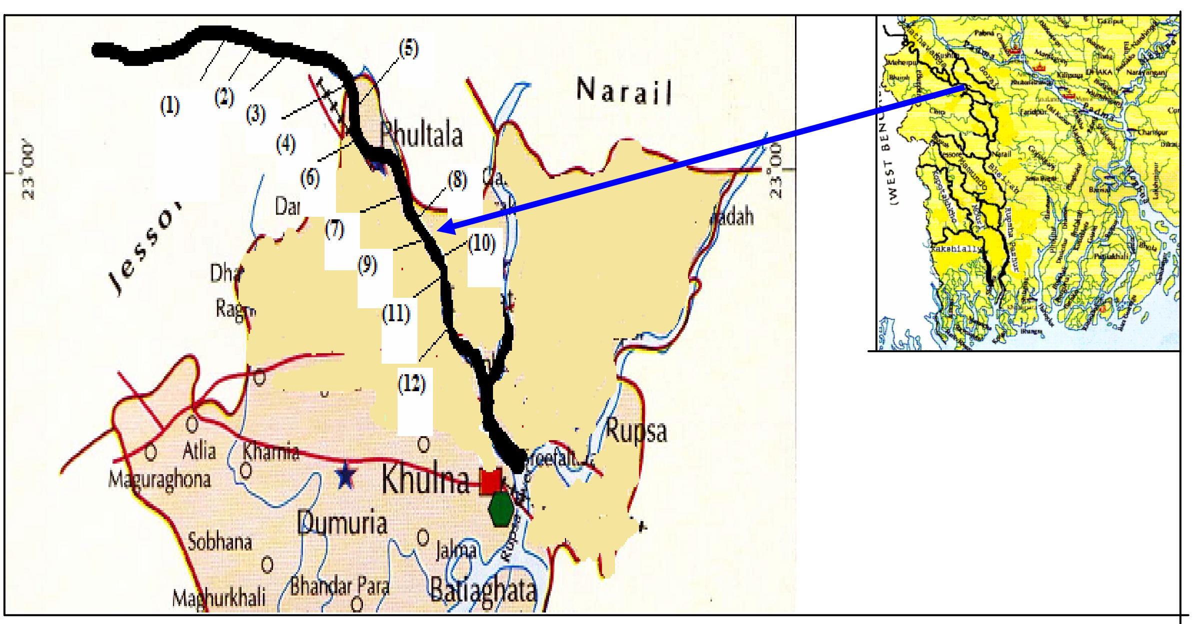

Fig 3.6.1: Sampling stations of Bhairab River.

(ii) Gorai River: Samples were collected by DoE according to standard sampling procedure from following points,

Table 3.6.2 Sampling points of Gorai River.

Sl. no.	Sampling points	Identification in figure
1	G.K. Ghat Kustia (Opposite Point)	(1)
2	G.K. Ghat (Kustia , Side Point)	(2)
3	G.K. Ghat (Kustia , Middle Point)	(3)
4	Kamarkhali Ghat (Magura , Side Point)	(4)
5	Kamarkhali Ghat (Magura, Middle Point)	(5)
6	Kamarkhali Ghat, (Magura, Opposite Point)	(6)

Samples were collected by DoE during the month April, May , July, August and September of 2007 during high tide and low tide.

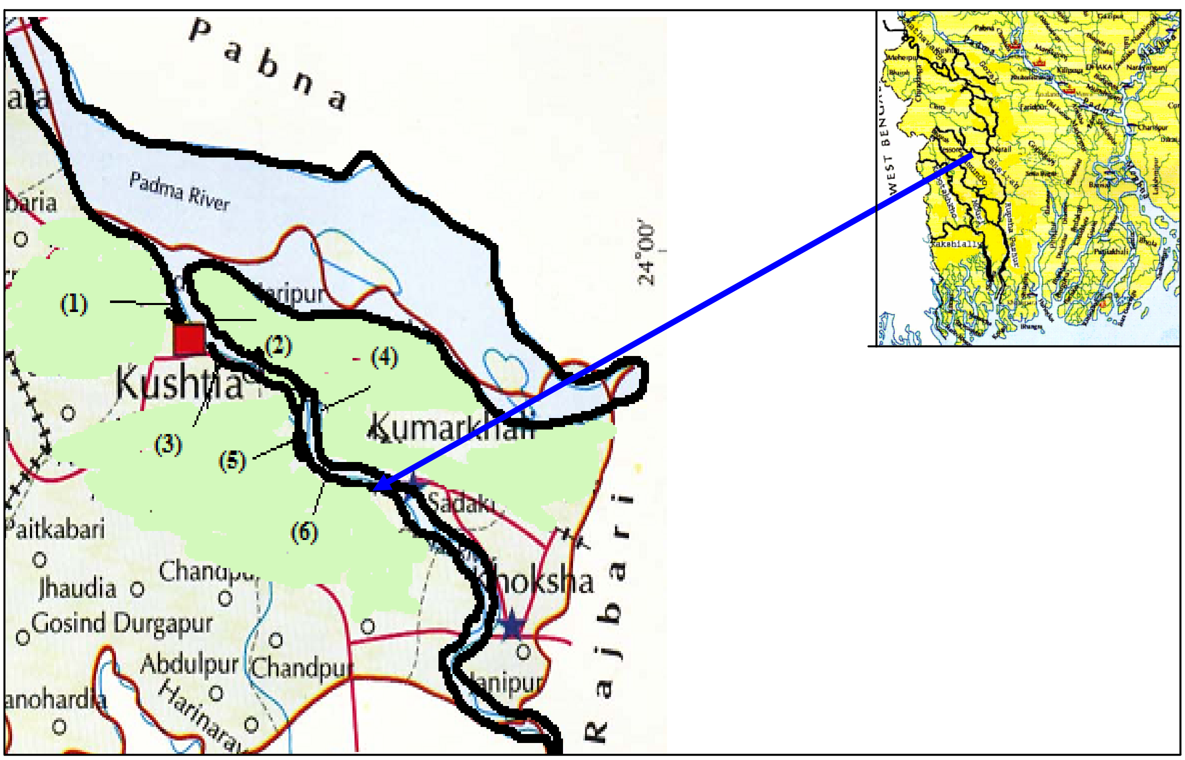

Fig 3.6.2: Sampling stations of Gorai River.

(iii) Rupsha River: Samples were collected by DoE according to standard sampling procedure from following points,

Table 3.6.3 Sampling points of Rupsha River.

Sl. no.	Sampling points	Identification in figure
1	Rupsha ghat (Khulna , Side Point)	(1)
2	Rupsha ghat (Khulna, Middle Point)	(2)
3	Rupsha ghat (Khulna , Opposite Point)	(3)
4	Bank of Rupsha River Rupsha ghat (Khulna , Side Point)	(4)
5	Bank of Rupsha River Rupsha ghat (Khulna, Side Point)	(5)

Samples were collected by DoE during the month April, May , August and September of 2007 during high tide and low tide.

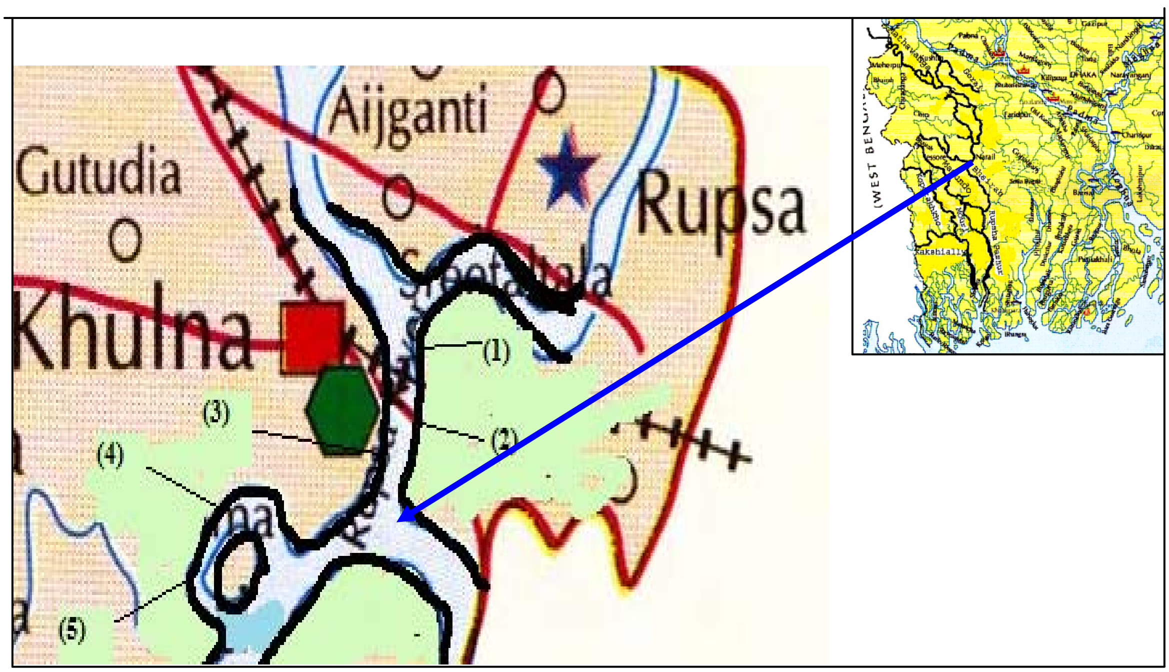

Fig 3.6.3: Sampling stations of Rupsha River.

(iv) Pasur River: Samples were collected by DoE according to standard sampling procedure from following points,

Table 3.6.4 Sampling points of Pashur River.

Sl. no.	Sampling points	Identification in figure
1	Mongla Ghat (Side Point)	(1)
2	Mongla Ghat (Middle Point)	(2)
3	Mongla Ghat (Opposite Point)	(3)
4	Mongla Ferry Ghat (Bagerhat Side Point)	(4)
5	Mongla Ferry Ghat (Bagerhat Middle Point)	(5)
6	Mongla Ferry Ghat (Bagerhat Opposite Point)	(6)

Samples were collected by DoE during the month April, May and September of 2007 during high tide and low tide.

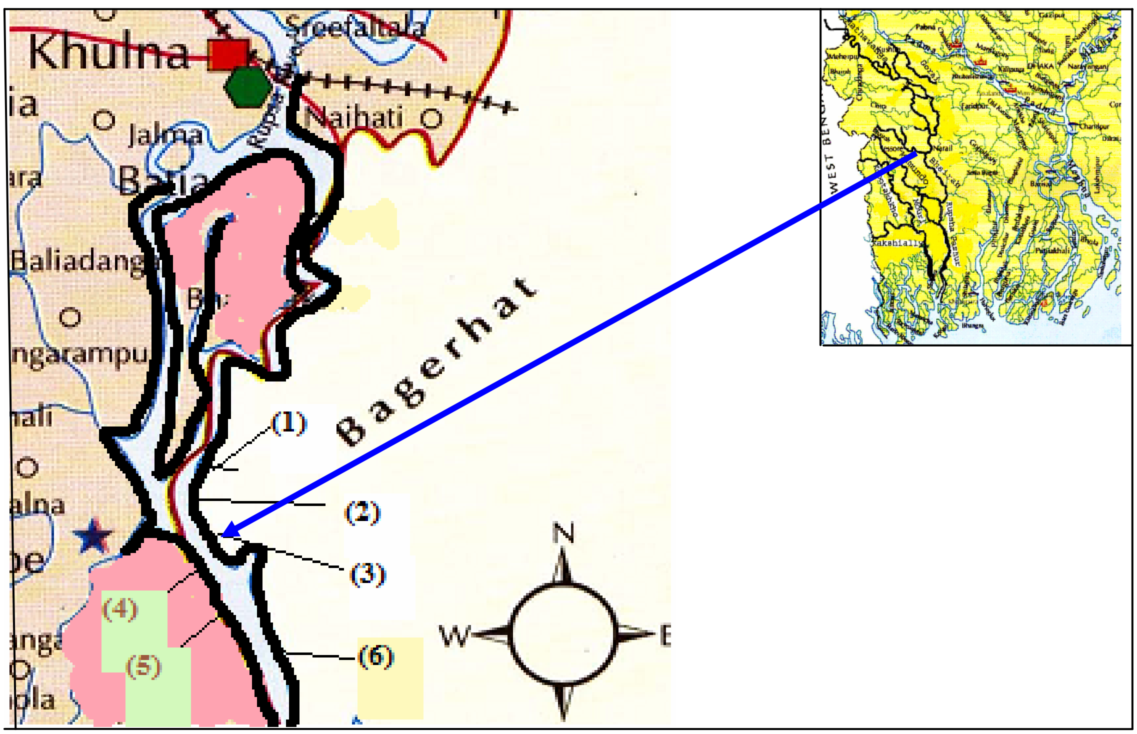

Fig 3.6.4 Sampling stations of Pashur River.

(v) Mathavanga River: Samples were collected by DoE according to standard sampling procedure from following points,

Table 3.6.5 Sampling points of Mathavanga River

Sl. no.	Sampling points	Identification in figure
1	200m upstream of droping point of Carew & Company	(1)
2	Main Drain of Carew & Company	(2)
3	200m Downstream of droping point of Carew & Company	(3)
4	100m upstream from dropping point of Mathavanga River (Chuadan)	(4)
5	Dropping Point of Mathavanga River (Darshawna, Chuadanga)	(5)
6	100m Downstream from dropping point of Mathavanga River (Chuadanga)	(6)

Samples were collected by DoE during the month April and May of 2007 during high tide and low tide.

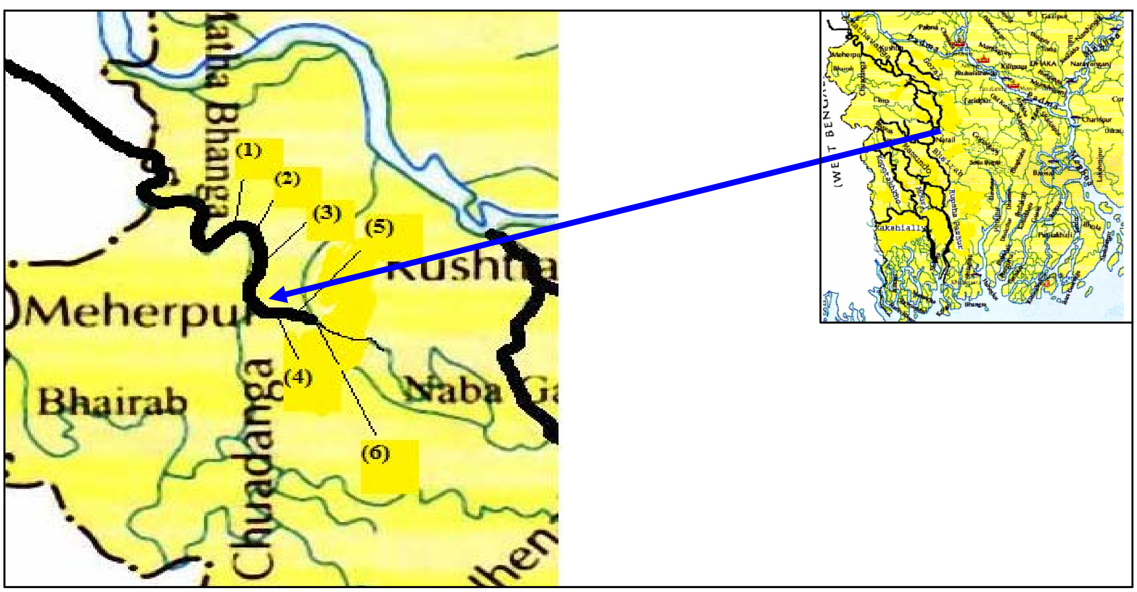

Fig 3.6.5 Sampling stations of Mathavanga River.

(vi) Kakshially River : Samples were collected by DoE according to standard sampling procedure from following points,

Table 3.6.6 Sampling points of Kakshially River

Sl. no.	Sampling points	Identification in figure
1	Kaligonj Shathkhira (Side Point)	(1)
2	Kaligonj Shathkhira (Middle Point)	(2)
3	Kaligonj Shathkhira (Opposite Point)	(3)
4	Bank of Kakshially river Kaligonj Shathkhira (Side Point)	(4)
5	Middle of Kakshially river Kaligonj Shathkhira (Middle Point)	(5)
6	Bank of Kakshially river Kaligonj Shathkhira (Middle Point)	(6)

Samples were collected by DoE during the month July and August of 2007 during high tide and low tide.

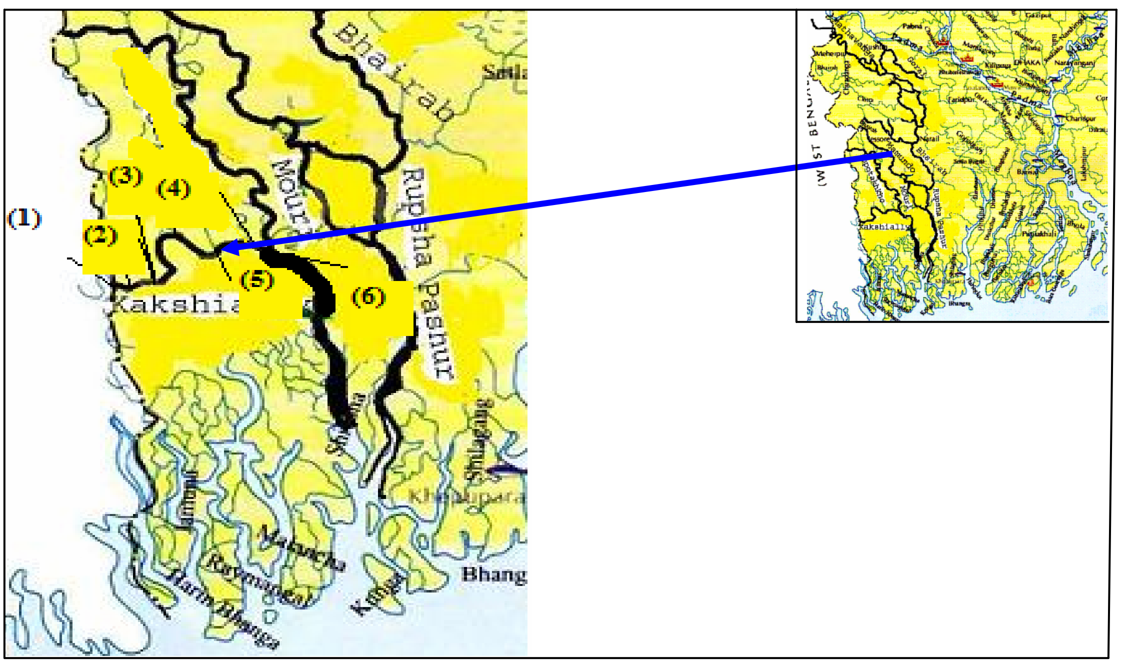

Fig 3.6.6: Sampling stations of Kakshially River.

(vii) Mouri River**:** Samples were collected by DoE according to standard sampling procedure from following points,

Table 3.6.7 Sampling points of Mouri River

Sl. no.	**Sampling points**	**Identification in figure**
1	Shashanghat (gollamari, khulna, 100m upstream)	(1)
2	Shashanghat (gollamari, khulna)	(2)
3	Shashanghat (gollamari, khulna, 100m downstream)	(3)
4	Mouri River from 100m upstream, Mohammadnagar, khulna	(4)
5	Mohammadnagar (Khulna)	(5)
6	Mouri River from 200m upstream, Mohammadnagar, khulna	(6)
7	100m Upstream from Gollamari bridge (khulna)	(7)
8	Bank of Mouri River of Gollamari bridge(khulna)	(8)
9	100m downstream from Gollamari bridge (khulna).	(9)

Samples were collected by DoE during the month May, June, July, August and September of 2007 during high tide and low tide.

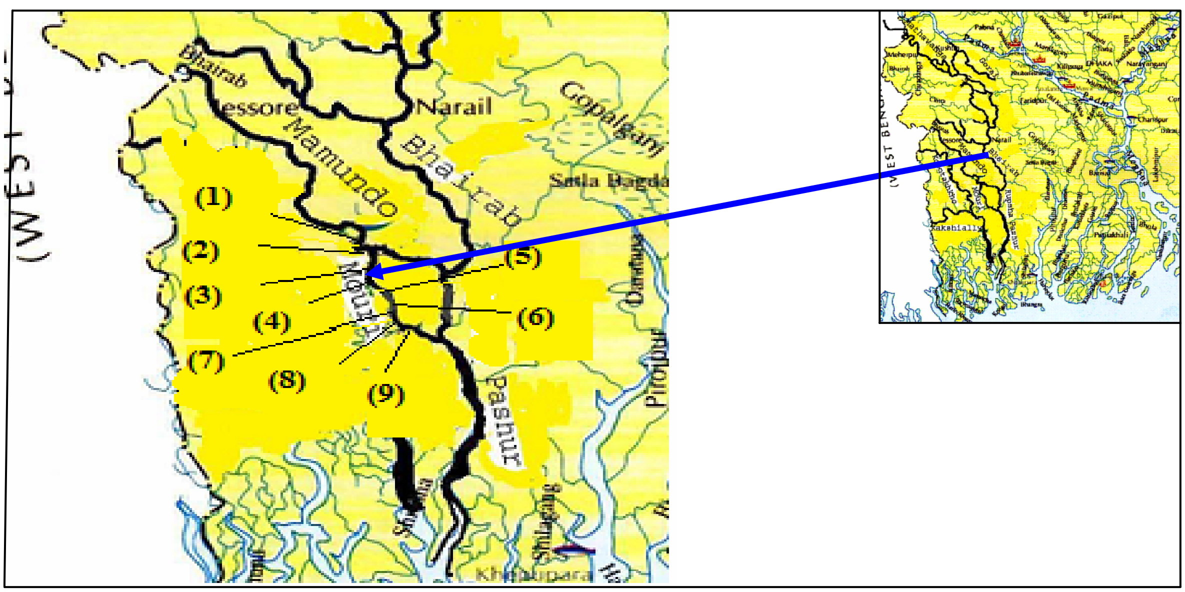

Fig 3.6.7 : Sampling stations of Mouri River.

(viii) Mamundo River: Samples were collected by DoE according to standard sampling procedure from following points,

Table 3.6.8 Sampling points of Mamundo River

Sl. no.	Sampling points	Identification in figure
1	Jayakhali (Shamnagar, Side point)	(1)
2	Jayakhali (Shamnagar, Middle Point)	(2)

Samples were collected by DoE during the month July of 2007 during high tide and low tide.

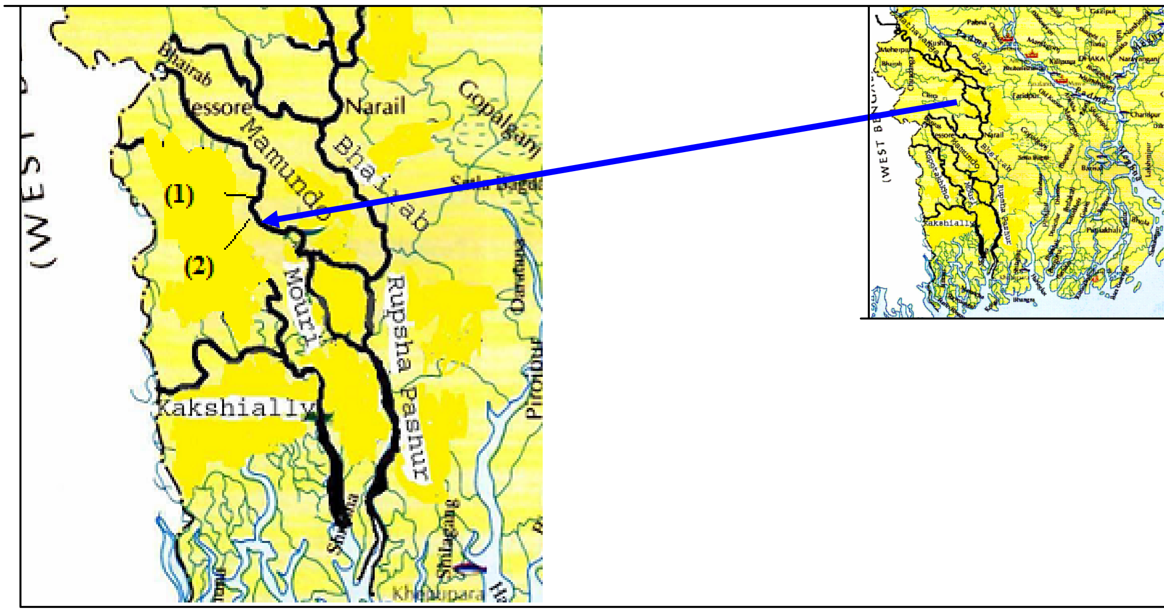

Fig 3.6.8: Sampling stations of Mamundo River.

(ix) Kopotakha River: Samples were collected by DoE according to standard sampling procedure from following points,

Table 3.6.9 Sampling points of Kopotakhkho River

Sl. no.	Sampling points	Identification in figure
1	Middle of Kopotakha river near Burigualini forest station	(1)
2	Deep Point of Kopotakha river from Burigualini forest station	(2)

Samples were collected by DoE during the month July of 2007 during high tide and low tide.

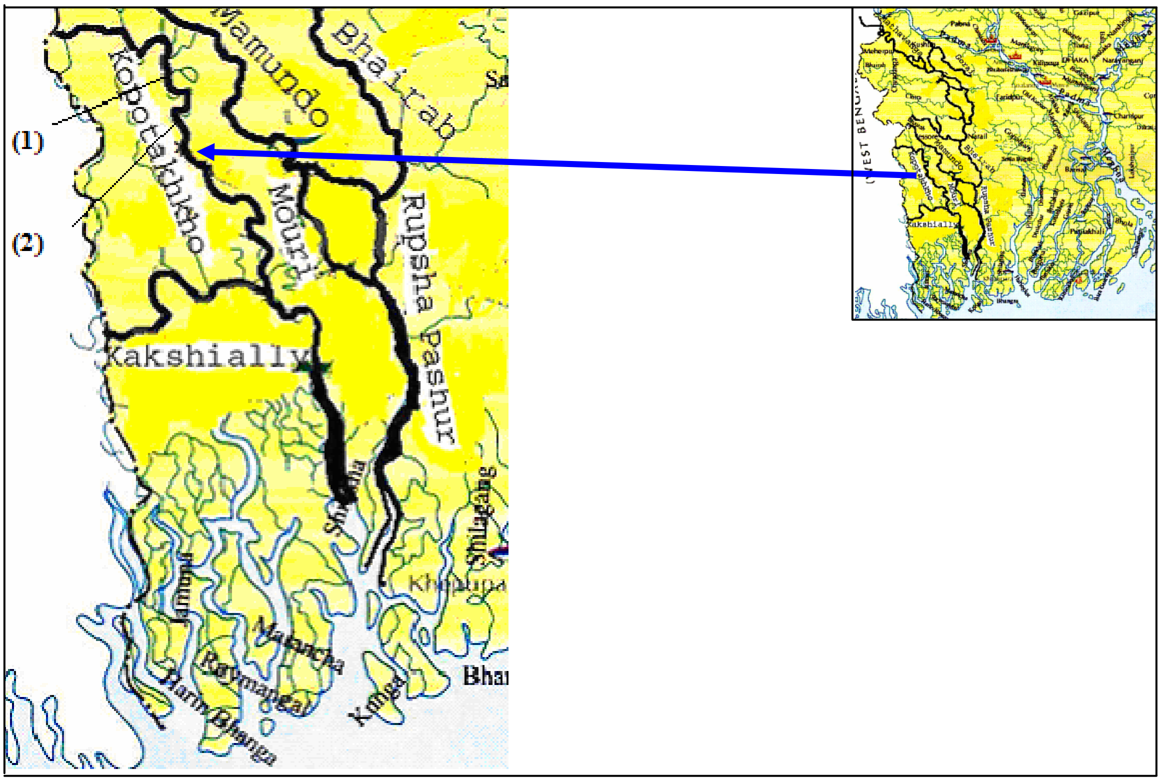

Fig 3.6.9: Sampling stations of Kopotakhkho River.

3.7 Analysis of various water quality parameter

The measured and analyzed water quality parameters involved both the physical and chemical parameters are temperature, electric conductivity, P^H, chloride content, P- alkalinity, T- alkalinity, turbidity, total solid, total dissolved solid, suspended solid, dissolved oxygen, BOD, COD.

3.8 Source of pollution

For the purpose of issuance of Environmental Clearance Certificate, the industrial units and projects shall, in consideration of their site and impact on the environment, DoE classified them into the following four categories:-

(a) Green;

(b) Orange – A;

(c) Orange – B; and

(d) Red.

Types of industries depending on raw materials, products and manufacturing processes which can be included in the above mentioned categories has been shown in Appendix-A. According to DoE Classification the list of industries (as a source of pollution) of southern region of Bangladesh are given in Appendix - B

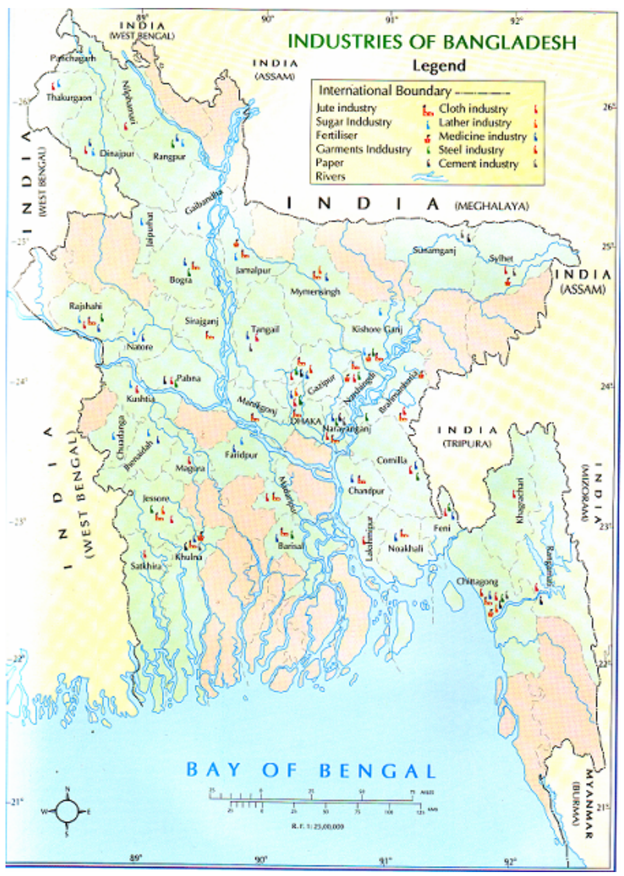

Figure 3.7.1: Industries of Bangladesh (Annual Report Ministry of Industry Bangladesh, 2003)

3.9 Laboratory techniques

3.9.1 Laboratory procedure for determination of P^H of water

P^H is a measure of the acid or alkaline condition of water. It is represented by a scale of zero to fourteen with seven being neutral. Most natural waters are slightly alkaline due to the presence of bicarbonate and less often carbonate. Those outside the desirable P^H range may exhibit sour tastes and accelerating the corrosion of metallic plumbing things and hot water services. Aeration removes carbon dioxide and may rise P^H value. Algae growth on water surface also removes carbon-dioxide and hence causes a rise in P^H range. A controlled value of P^H is desired in water supplies, sewage treatment and chemical process plants. In water supply P^H is important for coagulationn, disinfection, water softening and corrosion control. In biological treatment of waste P^H is the most significant. Organisms involved in treatment plants are operative within certain P^H range

Measurement of P^H is carried out either colourimetrically or elctrometrically. The electrometric method is expensive but accurate where as colorimetric method is cheap but serious errors may result from presence of colour, turbidity , high saline content, colloidal matter free chlorine and various oxidants and reductants. For colorimetric determination, a wide variety of indicators are used to determine P^H. In colorimetric measurement standard colour discs or standard colour solutions may be used.

Reagent: Buffer solution (at least two types)
Apparatus : Digital P^H meter .

Procedure:

1. Place sample in two beakers up to 1 ½ inch or 4 cm.
2. Calibrate the P^H meter by buffer solution.
3. .Submerge the tip of the electrode and check-temperature into the beaker

4. Turn the rotary knob to the ◦C position to display.
5. Turn the rotary knob to the P^H position to display the P^H measurement.

3.9.2 Laboratory procedure for determination of total solids, dissolved solids and suspended solids

Total solids is the term applied to the material residue left in the container after evaporation of the sample and its subsequent drying in an oven at a defined temperature. Total solids includes total suspended solids, the portion of total solids retained by a filter and total dissolved solid, the portion that passes through the filter. Solids are incorporated in water from its source. Every natural source of water contributes solids in water to some extent. The sewage from a community is very rich in dissolved and suspended solids. To determine whether water was suitable for domestic purpose, it was required to know how much solid it contains. According to USPHS. Water should not contain more than 500mg/l. of total dissolved solids. Bangladesh standard for total dissolved solids is 1500 mg/l. Water with high dissolved solids generally are of inferior palatability and may induce unfavorable physiological reaction in the transient consumer. Water high in suspended solids may be aesthetically unsatisfactory for such purposes as bathing. Water has boiling point of 100^0C It may rise by a few degree due to the presence of impurities, when water with the impurities is kept at 103^0C to 105^0C for 1day the water gets evaporated and the solids either in dissolved state or in suspended state remain as residue.

Apparatus :

1. Beaker	: 150 ml 2 Nos
2. Measuring Cylinder	: 100 ml/250 ml 1 Pcs
3. Funnel	: 1 Pcs
4. Dropper	: 1 Pcs
5. Filter	: 2 Pcs

Procedure for Total solids

1. Take a clear dry glass beaker (which as done by placing it in a 103^0C oven for a hour) of 150ml capacity weight the beaker and note the weight
2. Take 100 ml of the thoroughly mixed sample in beaker.
3. After sample is evaporated by placing the beaker in an oven maintained at 103^0 C i.e. (200^0 F) for a day, cool the beaker and weight.
4. Calculate total solids as follows

Total Solids, mg/l = (mg of solids X 1000) / ml of the sample taken.

Procedure for Dissolved Solid

1. Take a clear dry glass beaker (which as done by placing it in a 103^0C oven for a hour) of 150ml capacity weight the beaker and note the weight
2. Take a 100 ml (if the suspended matter is low , a large portion sample may be filtered) of sample from the bottle , filler it through a double layered filtrated paper collect the filtrate in the beaker .
3. After sample is evaporated by placing the beaker in an oven maintained at 103^0 C i.e. (200^0 F) for a day, cool the beaker and weight.
4. Calculate total solids as follows,

$$\text{Dissolved solids, mg/l} = \frac{\text{mg of solids x 1000}}{\text{ml. of the sample taken}}$$

Suspended solids mg/l = mg/l of T.S – mg/l of D.S.

3.9.3 Laboratory procedure for determination of alkalinity

The alkalinity of a water is a measure of its capacity to neutralize acids. It is the sum of measure of an aggregate property of water and can be interpreted in terms of specific substances only when the chemical composition of the sample is substances only when the chemical composition of the sample is known. Alkalinity is in many uses and treatments of natural waters and waste waters. Because the alkalinity of many surface waters is primarily a function of carbonate, bicarbonate and hydroxide content, it is taken as an indication of the concentration of these constituents. The measured value also may include contributions from borates, phosphates, silicates or other bases if these are present. Alkalinity measurements are used in the interpretation and control of water and wastewater treatment processes, Raw domestic waste water has an Alkalinity less than or only slightly greater than that of water supply.

There are three kinds of alkalmily, hydroxide (OH), normal carbonate (CO_3) , and bicarbonate (HCO_3). Normal carbonate is also called mono-carbonate. This test is-based on the determination of the alkaline content of a sample by titration with a standard acid solution. In this measurement the end points are taken as points of change in colour of the organic indicators, phenolphathelein and methyl change representing definite points to which the alkalinity of the sample has been reduced by the addition of the standard acid solution. Phenolphathelein gives a pink colour only in prescence of hydroxide or normal carbonate. The change from pink to colourless occurs at a P^H value of 8.3. Methyl orange is yellow in prescence of any of the three types of alkalinity and red in the presence of acid. The change in colour occurs at a P^H value approximately 4.4. When alkalinity is measured to the phenolphathelein end point called phenolphathelein alkalinity which is due to the prescence of either hydroxide or normal carbonate or both and when alkalinity is measured to methyl orange end point called methyl orange alkalinity which is due to any one of the three alkalinities or OH and normal carbonate and bicarbonate together. The following equations illustrate the reactions occurring when each of the three types of alkaknitv is tilled with an acid.

Hydroxide : $2\ Na\ OH + H_2SO_4 = Na_2SO_4 + 2\ H_2O$

Normal carbonate : $2\ Na_2CO_3 + H_2SO_4 = Na_2SO_4 + 2\ H_2CO_3$

Reagents

1. Phenolphathelein indicator

2. Standard 0.02 N Sulfuric Acid

3. Methyl Orange indicator

Apparatus

1. Beaker	: 150 ml 2 Nos
2. Measuring Cylinder	: 100 ml/250 ml 1 Pcs
3. Dropper	: 1 Pcs
4. Stirrer	: 1 Pcs

Procedure

1. Take 100 ml. of the sample into one beaker and same .amount of distilled water into other beaker.
2. Add 3 drops of phenolphthalein indicator to each. If the sample becomes pink, go to step (3) otherwise go to step (4).
3. Add 0.02N sulfuric acid from a burette until the pink colour just disappears. And record the ml, of the acid used.
4. Add 3 drops of methyl orange indicator to each beaker . If the sample becomes yellow and 0.02N sulfuric acid until the first difference in colour is noted when - compared with the distilled water. The end point is a slight orange tinge. Record the ml. of acids used.

Calculation

Total alkalinity as CaCO = Total ml. of acid used X 10 ppm.
P = ml. Of 0.02N acid used for the filtration with phenolphthalein indicator
T= ml. Of 0.02N acid used for the total titralion.
1 . If p= T Hydroxide alkalinity = p x 10 ppm
2. If p> T/2. Hydroxide alkalinity = (2.P-T) X 20 ppm
Carbonate alkalinity 2(T-P) X 1 ppm
3. If p = T/2 Carbonate alkalinity = 2P x 10 ppm .

4. If p< T/2 Carbonate alkalinity = 2P x 10 ppm

Bicarbonate alkalinity = (T-2P) x 10 ppm

5. If p = O Bicarbonate alkalinity = T x 10 ppm

3.9.4 Laboratory procedure for determination of turbidity

The term turbid is applied to water containing suspended interferes passage of light through the water for which visual depth is restricted , Turbidity used by a wide variety of suspended substances of various sizes ranging from colloidal to coarse particle in river water, the major source of turbidity is the bank and bed materials. Turbidity is important for water supply engineer as turbidity is not aesthetically acceptable to people. There is always a fear among the people that turbid water may cause diseases. For filtration, turbid water is not suitable as it cruises quick clogging of filter bed which implies the use of pre-treatment plant . The USPHS maximum unit of turbidity for drinking water is 10 NTU , where as that for Bangladesh is 25 NTU. Unit of turbidity is arbitrarily selected . one of the modern units is NTU (Nepholometric Turbidity Unit). 1 Unit of turbidity is defined as the interference of light caused by a mix of 1 mg/1 of SiO_2 to water.

Apparatus : Portlab Turbidimeter (Model -16800)

Procedure :

1. Ensure that the instrument has been standardized recently and that the span control has not been changed since standardization, with the instrument turned off. Check the mechanical zero setting.
2. Press the power switch and battery. Check switch and verify that the meter indicates within the battery check area. If it does not recharge battery pack
3. Press the appropriate range switch. Select the range that will exceed the expected turbidity of the sample under test.

4. Place the focusing tamplate into the cell holder and adjust the zero control for reading of zero NTU. .Remove the focusing template.

Use the while dot on the sample cell to o.ient the ceil m the same posilK- each time.

Cover the sample cell with the light shield and allow the meter to stabjoize , Re |hc turbidity of the sample.

3.9.5 Laboratory procedure fo determination of biochemical oxygen demand (BOD)

The Biochemical Oxygen Demand (BOD) determination is an empherical test in which standardised laboratory procedures are used to determine the relative oxygen requirements of wastewater, effluents and polluted waters. The test measures the oxygen required for the biochemical degradation of organic, inorganic materials such as sulfides and ferrous iron. It also may measure the oxygen used to oxidize reduced forms of nitrogen nitrogenous demand unless their oxidation is prevented bv an inhibitor. The method consists of placing a sample in a full airtight bottle and incubating the bottle under specified conditions for a specific time. Dissolved Oxygen (DO) is measured initially and after incubation. The BOD is computed from the difference between initial and final DO.

The reactions involved in the various steps of the Winkler method in the determination of dissolved oxygen, are represented by the following equations; Manganous sulfate reacts with potassium hydroxide in the alkaline potassium iodide mixture to produce a white floculent precipitate of manganous hydroxide.

$Mn\,SO_4 + 2\,KOH = Mn\,(OH)_2 + K_2\,SO_4$

If the white precipitate is obtained, there was no dissolved oxygen in the sample and there is no need to proceed further. A brown precipitate shews thai oxygen was present and reacted with the manganous hydroxide. Tlie brown precipitate is manganic basic oxide :

$2\,Mn\,(OH)_2 + O_2 = 2\,MnO\,(OH)_2$

Upon tlie addition of the acid, this precipitate is dissolved, forming manganic sulfate

$2 H_2 SO_4 =. \quad Mn (SO_4)_2 + 3H_2O$

There is an immediate reaction between this compound and the potassium iodide previously added, liberating iodine and resulting in the typical iodine coloration of the water :

$Mn(SO_4)_2 + 2KI = MnSO_4 + 2K_2SO_4 + I_2$

The quantity of iodine liberated by these reactions is equivalent to the quantity of oxygen present in the sample. The quantity of iodine is determined by titrating a portion of tlie solution with a standard solution of sodium thiosulfate :

$2 Na_2 S_2 O_3 + I_2 = Na_2 S_4 O_6 + 2 NaI$

Reagents

1. Manganous sulfate solution.
2. Alkaline potassium iodide solution.
3. 0.025N sodium thiosulfate.
4. Starch solution (indicator) .
5. Concentrated Sulfuric acid.

Apparatus

1. BOD bottle
2. Beaker (250 ml)
3. Measuring cylinder
4. Dropper
5. Starrier

Procedure

1. Determination of initial DO:

If the sample contains materials that reacts rapidly with DO, determine initial DO immediately after filling BOD bottle with diluted sample say initial DO is 0.

B. After particular days determine DO in sample dilutions. Say final DO is D_f .

Procedure

1. Collect the sample in an 8-oz. glass-stoppered_bottle. Be very careful to avoid contact of' the sample with air. The bottle should be completely filled.
2. Immediately after collection, add 1 ml. of manganous sulfate solution by means of pipette, dipping the end of the pipette just below the surface of the water.
3. Add 1 ml of alkaline potassium iodide_solution in a similar manner.
4. Insert the stopper and mix by inverting the bottle several times.
5. Allow the precipitate to settle halfway and mix again.
6. Again allow the precipitate to settle halfway.
7. Add 1 ml concentrated sulfuric acid.. Insert the stopper at once after the addition of acid and mix as before. '
8. Allow the solution to stand at least 5 minutes.
9. Withdraw 100 ml of the solution into an Erlemneyer flask and immediately add 0.025N sodium thiosulfate drop by drop, from a burette until the yellow colour almost disappears.
10. Add about 1 ml of starch solution and continue the adoition-of the sodium thiosulfate until the blue colour just disappears. Record the ml of sodium thiosrJfaie used. (Disregard any return of the blue colour,)

Dissolve Oxygen Present in'sample in mg/l = Ml of 0.025N sodium tliiosulfate used

BOD in mg/l = Di-Df / P

Where, P = decimal Volumetric fraction of sample used.

3.9.6 Laboratory procedure fo determination of chemical oxygen demand (COD)

Tlie oxygen consumed dcteimination is a measure of the amount of oxygen require to oxidize unstable material in a sample by means of potassium permanganate in an acid solution. The test has been largely replaced by the biochemical oxygen demand determination since it does not give results which are comparable to those obtained from biological oxidation processes which occur in nature . The test has an advantage in that the results can be obtained in less than 1 hour while the biochemical test requires at 5 days. Potassium reaction and attacks the carbonaceous and not the nitrogenous matter. Two standard solutions are required namely potassium permanganate and ammonium oxalate .

Reagents

1. Dilute Sulphuric Acid
2. Standard potassium permanganate
3. Standard ammonium oxalate

Apparatus

1. Beaker (250 ml)
2. Dropper
3. Starrier

Procedure

1. Pipette 100 ml of the sample into a 250 ml Erlenmeyer flask.
2. Add 10 ml of dil. Sulfuric acid and 10 ml of standard potassium permanganate .
3. Heat in a boilling water bath for exactly 30 min . Keeping me water in the bath above the level of the solution in the flask .

4 If the solution becomes faintly colon;, repeat the above using a smaller sample diluted to 100 ml with distilled water .

5. After 30 min, in the water bath add 10 ml of standard ammonium oxalate.
6. Titrate while hot with standard potassium permanganate to the first pink coloration , Record the ml of potassium permanganate used.

Calculations

$$\text{Oxygen consumed (i.e. COD) in mg/l} = \frac{\text{ml of } KMNO_4 \text{ used in step-6 X 100}}{\text{ml. of the sample used}}$$

$$\text{Oxygen consumed (i.e. COD) in mg/l} = \frac{\text{(K-N) – (k-n) X 100}}{\text{ml. of the sample used}}$$

K = Total ml of $KMnO_4$Oxalate used for the sample.

N = Total ml of Oxalate used for the sample

k= ml of KMnO4 used for the distilled water

n= ml of oxalate used for the distilled water

3.10 Summary

Though author used secondary data all through this research work, still this chapter had been developed to give a brief and straightforward description from collecting sample to produce raw data in a simple way. Chemical analysis was done by DoE following standard laboratory test and statistical analysis had done in chapter-5 by Microsoft Excel in Windows XP 2007 platform. Using this raw data further steps had been taken.

Chapter 4

INDICATORS AND PARAMETERS

4.1 General

This chapter provides some information on the water quality parameter and briefly describes what they mean. It also outlines the basic concept on indicators and parameters. This chapter will not give the idea about the all parameters but the parameter on which secondary data were available.

4.2 Indicators

Surface water quality standards (WQS) comprising indicators and threshold values are set both by type of water use and by content of discharge into specific water bodies. Enforcement of these standards is low and patchy. Responsibility for enforcement lays with the DoE under the 1995 Environmental Conservation Act and the 1997 Environmental Conservation Rules.

For protection of aquatic eco-systems, it is regulation of the resulting concentrations in the receiving waters that is the key. The ambient WQS rather than the end of pipe discharge or water use WQS are therefore the key parameters for water resource planning, as they effectively limit the cumulative effects of discharges. They are the standards that should from the criteria for water quality evaluation in IEEs and EIAs for projects, which have impacts on water resources.

4.3 Parameters of concern

4.3.1 Physical Parameters

Physical parameters define those characteristics of water that respond to the senses of touch, taste, or smell. temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid are Physical parameters of concern in this study

(i) Temperarure

The temperature of waste water is commonly higher than that of the local water supply because of addition of warm water from house holds and industrial activities. The temperature of water is a very important parameter because of its effect on chemical reactions and reaction rates, aquatic life and suitability of water for beneficial uses. Industrial establishment that use surface water for cooling-water purposes are particularly concerned with temperature of the intake water (Metcalf and Eddy, 2003).

(ii) Turbidity

Turbidity is a measure of light transmitting properties of water. It is another test used to indicate the quality of waste discharges and natural waters with respect to colloidal and residual suspended matter. The measurement of turbidity is based on comparison of the intensity of light scattered by a reference suspension under the same conditions. The result of turbidity measurements are reported as nephelometric turbidity unit (NTU) . Colloidal matters will scatter or absorb light and thus prevent its transmission. It should be noted that presence of air bubbles in the fluid will cause erroneous turbidity readings (Metcalf and Eddy, 2003).

(iii) Conductivity or Electric conductivity

The electric conductivity (EC) of a water is a measure of the ability of a solution to conduct an electrical current. Because the electrical current is transported by the ions in solution, the condu- ctivity increases as the concentration of ion increases. In effect, the measured EC value is used as surrogate measure of total dissolved solids concentration. Electric conductivity in SI units is expressed as millisimens per meter (mS/m) and in micromhos per centimeter (μmho/cm) (Metcalf and Eddy, 2003). EC is a measure of water's ability to conduct an electrical current. It is related to the amount of dissolved minerals which are present or conductivity indicate the total inorganic mineral content in water. EC is measured in µmho/cm at 25^0 C . It has no standard according to WHO guideline or Bangladesh Standards ECR, 1997. According to USP (United States Pharmacopeia) the standard value of EC will be 4.7-5.8 µ mho /cm (depending on pH). But in common practice it is taken as if it is much greater than two times (Mechenic C. & Endrews E, 2001) the hardness it may indicate the prescence of contamination such as sodium, chloride or sulphate. Changing the conductivity over time indicates changing water quality

(iv) Total Solids (Dissolved and Suspended)

Total solids is the term applied to the material residue left in the container after evaporation of the sample and its subsequent drying in an oven at a defined temperature Solids can be dispersed in water in both suspended and dissolved forms. Water with a total solid content of less than 500 mg/l is most desirable.

(v) Suspended solids

The material remaining in the filter after filtration for the solids analysis in the water is considered to be dissolved solid. Suspended material may result from human use of the water. Domestic wastewater usually contains large quantities of suspended solids that are mostly organic in nature. Industrial use of water may result in a wide variety of suspended impurities of either organic or inorganic nature. Suspended material may be objectionable in water for several reasons. It is aesthetically displeasing and provides adsorption sites for chemical and biological agents. Suspended organic solids may be degraded biologically, resulting in objectionable by-products. Biologically active (live) suspended solids may include disease-causing organisms as well as organisms such as toxin-producing strains of algae.

Suspended solids, where such material is likely to be organic and/or biological in nature, are an important parameter of water. The suspended-solids parameter is used to measure the quality of the drinking water, to monitor several treatment processes, and to measure the quality of the water used for daily household use. (Peavy, 1985, Davis, 1991)

(vi) Dissolved Solids

The material remaining in the water after filtration for the suspended-solids analysis is considered to be dissolved. This material is left as a solid residue upon evaporation of the water and constitutes a part of total solids.

Dissolved material results from the solvent action of water on solids, liquids, and gases. Like suspended material, dissolved substances may be organic or inorganic in nature. Inorganic substances that may be dissolved in water include minerals, metals, and gases. Water may come in contact with these substances in the atmosphere, on surfaces, and within the soil. Materials from the decay products of vegetation, from organic chemicals, and from the organic gases are common organic dissolved constituents of water. The solvent capability of water makes it an ideal means by which waste products can be carried away from industrial sites and homes. (Peavy, 1985, Davis, 1991)

Many dissolved substances are undesirable in water. Dissolved minerals, gases, and organic constituents may produce aesthetically displeasing color, tastes, and odors. Some chemicals may be toxic, and some of the dissolved organic constituents have been shown to be carcinogenic. Total dissolved solids (DS) can have an important effect on the taste of drinking-water. The palatability of water with a DS level of less than 600 mg/l is generally considered to be good; drinking-water becomes increasingly unpalatable at TDS levels greater than 1200 mg/l. Water with extremely low concentrations of DS may be unacceptable because of its flat, insipid taste. The presence of high levels of DS may also be objectionable to consumers owing to excessive scaling in water pipes, heaters, boilers, and household appliances

Because no distinction among the constituents is made, the DS parameter is included in the analysis of water only as a gross measurement of the dissolved material. The amount of dissolved solids present in water is an important consideration in its suitability for domestic use. Waters with higher solids content often have a laxative and sometimes the reverse effect upon people. (Peavy, 1985 , Davis, 1991)

4.3.2 Chemical Parameters

Water has been called the universal solvent, chemical parameters are related to the solvent capabilities of water. $P^{H,}$ chloride, alkalinity or T-alkalinity, hardness, DO, BOD, COD, are chemical parameters of concern in this study.

(i) P^H

P^H is the term used universally to express the intensity of the acid or alkaline condition of a solution. It is a measure of the concentration of free hydrogen ions (H+) in water and expressed as $P^H = -\log(H^+)$. The P^H of an aqueous system is a measure of the acid-base equilibrium achieved by various dissolved compounds and, in most natural waters, is controlled by the CO2-HCO3-CO3 equilibrium system. In most raw water sources pH lies within the range 6.5 - 8.5. The P^H scale as shown in Fig 4.1 is usually represented as ranging from 0 to 14, with P^H 7 representing absolute neutrality. Acid condition increase as pH values decrease and alkaline conditions increases as the P^H values increase. (Peavy, 1985, Davis, 1991)

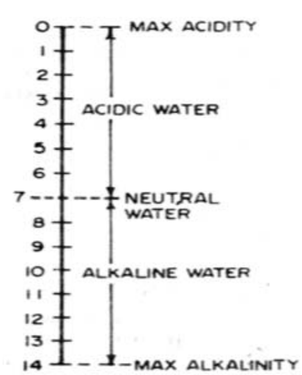

Fig 4.3.1: P^H Scale

Although P^H usually has no direct impact on consumers, it is one of the most important operational water quality parameters. Careful attention to P^H control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfections. For effective disinfections with chlorine, the P^H should preferably be less than 8. The P^H of the water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems. Failure to do so can result in the contamination of drinking-water and in adverse effects on its taste, odor, and appearance.

The optimum P^H required will vary in different supplies according to the composition of the water and the nature of the construction materials used in the distribution system, but it is often in the range 6.5–9.5. In water supply P^H is important for coagulation, disinfections, water softening and corrosion control. In biological treatment of water, pH is very important as the organisms involved in treatment processes operate within a certain P^H range. Dissolution and mobility of metal in natural waters are also greatly influenced by the P^H of water. Extreme values of P^H can result from accidental spills, treatment breakdowns, and cured insufficient cement mortar pipe linings. No health-based guideline value has been proposed for P^H. (Peavy, 1985, Davis, 1991)

(ii) T- Alkalinity

T-Alkalinity is defined as the quantity of ions in water that will react to neutralize hydrogen ions. Alkalinity is thus a measure of the ability of water to neutralize acids. The alkalinity is due primarily to salts of weak acids and strong bases. Such substances act as buffers to resist a drop in P^H resulting from acid addition. Alkalinity is thus a measure of the buffer capacity.

Constituents of alkalinity in natural water systems include CO_3^{2-}, HCO_3^-, OH^-, $HSiO_3^-$, H_2BO_3, HPO_4^{2-}, $H^2PO_4^-$, HS^-, and NH_3^0. These compounds result from the dissolution of mineral substances in the soil and atmosphere. Most of the alkalinity in natural waters is caused by three major classes of materials: bicarbonate, carbonates, and hydroxides. Bicarbonates represent the most common form of alkalinity since they are formed, in large quantities, from the action of carbon dioxide upon basic materials in the soil. Other salts of weak acids, such as borate, silicates, and phosphates, may be present in small amounts. A few organic acids, such as humic acid, add to the alkalinity of natural waters. (Peavy, 1985, Davis, 1991)

In large quantities, alkalinity imparts a bitter taste to water. The principal objection to alkaline water, however, is the reactions that can occur between alkalinity and certain cations in the water. The resultant precipitate can foul pipes and other water-systems appurtenances. Excessive or insufficient alkalinity interferes with water treatment (coagulation)

Alkalinity measurements are often included in the analysis of natural waters to determine their buffering capacity. It is also used frequently as process control variable in water and wastewater treatment. Maximum levels of alkalinity have not been set by EPA for drinking water or for wastewater discharges

(iii) Dissolved Oxygen (DO)

Dissolved Oxygen (DO) content in surface water depends on the amount and characteristics of the unstable organic matters in the water. It is an important factor in assessing the self-purification capacity of polluted streams

In liquid waste, dissolved oxygen is the factor that determines whether the biological changes are brought about by aerobic or by anaerobic organism. The former use free oxygen for oxidation of organic and inorganic matter had produced innocuous end products, whereas the latter bring about such oxidation through the reduction of certain inorganic salts such as sulfates, and the end products are often very obnoxious. (Peavy, 1985, Davis, 1991)

The raw water temperature, composition, treatment, and any chemical or biological processes taking place in the distribution system influence the dissolved oxygen content of water. Depletion of dissolved oxygen in water supplies can encourage the microbial reduction of nitrate to nitrite and sulfate to sulfide, giving rise to odor problems. Oxygen is a highly active so DO in water affects oxidation-reduction reactions involving iron, manganese, copper, and compounds containing Nitrogen and Sulphur. Oxygen is a significant factor in the corrosion of iron and steel, particularly in water distribution systems and in steam boilers.

No health-based guideline value has been recommended for dissolved oxygen.

DO is the fundamental requirement for aquatic life and hence the ability of the water to maintain certain minimal concentration of DO is of vital importance. Fish requires the highest levels of DO, invertebrates lower levels of DO and bacteria the least. For instance, for diversified warm water biota, including fish, the DO concentration should be at least 5 mg/1. In general a water of good quality should be low in oxygen consumed

(iv) Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is usually defined as the amount of oxygen required by microorganisms while stabilizing decomposable organic matter under aerobic condition. BOD is a characteristic, not a constituent, of the water. So the BOD is the measurement of oxygen consumed by living organisms (mainly bacteria).

BOD is the major criterion used in stream pollution control where organic loading must be restricted to maintain desired dissolved oxygen levels. The BOD test is widely used to determine the pollution strength of domestic water in terms of the oxygen in aerobic condition.

Biochemical Oxygen Demand (BOD) determination is used to measure the purification capacity of streams and serves regulatory authorities checking the quality water source. Information regarding BOD of water is an important consideration in the design of treatment facilities. Unpolluted water should have less than 5 ppm of BOD. Higher amounts are danger signals demanding investigation of the cause before the water is pronounced potable. (Peavy, 1985, Davis, 1991)

(v) Chemical oxygen demand (COD)

COD is the chemical oxygen demand, it is a test widely used in the operation of treatment facilities because of the speed with which results can be obtained. It is principally used for biologically inert organic matter. Chemical oxidizing agents are used for measuring the oxygen demand of polluted waters.

(vi) Chloride

Chloride is widely distributed in nature, generally in the form of sodium (NaCl), potassium (KCl) and calcium chloride ($CaCl_2$). Chlorides occur in natural waters in widely varying concentrations. Upland and mountain supplies are quite low in chlorides, whereas rivers and groundwater usually have a considerable amount. Chlorides gain access to natural waters in many ways. The solvent power of water dissolves chlorides from topsoil and deeper formations. In addition, ocean and seawater invasion of rivers, and intrusion of seawater into fresh groundwater aquifers also contribute chloride to natural waters. Wastewater influents and many industrial wastes also add considerable chlorides to receiving streams. (Peavy, 1985, Davis, 1991)

High concentrations of chloride give an undesirable taste to water and beverages. Taste thresholds for the chloride anion depend on the associated cation and are in the range of 200–300 mg/l for sodium, potassium, and calcium chloride. Excess chloride is corrosive to metals in the water distribution system, particularly in water of low alkalinity. Higher chloride content in inland water usually indicates sewage pollution. Consumers can become accustomed to concentrations in excess of 250 mg/l. No health-based guideline value is proposed for chloride in drinking-water

The United States Environmental Protection Agency (EPA) says that if you have chlorine in excess of 250 mg/l in your drinking water, it is likely that you may have any one or more of the following concerns: "High blood pressure, salty taste, corroded pipes, fixtures and appliances, blackening and pitting of stainless steel." No health-based guideline value is proposed for chloride in drinking-water

4.4 Summary

Indicators and parameters had been described in two categories Physical and Chemical. In next steps of this research work all data had been analyzed and discussed depends on this category.

Chapter 5

RESULTS AND DISCUSSIONS.

5.1 General

This chapter outlines on how the collected data had been statically analyzed by Microsoft Excel in Windows Platform and compared with national water quality standards set by Bangladesh Government as well as WHO standard.

5.2 Availability of Data

Data was collected from DoE as per following schedule,

Table 5.2.1: The schedule of collected samples were from the selected rivers as follows

Sl. No.	Rivers	Sample collection time	Period
1	Bhairab	April, May and August of 2007	Pre monsoon and Monsoon
2	Gorai	April, May , July, August and September of 2007	Pre monsoon and Monsoon
3	Rupsha	April, May , August andSeptember of 2007	Pre monsoon and Monsoon
4	Poshur	April, May and September of 2007	Pre monsoon and Monsoon
5	Kakshially	July and August of 2007	Monsoon
6	Mouri	May, June, July, August and September of 2007	Pre monsoon and Monsoon
7	Kopotakha	July of 2007	Monsoon
8	Mathavanga	April and May of 2007	Pre monsoon
9	Mamundo	July of 2007	Monsoon

5.3 Parameterization of water quality parameter of Bhairab River

5.3.1 Physical parameter

Among all physical properties the concern of these study was focused on Physical parameters such as temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid for Bhairab River.

(i) Temperature

Table 5.3.1: Statistical presentation of Temperature of Bhairab River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (^{0}C)	30.38	27.13	Optimum Temp for Carp fish is 32 ^{0}C Diatoms grow best at 15-25 ^{o}C, Green algae grow best at 25-35 ^{o}C, Blue-green algae at 30-40 ^{o}C.
Std Deviation	0.57	0.23	
Variance	0.32	0.05	
Minimum (^{0}C)	29.50	27.00	
Maximum (^{0}C)	31.00	27.50	

Source: (i) CWQB, 1963. (ii) EPA, 1976.

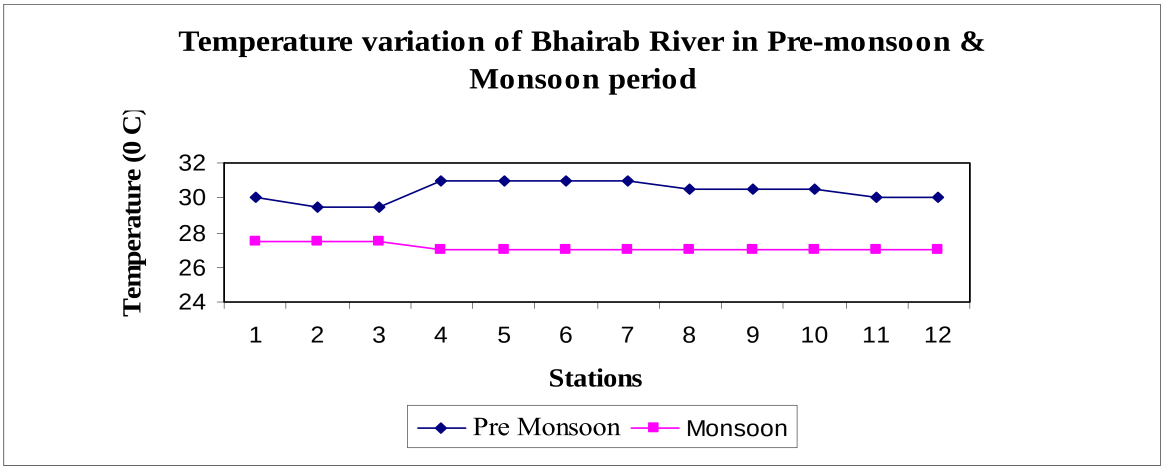

Figure 5.3.1: Graphical representation of temperature of Bhairab River.

(ii) Turbidity

Table 5.3.2: Statistical presentation of Turbidity of Bhairab River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (NTU)	42.28	40.64	Amount of fish 162 lb/ acre for 25 NTU, 94 lb/ acre for 25 -100 NTU, 29 lb/ acre for over 100 NTU. Usable for Beverages if turbidity is 1-2 NTU Food products for 10 NTU Water used in boilers for 1-20 NTU (varies with type of boiler) High grade paper for 5-25 NTU Water used for cooling for 50 NTU. Tanning leather for 20 NTU
Std Deviation	16.30	11.43	
Variance	265.84	130.55	
Minimum (NTU)	22.50	30.50	
Maximum (NTU)	60.50	60.50	

Source: CWQB, 1963.

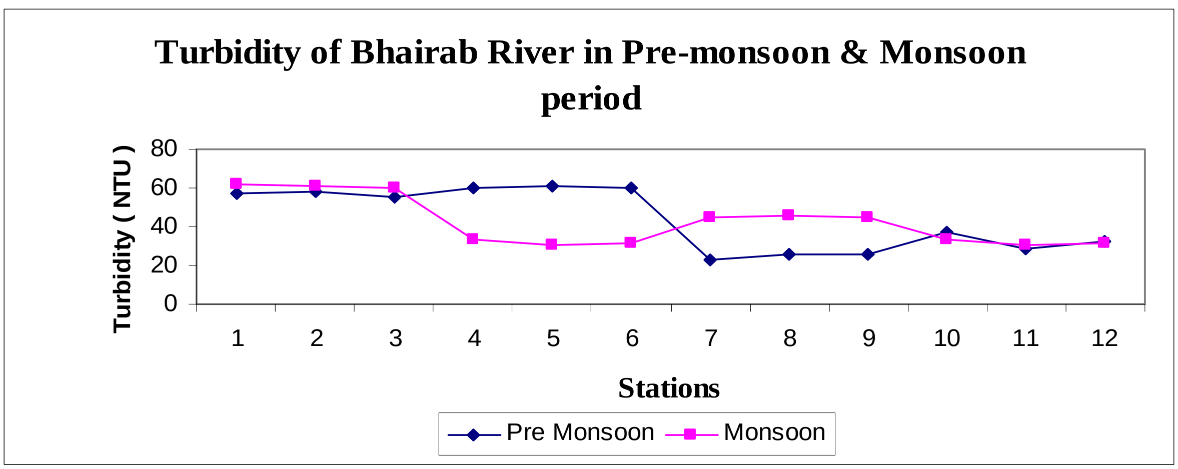

Figure 5.3.2: Graphical representation of Turbidity of Bhairab River.

(iii) Electric Conductivity

Table 5.3.3: Statistical presentation of Electric Conductivity of Bhairab River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (dS/m)	20.367	0.485	Three categories of EC is specified by FAO for irrigation. (i) None (<0.7 dS/m) , (ii) Slight to moderate (0.7 to 3.0 dS/m), (iii) Severe (> 3.0 dS/m).
Std Deviation	5.61	0.09	
Variance	31.53	0.01	
Min (dS/m)	15.06	0.431	
Max (dS/m)	28.43	0.68	

Source : Ayres and Westcot 1985.

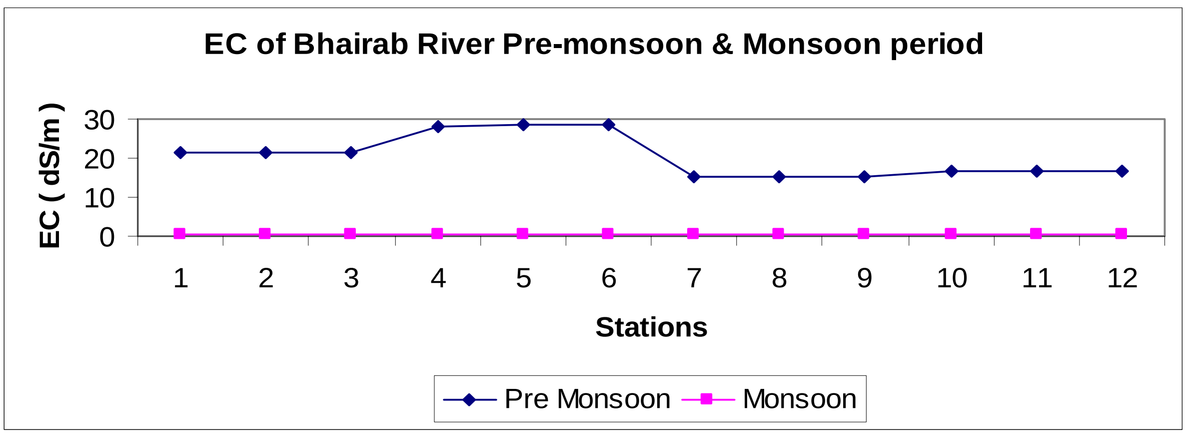

Figure 5.3.3: Graphical representation of EC of Bhairab River.

(iv) Total Solid

Table 5.3.4 Statistical presentation of Total Solid of Bhairab River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	9904.45	274.09	Compared with the standards of suspended and dissolved solids.
Std Deviation	1910.33	58.23	
Variance	3649360.07	3390.69	
Minimum (mg/l)	7877.00	240.00	
Maximum (mg/l)	12707.00	421.00	

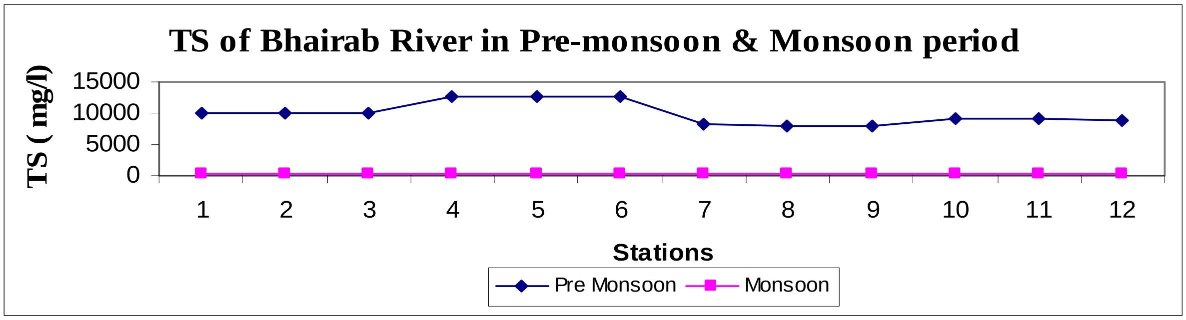

Figure 5.3.4: Graphical representation of TS of Bhairab River.

(v) Total Dissolved Solid

Table 5.3.5 Statistical presentation of Total Dissolved Solid of Bhairab River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	9787.64	223.82	Three categories of TDS is specified by FAO for irrigation. (i) None (< 450 mg/l) , (ii) Slight to moderate (450-2000 mg/l), (iii) Severe (> 2000 mg/l).
Std Deviation	1898.44	61.18	
Variance	3604058.45	3743.56	
Minimum (mg/l)	7756.00	194.00	
Maximum (mg/l)	12568.00	381.00	

Source : Ayres and Westcot 1985.

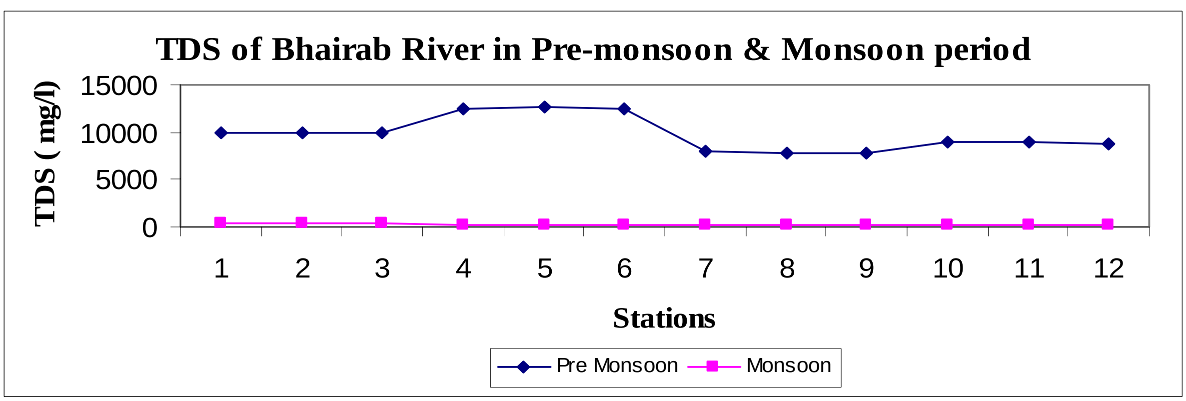

Figure 5.3.5: Graphical representation of TDS of Bhairab River.

(vi) Suspended Solid

Table 5.3.6 Statistical presentation of Suspended Solid of Bhairab River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	116.82	50.27	SS for fish culture is <1500 ppm.
Std Deviation	17.78	13.44	For drinking water allowable
Variance	316.16	180.62	concentration (maximum)
Minimum (mg/l)	94.00	40.00	Bangladesh standard 10 mg/l
Maximum (mg/l)	141.00	76.00	WHO standard is 10 mg/l.

Source : ECR 1997.

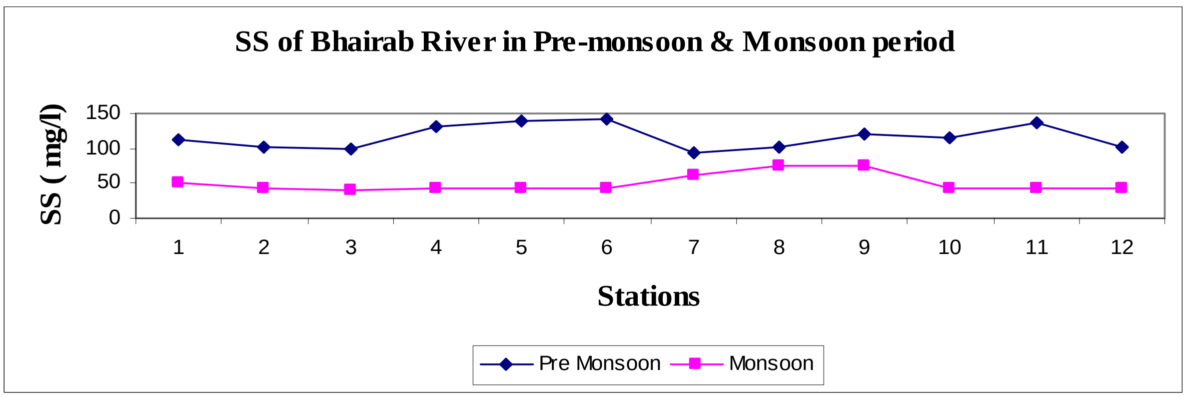

Figure 5.3.6: Graphical representation of SS of Bhairab River.

Some aspects of physical water quality parameters of Bhairab River for Pre Monsoon and Monsoon period have been presented. The average value of water temperature were 30.38 ^{0}C (Pre Monsoon) and 27.13 ^{0}C (Monsoon), Temperature of Bhairab River water showed that it might be tolerable for aquaculture like Carp fish, Diatoms, Green algae and Blue-green algae.

Turbidity of Bhairab River water were seen to be 42.28 NTU (Pre Monsoon) and 40.64 NTU (Monsoon), SS were 116.82 mg/l (Pre Monsoon) and 50.27 mg/l (Monsoon) and TDS were 9787.64 mg/l (Pre Monsoon) and 223.82 mg/l (Monsoon) respectively. Turbidity of water mainly caused by silt, clay, waste materials, heavy particles, dumps etc. Turbidity always indicated the amount of various particles present in water which includes both the total dissolved and suspended solids present in water (Onyema, 2007).

The value of different physical water quality parameters showed a higher rate in Pre Monsoon period than in Monsoon Period. These values decrease gradually as a result of more surface water flow in the river during monsoon period. Production of fish culture of Bhairab River is seen to be favorable to produce 94 lb/acre of fish. Water of Bhairab River is usable for cooling purpose. Bhairab River water needs to be pretreated before using in beverage industries, food products, boiler, pulp paper industries and tanning leather.

The mean value of EC of Bhairab River were seen to be 20.367 dS/m (Pre monsoon) 0.485 dS/m (Monsoon). That indicates the inorganic mineral content is high. The results of the present study clearly indicate that the water of Bhairab River was carrying higher value of EC in Pre monsoon period and is not suitable for maintaining the normal functioning of aquatic organisms. But in Monsoon period its water can be used for irrigation due to lower value of EC.

The standard values of SS and TDS were seen to be 10 mg/L and 1000 mg/L for the inland surface water of Bangladesh (Alam, *et al.,* 2007). After analysis the mean value of SS were found to be 116.82 mg/l (Pre Monsoon) and 50.27 mg/l (Monsoon) and TDS were 9787.64 mg/l (Pre Monsoon) and 223.82 mg/l (Monsoon). The amount of SS and TDS were also considerably high in Pre Monsoon period in the unit volume of water in Monsoon period. So in monsoon period Bhairab River water is favorable for any purpose. But in Pre Monsoon period both SS and TDS is very high. So in Pre Monsoon period Bhairab River Water needs pre treatment before use. The heavy particles present in the waste materials become settled on the river bottom and the remaining lighter particles are carried out with water in the form of suspended and dissolved forms. Higher amount of various solids present in water have a negative impact on the productivity and maintaining good water quality as these reduce the light penetration in water.

5.3.2 Chemical parameter

There are different chemical properties which can indicate the status of river water quality but for the study properties like P^H, chloride, alkalinity or T-alkalinity, hardness, DO, BOD, COD for Bhairab River were considered.

(i) P^H

Table 5.3.7 Statistical presentation of P^H of Bhairab River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean	7.68	7.51	Optimum P^H for aquaculture Fish eggs could be hatched, but deformed young were often produced between P^H 3.8 - 10 Limit of P^H for resistant fish species is 4-10.1 Range tolerated by trout is P^H 4.1- 9.5 Best range for the growth of algae is P^H 7.5-8.4. Food canning when minimum P^H 7.5 freezing when minimum P^H 7.5 Washing clothes when P^H 6-6.8 Rayon manufacturing when P^H 7.8-8.3 Tanning leather when P^H 6-8
Std Deviation	0.10	0.27	
Variance	0.01	0.07	
Minimum	7.50	7.20	
Maximum	7.81	7.85	

Source : CWQB, 1963.

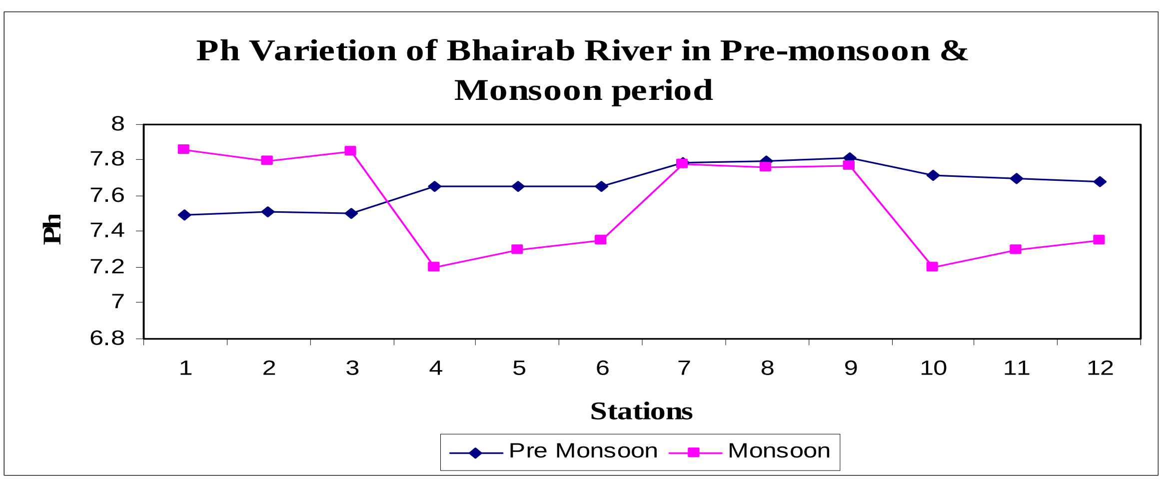

Figure 5.3.7: Graphical representation of PH of Bhairab River.

(ii) Chloride content

Table 5.3.8 Statistical presentation of Chloride of Bhairab River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	4280.83	31.59	Recommended for aquaculture Fish and aquatic life is 0.01 mg/l. Max fish can tolerate 0.37 mg/l. Minimum requirement for High-grade paper is 0.3 mg/ For surface irrigation 4-10 mg/l (Slight to moderate), > 10 mg/l (Severe).
Std Deviation	1187.17	6.66	
Variance	1409365.90	44.34	
Minimum (mg/l)	3155.30	25.00	
Maximum (mg/l)	6008.50	43.00	

Source : EPA, 1976.

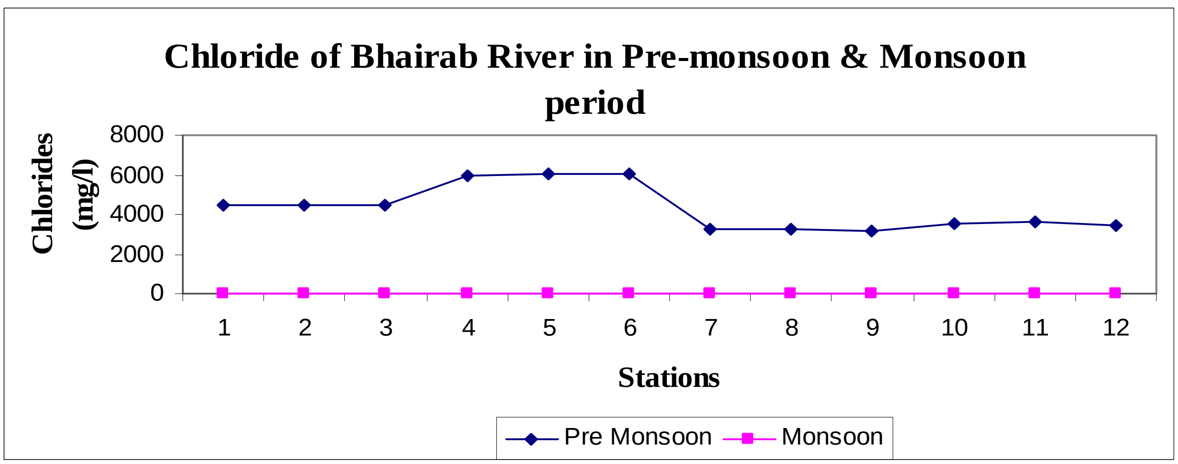

Figure 5.3.8: Graphical representation of Chloride content of Bhairab River.

(iii) T- Alkalinity

Table 5.3.9 Statistical presentation of T-Alkalinity of Bhairab River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	48.32	30.00	Recommended max alkalinity for,

Table 5.3.9 (Continue)

Std Deviation	12.31	0.00	Carbonated beverages 85 mg/l Food products (canning) 300 mg/l Fruit juice 100 mg/l Pulp and paper making 50 mg/l Textile mill products 50-200 mg/l Rayon manufacture 50 mg/l Limit for fish culture is 50-400 mg/l
Variance	151.46	0.00	
Minimum (mg/l)	30.00	30.00	
Maximum (mg/l)	60.50	30.00	

Source: (i) CWQB, 1963. (ii) EPA, 1976.

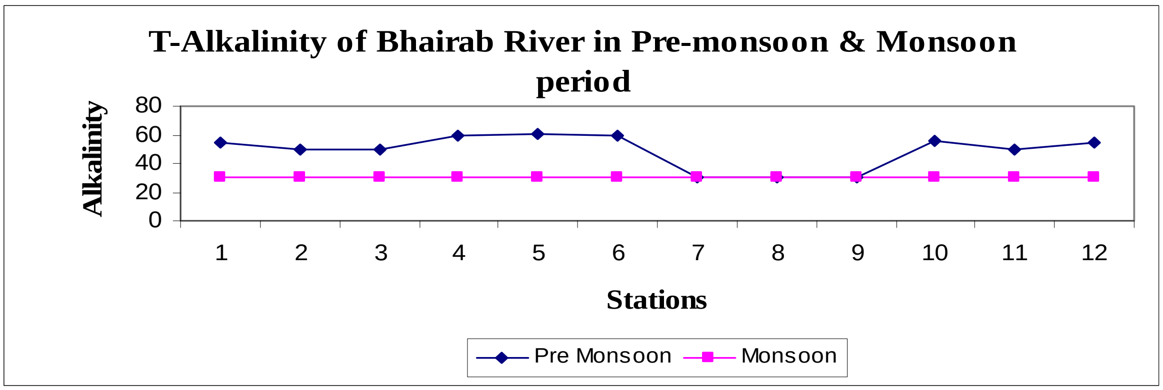

Figure 5.3.9: Graphical representation of T-Alkalinity of Bhairab River.

(iv) Dissolved Oxygen

Table 5.3.10 Statistical presentation of Dissolved Oxygen of Bhairab River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	5.42	5.89	Usable for Irrigation when DO ≥ 5 mg/l. Fisheries when DO ≥ 5 mg/l. Recreational act. DO ≥ 5 mg/l Drinking purpose at DO ≥ 6 mg/l after disinfection. Cooling industries at DO ≥ 5 mg/l.
Std Deviation	0.12	0.10	
Variance	0.01	0.01	
Minimum (mg/l)	5.20	5.80	
Maximum (mg/l)	5.60	6.00	

Source: ECR 1997.

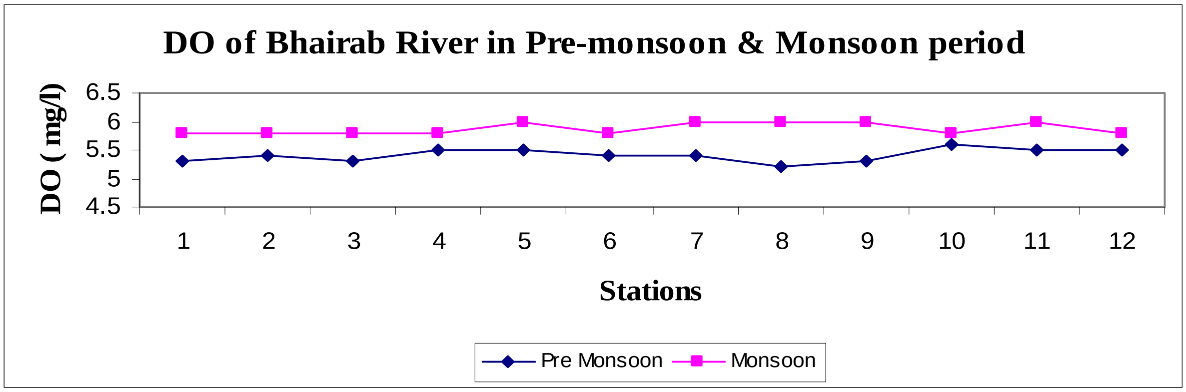

Figure 5.3.10: Graphical representation of DO of Bhairab River.

(iv) BOD

Table 5.3.11 Statistical presentation of BOD of Bhairab River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean	1.76	0.98	Usable for Irrigation when BOD ≤ 2mg/l.
Std Deviation	0.59	0.32	Fisheries when BOD ≤ 6mg/l.
Variance	0.35	0.10	Recreational activity BOD ≤ 3mg/l.
Minimum	1.20	0.5	Drinking purpose BOD ≤ 2mg/l after disinfection.
Maximum	2.50	1.25	Cooling industries BOD ≤ 10mg/l.

Source : ECR 1997

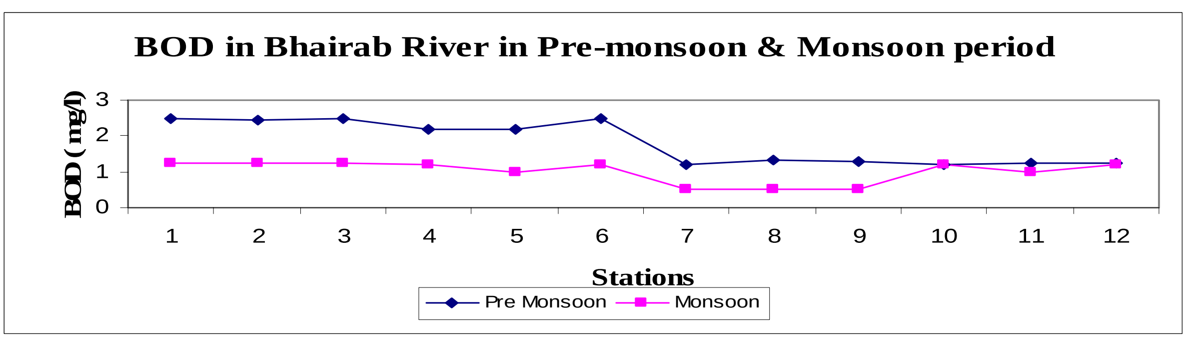

Figure 5.3.11: Graphical representation of BOD of Bhairab River.

(vi) COD

Table 5.3.12: Statistical presentation of COD of Bhairab River

Statistics	Pre-Monsoon	Monsoon	Remark
Mean	35.45	35.36	Usable for bathing purpose when COD is 180-270 mg/l .
Std Deviation	8.20	6.47	
Variance	67.27	41.85	
Minimum	25.00	30.00	
Maximum	45.00	45.00	

Source : Wintgens *et al.*, 2005

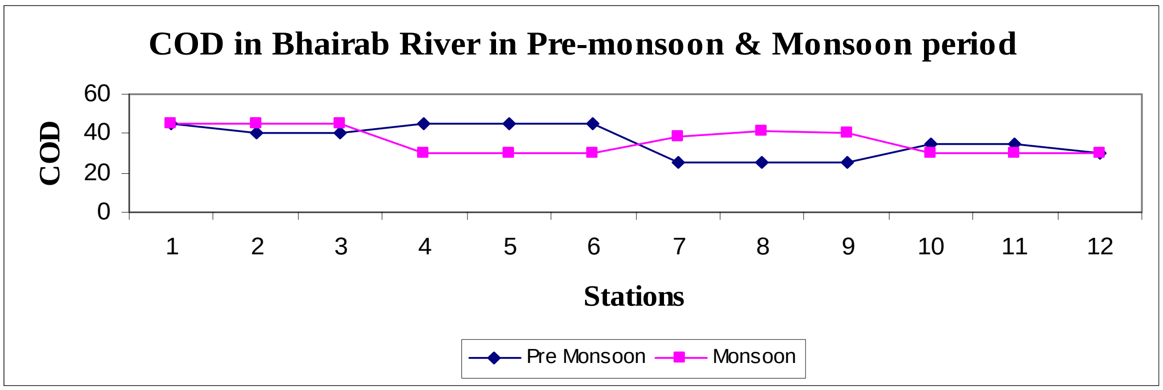

Figure 5.3.12: Graphical representation of COD of Bhairab River at different sampling station.

The mean values of the various chemical parameters of the Bhairab River water are presented. The mean value of water pH at different stations of the river was found as 7.68 (Pre Monsoon) and 7.51 (Monsoon). The value of pH was normal compared with the standard level as the optimum value of water pH is 6.5-8.5 or around 7 for the drinking purpose. as well as aquatic organisms and the tolerable range is between 6 and 8.5 (ECR 1997). The PH value of Bhairab River water is also fit for fish culture and algae growth as well as industrial and manufacturing processes like Food canning, freezing, Rayon manufacturing and Tanning leather. But this water needs to be pretreated in case of washing clothes.

The mean values of dissolve oxygen (DO) were 5.42 mg/l (Pre Monsoon), 5.89 mg/l (Monsoon) at various stations throughout the experimental period. Sampling result at the pre monsoon and monsoon period revealed that the values of DO were slightly low. Bhairab River water is fit for Irrigation, fish culture, recreational activity and Cooling industries But this water needs to be pretreated in case of use it for drinking purpose after disinfection. DO is very important for identifying a suitable aquatic body and also to estimate productivity of an aquatic system (Romesh and Anbu, 1996; Davies, *et al.*, 2008). The low oxygen of this river water was due to the excess dumping (domestic and urban sewage, industrial effluents, agricultural wastes etc.). The major effect of sewage in water is that it reduces oxygen content of water as the organic matter content of sewage is higher (Ragothaman and Trivedy, 2002).

The mean value of biochemical oxygen demand (BOD) are 1.76mg/l (Pre Monsoon) and 0.98 mg/l (Monsoon) and chemical oxygen demand (COD) at different sampling stations were 35.45 mg/l (Pre Monsoon), 35.36 mg/l (Monsoon) respectively. BOD and COD levels were observed higher at the Pre monsoon and Monsoon period. A standard value of COD for drinking purposes is 4 mg/L and For bathing is 180-270 mg/L while in the case of biochemical oxygen demand (BOD), standard for drinking purpose is 0.2mg/L, sewage effluent 20 mg/L (Wintgens *et. al*, 2005; Jalil and Njiru, 2010). Oxygen being the basic requirement of almost all plant and animal life, its presence in sufficient quantities is important to support and sustain life. All organic matters undergo biodegradation and exhibit a biochemical oxygen demand (BOD) or a chemical oxygen demand (COD) as oxygen is required for their degradation (Khatri, 1984). The typical sources include sewage from domestic and animal source, industrial wastes, natural decaying vegetation, decay of dead plants and animals. This type of water pollution becomes a severe problem when the oxygen required for biodegradation or chemical oxidation is greater than the available oxygen in the ecosystem. The estimation of BOD gives an indication of the amount of pollution in a body of water. The high amount of BOD indicates large bacterial and fungal population. Owing to metabolic activities of these organisms, the dissolved oxygen gets reduced and the area is found without oxygen. Aquatic organisms such as fishes either evade this area or are killed (Khatri, 1985). After above analysis we found that Bhairab River water is suitable for irrigation, fish culture, recreational activities, drinking purpose (after disinfection) and cooling purpose in industries.

5.4 Parameterization of water quality parameter of Gorai River

5.4.1 Physical parameter

Among all physical properties the concern of these study was focused on Physical parameters such as temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid for Gorai River.

(i) Temperature

Table 5.4.1: Statistical presentation of Temperature of Gorai River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (^{0}C)	30.83	27.50	Optimum Temp for
Std Deviation	0.82	0.55	Carp fish is 32 ^{0}C
Variance	0.67	0.30	Diatoms grow best at 15-25 ^{o}C,
Minimum (^{0}C)	30.00	27.00	Green algae grow best at 25-35 ^{o}C,
Maximum (^{0}C)	32.00	28.00	Blue-green algae at 30-40 ^{o}C.

Source: (i) CWQB, 1963. (ii) EPA, 1976.

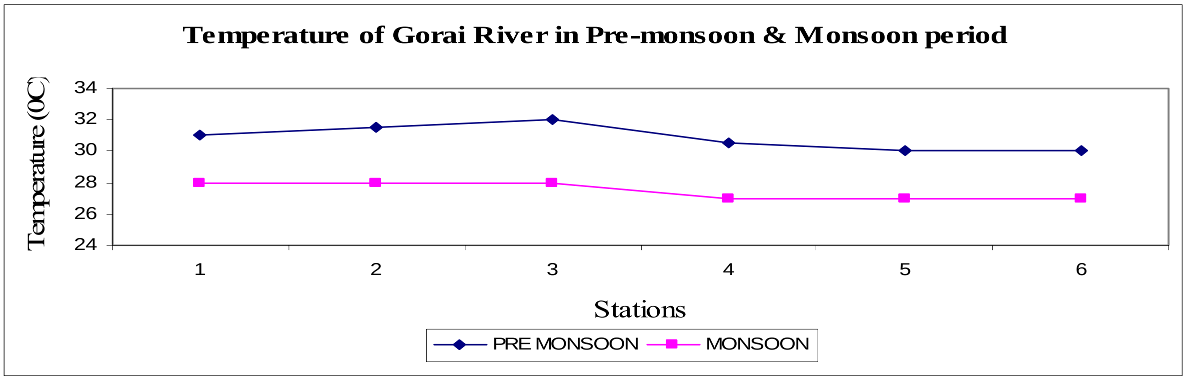

Figure 5.4.1: Graphical representation of temperature of Gorai River.

(ii) Turbidity

Table 5.4.2: Statistical presentation of Turbidity of Gorai River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (NTU)	23.73	43.42	Amount of fish 162 lb/ acre for 25 NTU, 94 lb/ acre for 25 -100 NTU, 29 lb/ acre for over 100 NTU. Usable for Beverages if turbidity is 1-2 NTU Food products for 10 NTU Water used in boilers for 1-20 NTU (varies with type of boiler) High grade paper for 5-25 NTU Water used for cooling for 50 NTU. Tanning leather for 20 NTU
Std Deviation	6.88	13.02	
Variance	47.33	4783.98	
Minimum (NTU)	14.00	30.50	
Maximum (NTU)	31.00	60.00	

Source: CWQB, 1963.

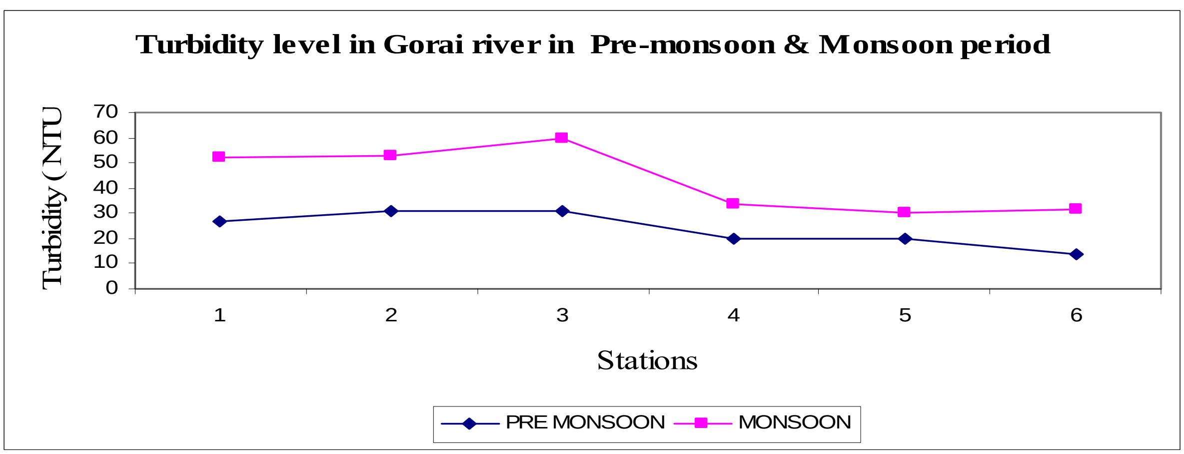

Figure 5.4.2: Graphical representation of Turbidity of Gorai River.

(iii) Electric Conductivity

Table 5.4.3: Statistical presentation of Electric Conductivity of Gorai River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (dS/m)	0.53	0.40	Three categories of EC is specified by FAO for irrigation. (i) None (<0.7 dS/m) , (ii) Slight to moderate (0.7 to 3.0 dS/m), (iii) Severe (> 3.0 dS/m).
Std Deviation	0.25	0.03	
Variance	0.06	0.00	
Min (dS/m)	0.03	0.38	
Max (dS/m)	0.84	0.44	

Source : Ayres and Westcot 1985.

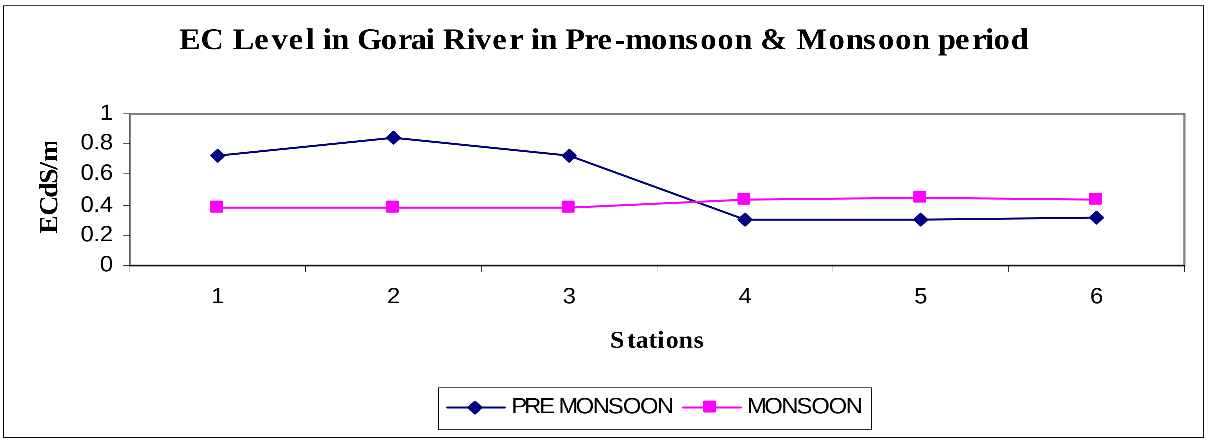

Figure 5.4.3: Graphical representation of EC of Gorai River.

(iv) Total Solid

Table 5.4.4 Statistical presentation of Total Solid of Gorai River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	547.50	211.17	Compared with the standards as suspended and dissolved solids.
Std Deviation	385.76	33.16	
Variance	148812.30	1099.37	
Minimum (mg/l)	188.00	178.00	
Maximum (mg/l)	921.00	244.00	

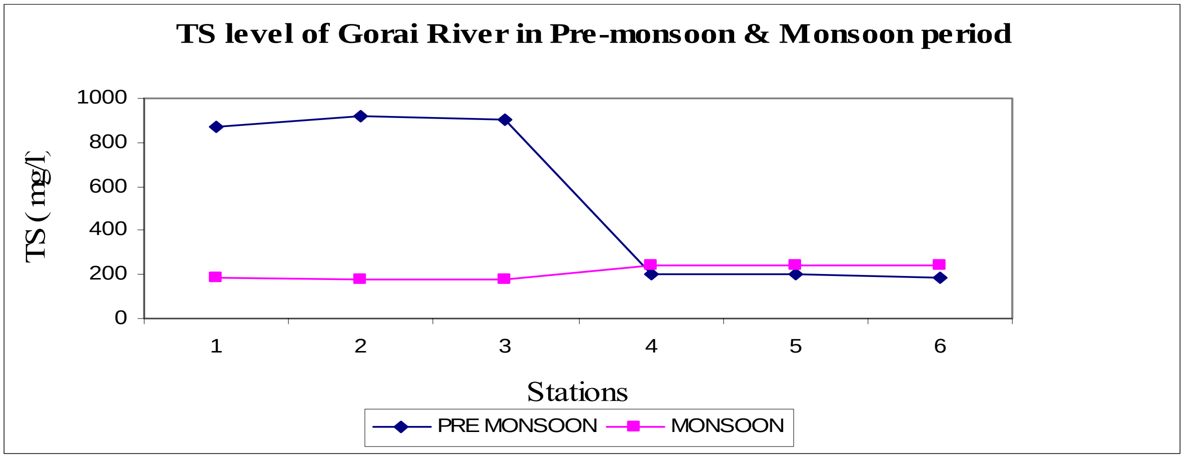

Figure 5.4.4: Graphical representation of TS of Gorai River.

(v) Total Dissolved Solid

Table 5.4.5 Statistical presentation of Total Dissolved Solid of Gorai River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	490.83	170.33	Three categories of TDS is specified by FAO for irrigation. None (< 450 mg/l) , Slight to moderate (450-2000 mg/l) Severe (> 2000 mg/l).
Std Deviation	358.18	30.82	
Variance	128289.37	949.87	
Minimum (mg/l)	160.00	138.00	
Maximum (mg/l)	835.00	200.00	

Source : Ayres and Westcot 1985.

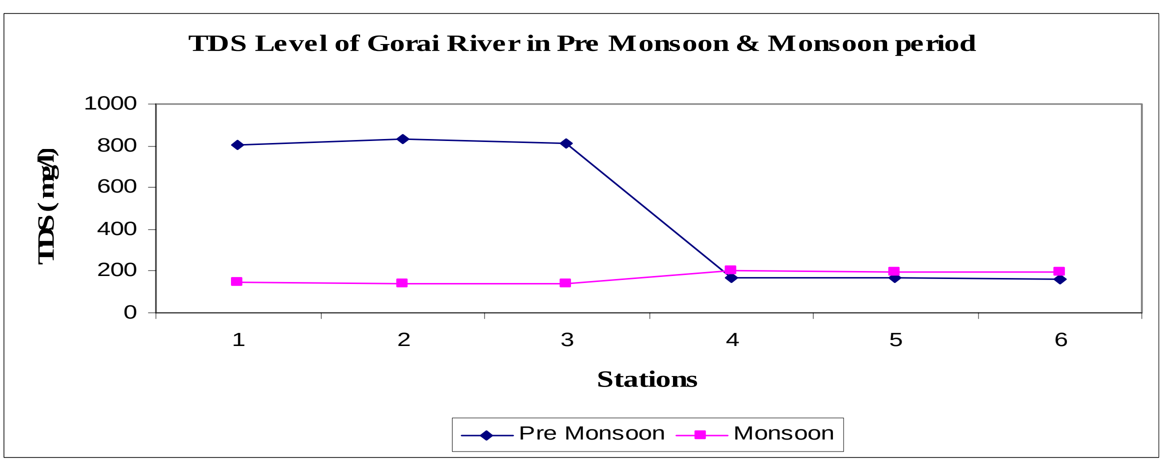

Figure 5.4.5: Graphical representation of TDS of Gorai River.

(vi) Suspended Solid

Table 5.4.6 Statistical presentation of Suspended Solid of Gorai River
Source : ECR 1997.

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	56.67	40.83	SS for fish culture is <1500 ppm.
Std Deviation	28.55	2.56	For drinking water, allowable
Variance	815.07	6.57	concentration (maximum)
Minimum (mg/l)	28.00	38.00	Bangladesh standard 10 mg/l
Maximum (mg/l)	91.00	44.00	WHO standard is 10 mg/l.

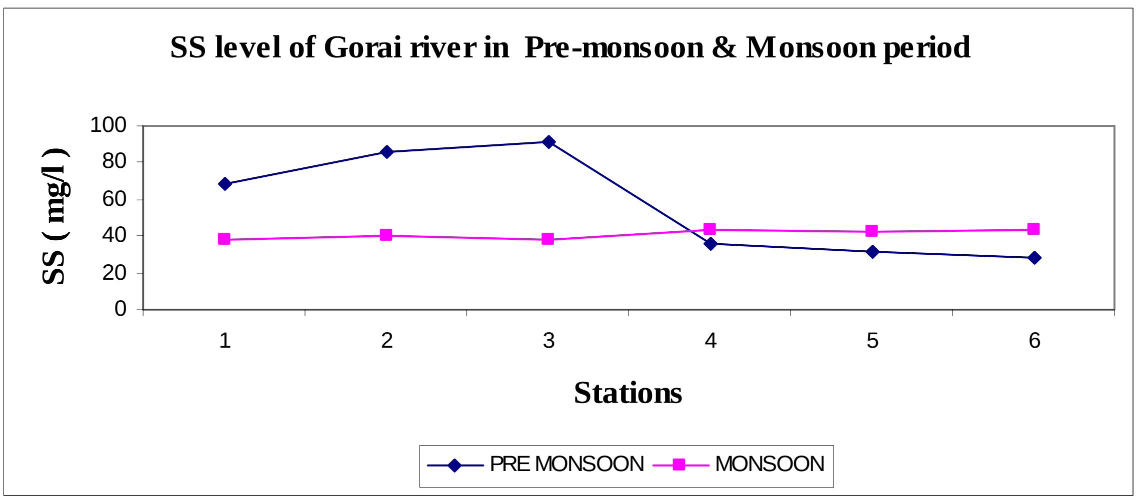

Figure 5.4.6: Graphical representation of SS of Gorai River.

Some aspects of physical water quality parameters of Gorai River for Pre Monsoon and Monsoon period have been presented. The average value of water temperature were 30.83^{0}C (Pre Monsoon) and 27.50 ^{0}C (Monsoon), Temperature of Gorai River water showed that it might be tolerable for aquaculture like Carp fish, Green algae and Blue-green algae.

Turbidity of Gorai River water were seen to be 23.73 NTU (Pre Monsoon) and 43.42 NTU (Monsoon), SS were 56.67 mg/l (Pre Monsoon) and 40.83 mg/l (Monsoon) and

TDS were 490.83 mg/l (Pre Monsoon) and 170.33 mg/l (Monsoon) respectively. Turbidity of water mainly caused by silt, clay, waste materials, heavy particles, dumps etc. Turbidity always indicated the amount of various particles present in water which includes both the total dissolved and suspended solids present in water (Onyema, 2007). The value of different physical water quality parameters showed a higher rate in Pre Monsoon period than in Monsoon Period. These values decrease gradually as a result of more surface water flow in the river during monsoon period. Production of fish culture of Gorai River is seen to be favorable to produce 94 lb/acre of fish. Water of Gorai River is usable for cooling purpose. Gorai River water needs to be pretreated before using in beverage industries, food products, boiler, pulp paper industries and tanning leather.

The mean value of EC of Gorai River were seen to be 0.53 dS/m (Pre monsoon) 0.40 dS/m (Monsoon).The results of the present study clearly indicate that the water of Gorai River was carrying considerable limit of EC , which is safe for irrigation according to FAO.

The standard values of SS and TDS were seen to be 10 mg/L and 1000 mg/L for the inland surface water of Bangladesh (Alam, *et al.,* 2007). After analysis the mean value of SS were found to be 56.67 mg/l (Pre Monsoon) and 40.83 mg/l (Monsoon) and TDS were 490.83 mg/l (Pre Monsoon) and 170.33 mg/l (Monsoon) . The amount of SS and TDS were considerably high in Pre Monsoon Period. But in Monsoon period its value is low. So in monsoon period Gorai River water is favorable for any purpose. The heavy particles present in the waste materials become settled on the river bottom and the remaining lighter particles are carried out with water in the form of suspended and dissolved forms. Higher amount of various solids present in water have a negative impact on the productivity and maintaining good water quality as these reduce the light penetration in water.

5.4.2 Chemical parameter

There are different chemical properties which can indicate the status of river water quality but for the study properties like P^H, chloride, alkalinity or T-alkalinity, hardness, DO, BOD, COD for Gorai River were considered.

(i) P^H

Table 5.4.7 Statistical presentation of P^H of Gorai River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean	7.32	7.53	Optimum P^H for aquaculture Fish eggs could be hatched, but deformed young were often produced between P^H 3.8 - 10 Limit of P^H for resistant fish is 4-10.1 Range tolerated by trout is P^H 4.1- 9.5 Best range for the growth of algae P^H 7.5-8.4. Food canning when minimum P^H 7.5 freezing when minimum P^H 7.5 Washing clothes when P^H 6-6.8
Std Deviation	0.14	0.27	
Variance	0.02	0.08	
Minimum	7.20	7.20	
Maximum	7.50	7.80	

Source : CWQB, 1963.

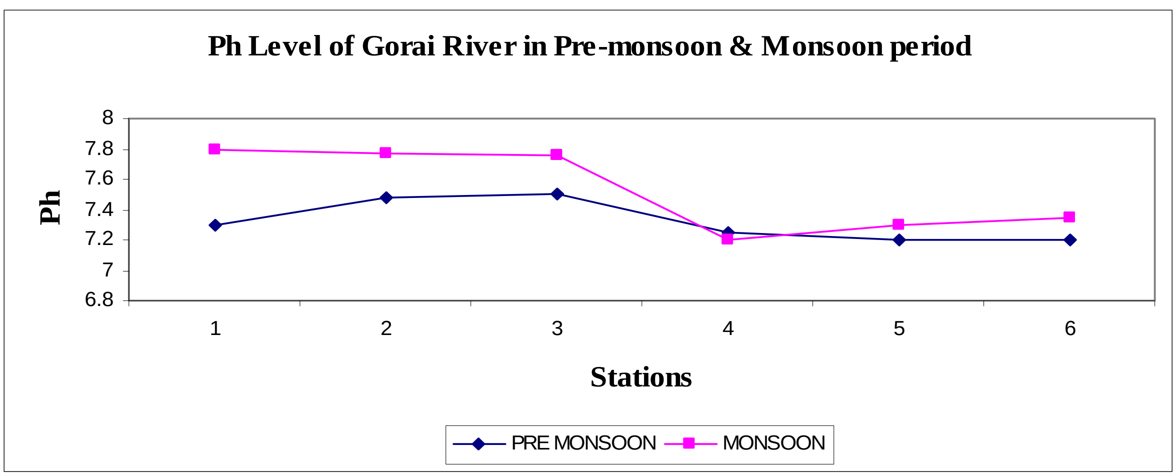

Figure 5.4.7: Graphical representation of PH of Gorai River.

(iii) Chloride content

Table 5.4.8 Statistical presentation of Chloride of Gorai River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	122.58	24.50	Recommended for aquaculture Fish and aquatic life is 0.01 mg/l. Max fish can tolerate 0.37 mg/l. Minimum requirement for High-grade paper is 0.3 mg/l For surface irrigation 4-10 mg/l (Slight to moderate) > 10 mg/l (Severe).
Std Deviation	94.29	2.68	
Variance	8890.04	7.20	
Minimum (mg/l)	35.00	21.00	
Maximum (mg/l)	220.00	28.50	

Source : EPA, 1976.

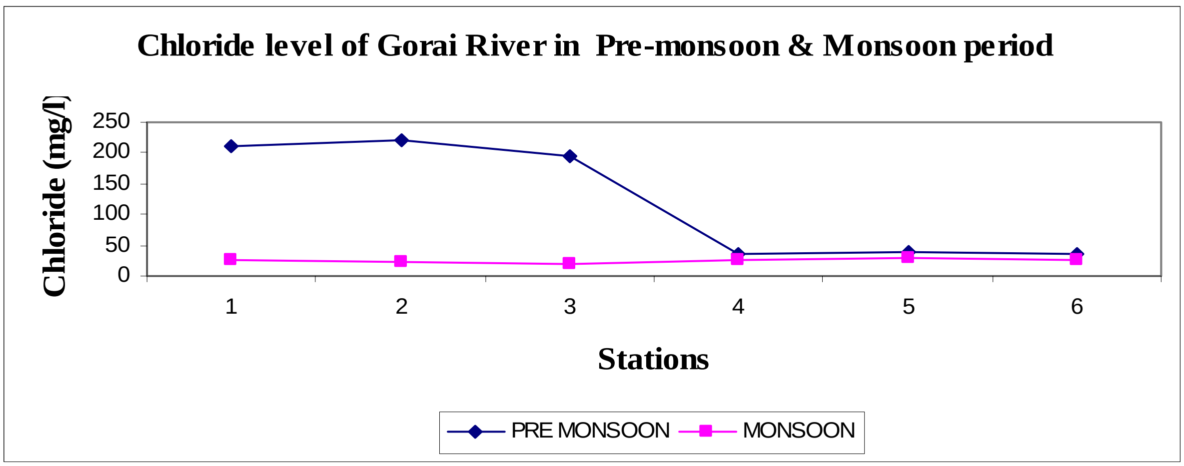

Figure 5.4.8: Graphical representation of Chloride content of Gorai River.

(iv) T- Alkalinity

Table 5.4.9 Statistical presentation of Alkalinity of Gorai River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	31.07	38.14	Recommended max alkalinity for, Food products (canning) 300 mg/l Carbonated beverages 85 mg/l
Std Deviation	11.34	16.45	
Variance	9.20	103.48	

Table 5.4.9 (Continue)

Variance	9.20	103.48	Fruit juice 100 mg/l Pulp and paper making 50 mg/l Textile mill products 50-200 mg/l Rayon manufacture 50 mg/l Limit for fish culture is 50-400 mg/l
Minimum (mg/l)	26.50	30.00	
Maximum (mg/l)	35.00	53.00	

Source: (i) CWQB, 1963.

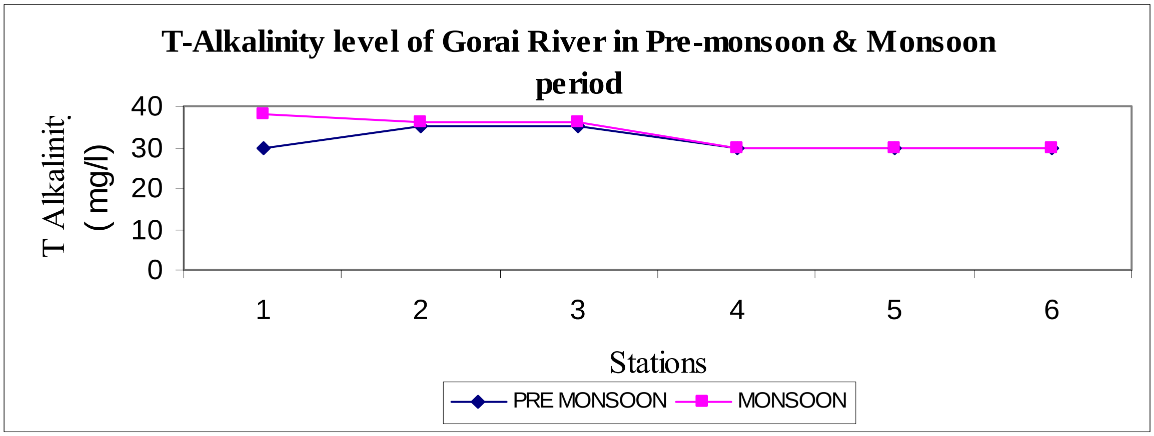

Figure 5.4.9: Graphical representation of T-Alkalinity of Gorai River.

(iv) Dissolved Oxygen

Table 5.4.10 Statistical presentation of Dissolved Oxygen of Gorai River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	6.15	5.93	Usable for Irrigation when DO ≥ 5 mg/l. Fisheries when DO ≥ 5 mg/l. Recreational act. DO ≥ 5 mg/l Drinking purpose at DO ≥ 6 mg/l after disinfection. Cooling industries at DO ≥ 5 mg/l.
Std Deviation	0.38	0.10	
Variance	0.15	0.01	
Min (mg/l)	5.80	5.80	
Max (mg/l)	6.50	6.00	

Source: ECR 1997.

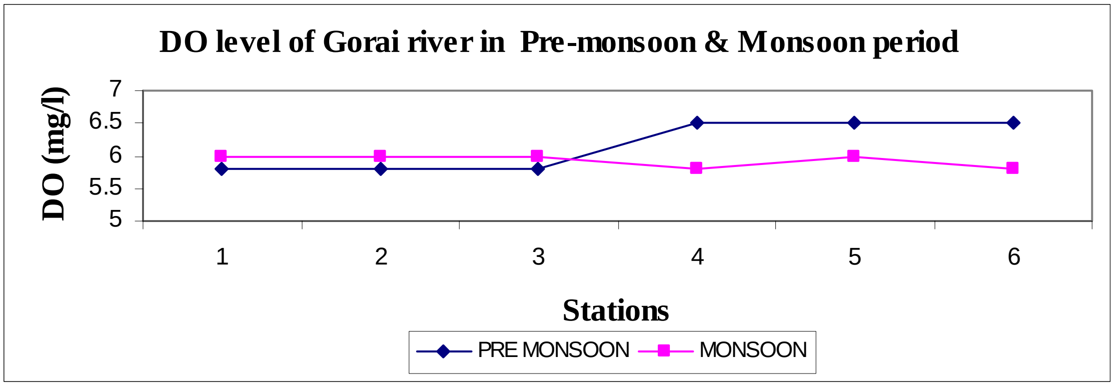

Figure 5.4.10: Graphical representation of DO of Gorai River.

(iii) BOD

Table 5.4.11 Statistical presentation of BOD of Gorai River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	0.75	0.87	Usable for Irrigation when ≤ 2mg/l.
Std Deviation	0.38	0.30	Fisheries when ≤ 6mg/l.
Variance	0.15	0.09	Recreational activity ≤ 3mg/l.
Min (mg/l)	0.40	0.60	Drinking purpose ≤ 2mg/l
Max (mg/l)	1.10	1.20	Cooling industries ≤ 10mg/l.

Source : ECR 1997

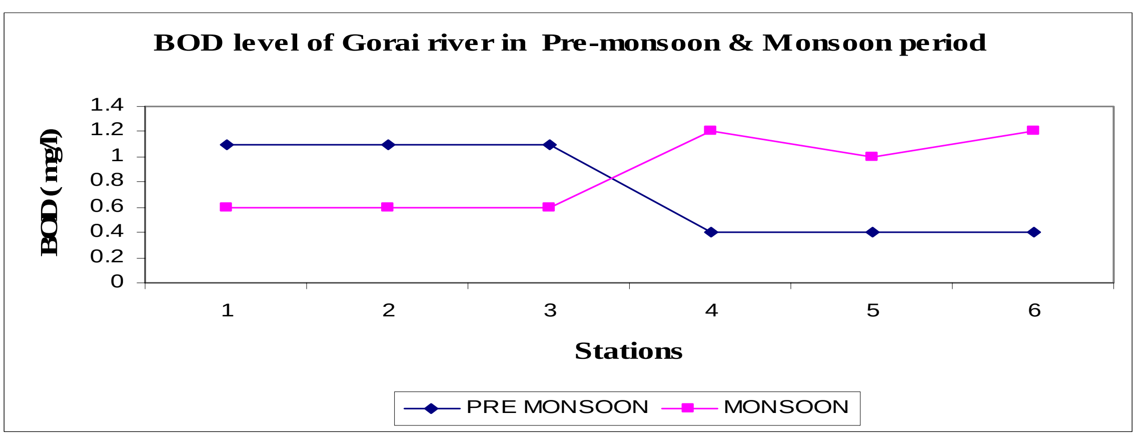

Figure 5.4.11: Graphical representation of BOD of Gorai River.

(vi) COD

Table 5.4.12: Statistical presentation of COD of Gorai River

Statistics	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	29.67	25.00	Usable for bathing purpose when COD is 180-270 mg/l .
Std Deviation	4.55	5.48	
Variance	20.67	30.00	
Min (mg/l)	25.00	20.00	
Max (mg/l)	35.00	30.00	

Source : Wintgens et al 2005

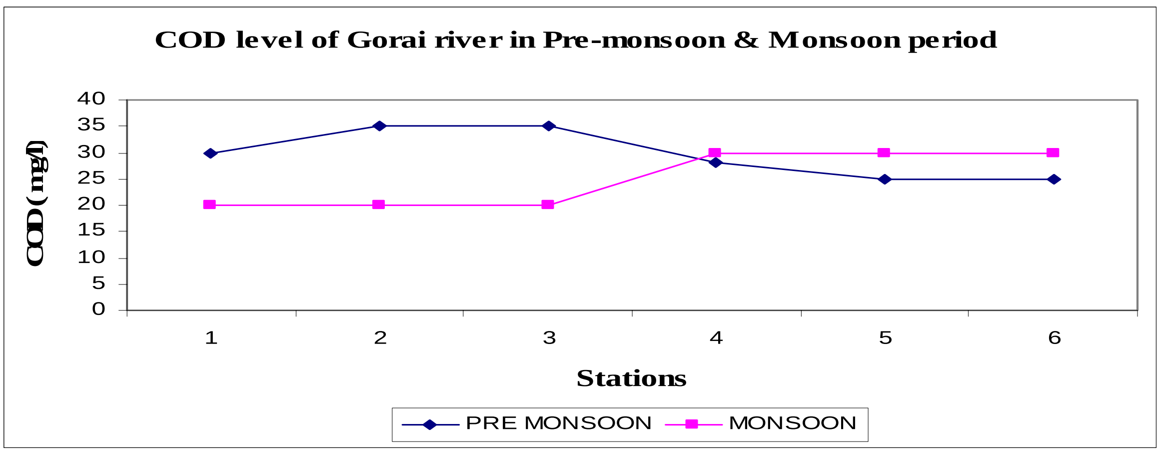

Figure 5.4.12: Graphical representation of COD of Gorai River at different sampling station.

The mean values of the various chemical parameters of the Gorai River water are presented. The mean value of water pH at different stations of the river was found as 7.32 (Pre Monsoon) and 7.53 (Monsoon). The value of pH was normal compared with the standard level as the optimum value of water pH is 6.5-8.5 or around 7 for the drinking purpose. as well as aquatic organisms and the tolerable range is between 6 and 8.5 (ECR 1997). The P^H value of Gorai River water is also fit for fish culture and algae growth as well as industrial and manufacturing processes like Food canning, freezing, Rayon manufacturing and Tanning leather. But this water needs to be pretreated in case of washing clothes. The mean values of dissolve oxygen (DO) were 6.15mg/l (Pre

Monsoon), 5.93 mg/l (Monsoon) at various stations throughout the experimental period. Sampling result at the pre monsoon and monsoon period revealed that the values of DO were slightly low. Gorai River water is fit for Irrigation, fish culture, recreational activity and Cooling industries But this water needs to be pretreated in case of use it for drinking purpose after disinfection. DO is very important for identifying a suitable aquatic body and also to estimate productivity of an aquatic system (Romesh and Anbu, 1996; Davies, *et al.*, 2008). The low oxygen of this river water was due to the excess dumping (domestic and urban sewage, industrial effluents, agricultural wastes etc.). The major effect of sewage in water is that it reduces oxygen content of water as the organic matter content of sewage is higher (Ragothaman and Trivedy, 2002).

The mean value of biochemical oxygen demand (BOD) are 0.75mg/l (Pre Monsoon) and 0.87 mg/l (Monsoon) and chemical oxygen demand (COD) at different sampling stations were 29.67 mg/l (Pre Monsoon), 25.00 mg/l (Monsoon) respectively. BOD and COD levels were observed higher at the Pre monsoon and Monsoon period. A standard value of COD for drinking purposes is 4 mg/L and For bathing is 180-270 mg/L while in the case of biochemical oxygen demand (BOD), standard for drinking purpose is 0.2 mg/L, sewage effluent 20 mg/L (Wintgens *et al.,* 2005; Jalil and Njiru, 2010). Oxygen being the basic requirement of almost all plant and animal life, its presence in sufficient quantities is important to support and sustain life. All organic matters undergo biodegradation and exhibit a biochemical oxygen demand (BOD) or a chemical oxygen demand (COD) as oxygen is required for their degradation (Khatri, 1984). The typical sources include sewage from domestic and animal source, industrial wastes, natural decaying vegetation, decay of dead plants and animals. This type of water pollution becomes a severe problem when the oxygen required for biodegradation or chemical oxidation is greater than the available oxygen in the ecosystem. The estimation of BOD gives an indication of the amount of pollution in a body of water. The high amount of BOD indicates large bacterial and fungal population. Owing to metabolic activities of these organisms, the dissolved oxygen gets reduced and the area is found without oxygen. Aquatic organisms such as fishes either evade this area or are killed (Khatri, 1985). After above analysis we found that Gorai River water is suitable for irrigation, fish culture, recreational activities, drinking purpose (after disinfection) and cooling purpose in industries.

5.5 Parameterization of water quality parameter of Rupsha River

5.5.1 Physical parameter

Among all physical properties the concern of these study was focused on Physical parameters such as temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid for Rupsha River.

(i) Temperature

Table 5.5.1: Statistical presentation of Temperature of Rupsha River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (^{0}C)	30.33	27.50	Optimum Temp for
Std Deviation	0.29	0.00	Carp fish is 32 ^{0}C
Variance	0.08	0.00	Diatoms grow best at 15-25 ^{o}C,
Minimum (^{0}C)	30.00	27.50	Green algae grow best at 25-35 ^{o}C,
Maximum (^{0}C)	30.50	27.50	Blue-green algae at 30-40 ^{o}C.

Source: (i) CWQB, 1963. (ii) EPA, 1976.

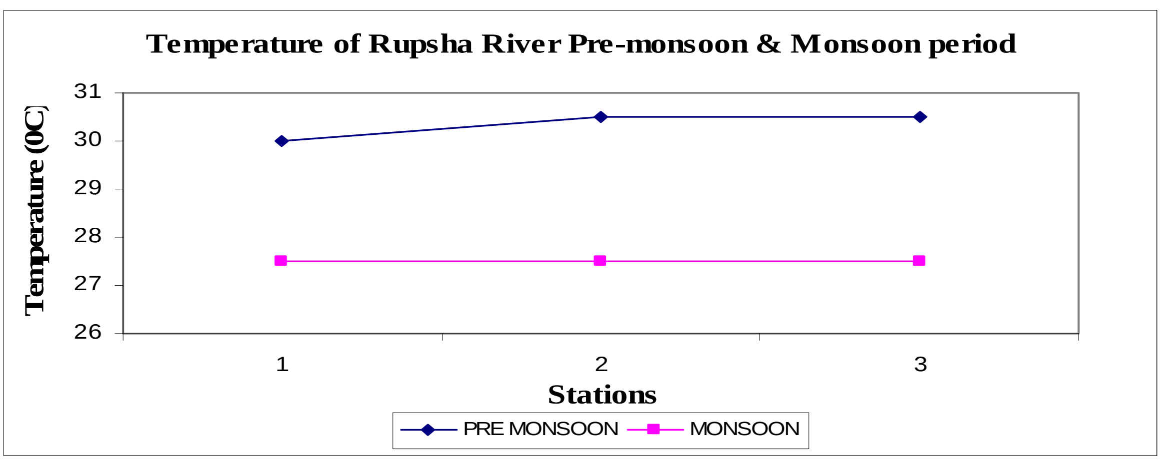

Figure 5.5.1: Graphical representation of temperature of Rupsha River.

(ii) Turbidity

Table 5.5.2: Statistical presentation of Turbidity of Rupsha River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (NTU)	51.37	58.50	Amount of fish 162 lb/ acre for 25 NTU, 94 lb/ acre for 25 -100 NTU, 29 lb/ acre for over 100 NTU. Usable for Beverages if turbidity is 1-2 NTU Food products 10 NTU Water used in boilers 1-20 NTU (varies with type of boiler) High grade paper 5-25 NTU Water used for cooling 50 NTU. Tanning leather 20 NTU
Std Deviation	3.36	0.00	
Variance	11.30	22316.75	
Minimum (NTU)	47.50	58.50	
Maximum (NTU)	53.60	58.50	

Source: CWQB, 1963.

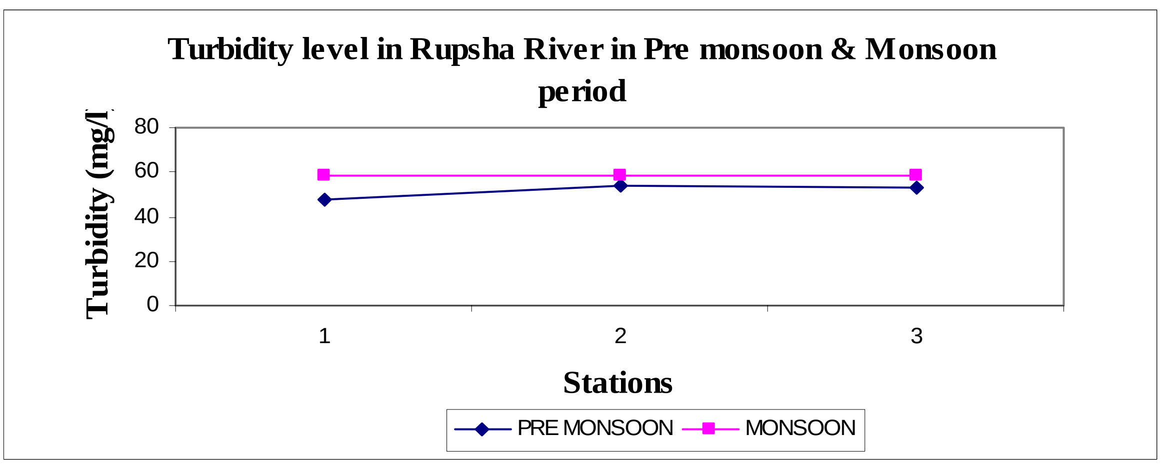

Figure 5.5.2: Graphical representation of Turbidity of Rupsha River.

(iii) Electric Conductivity

Table 5.5.3: Statistical presentation of Electric Conductivity of Rupsha River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (dS/m)	28.23	0.62	Three categories of EC is specified by FAO for irrigation. None (<0.7 dS/m) , Slight to moderate (0.7 to 3.0 dS/m) Severe (> 3.0 dS/m)
Std Deviation	0.04	0.00	
Variance	0.00	0.00	
Min (dS/m)	28.20	0.62	
Max (dS/m)	28.28	0.62	

Source: Ayres and Westcot 1985.

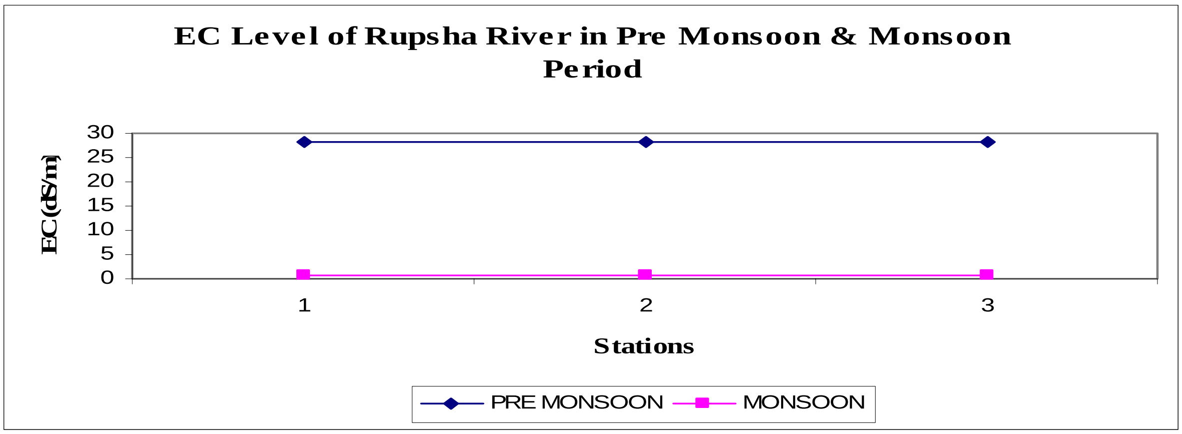

Figure 5.5.3: Graphical representation of EC of Rupsha River.

(iv) Total Solid

Table 5.5.4 Statistical presentation of Total Solid of Rupsha River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	11156.00	315.33	Compared with the standards of suspended and dissolved solids.
Std Deviation	94.64	8.50	
Variance	8956.00	72.33	
Minimum (mg/l)	11050.00	309.00	
Maximum (mg/l)	11232.00	325.00	

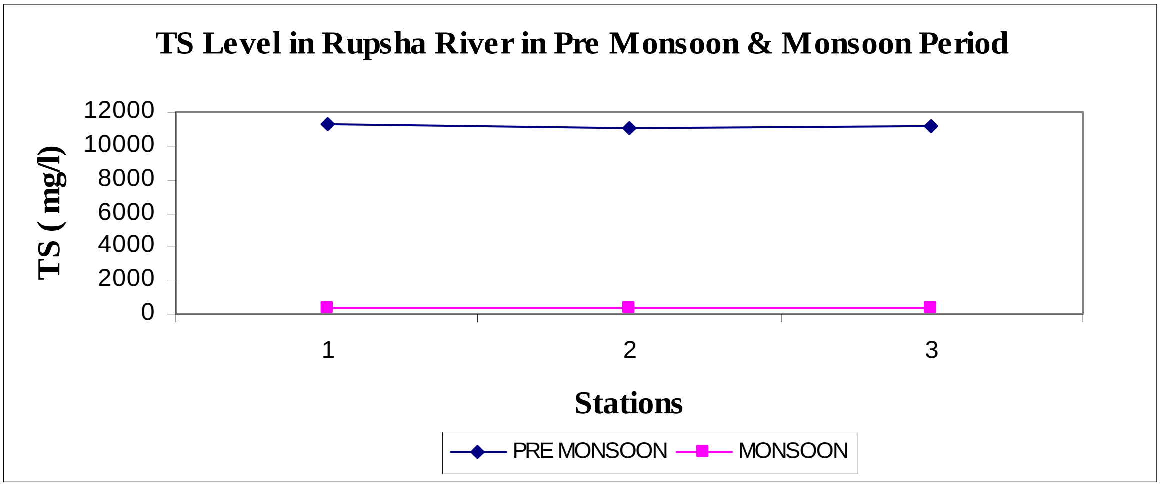

Figure 5.5.4: Graphical representation of TS of Rupsha River.

(v) Total Dissolved Solid

Table 5.5.5 Statistical presentation of Total Dissolved Solid of Rupsha River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	11043.33	265.00	Three categories of TDS is
Std Deviation	91.68	8.66	None (< 450 mg/l)
Variance	8404.33	75.00	Slight to moderate (450-2000 mg/l)
Minimum (mg/l)	10939.00	260.00	Severe (> 2000 mg/l).
Maximum (mg/l)	11111.00	275.00	

Source: Ayres and Westcot 1985.

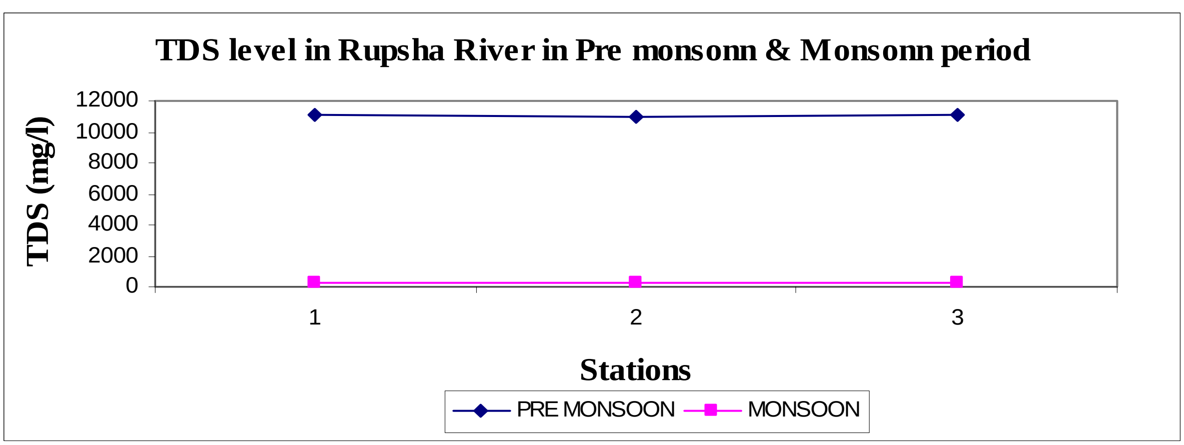

Figure 5.5.5: Graphical representation of TDS of Rupsha River.

(vi) Suspended Solid

Table 5.5.6 Statistical presentation of Suspended Solid of Rupsha River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	112.67	50.33	SS for fish culture is <1500 ppm. For drinking water, allowable concentration (maximum) Bangladesh standard 10 mg/l WHO standard is 10 mg/l.
Std Deviation	7.64	1.53	
Variance	58.33	2.33	
Minimum (mg/l)	106.00	49.00	
Maximum (mg/l)	121.00	52.00	

Source : ECR 1997.

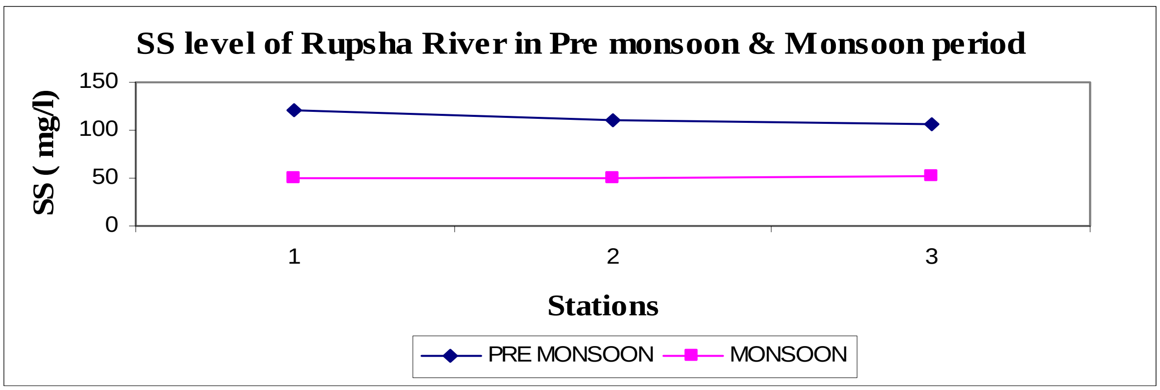

Figure 5.5.6: Graphical representation of SS of Rupsha River.

Some aspects of physical water quality parameters of Rupsha River for Pre Monsoon and Monsoon period have been presented. The average value of water temperature were 30.33^0C (Pre Monsoon) and 27.50 ^{0}C (Monsoon), Temperature of Rupsha River water showed that it might be tolerable for aquaculture like Carp fish, Green algae and Blue-green algae.

Turbidity of Rupsha River water were seen to be 51.37 NTU (Pre Monsoon) and 58.50 NTU (Monsoon), SS were 112.67 mg/l (Pre Monsoon) and 50.33 mg/l (Monsoon) and TDS were 11043.33 mg/l (Pre Monsoon) and 265.00 mg/l (Monsoon) respectively. Turbidity of water mainly caused by silt, clay, waste materials, heavy particles, dumps etc. Turbidity always indicated the amount of various particles present in water which includes both the total dissolved and suspended solids present in water (Onyema, 2007). The value of different physical water quality parameters showed a higher rate in Pre Monsoon period than in Monsoon Period. These values decrease gradually as a result of more surface water flow in the river during monsoon period. Production of fish culture of Rupsha River is seen to be favorable to produce 94 lb/acre of fish. Water of Rupsha River is usable for cooling purpose. Rupsha River water needs to be pretreated before using in beverage industries, food products, boiler, pulp paper industries and tanning leather.

The mean value of EC of Rupsha River were seen to be 28.23 dS/m (Pre monsoon) 0.62 dS/m (Monsoon). That indicates the inorganic mineral content is high in Pre monsoon period and is not suitable for maintaining the normal functioning in irrigation. But in Monsoon period the mean value of EC is with in the safe range for use in irrigation.

The standard values of SS and TDS were seen to be 10 mg/L and 1000 mg/L for the inland surface water of Bangladesh (Alam, *et al.,* 2007). After analysis the mean value of SS were found to be 112.67 mg/l (Pre Monsoon) and 50.33 mg/l (Monsoon) and TDS were 11043.33 mg/l (Pre Monsoon) and 265.00 mg/l (Monsoon) . The amount of SS and TDS were considerably high in Pre Monsoon period but at the same time TDS and SS was very low in the unit volume of water in Monsoon period. So in monsoon period Rupsha River water is favorable for any purpose. But in Pre Monsoon period Rupsha River Water needs pre treatment before use. The heavy particles present in the waste materials become settled on the river bottom and the remaining lighter particles are carried out with water in the form of suspended and dissolved forms. Higher amount of various solids present in water have a negative impact on the productivity and maintaining good water quality as these reduce the light penetration in water.

5.5.2 Chemical parameter

There are different chemical properties which can indicate the status of river water quality but for the study properties like P^H, chloride, alkalinity or T-alkalinity, hardness, DO, BOD, COD for Rupsha River were considered.

(i) P^H

Table 5.5.7 Statistical presentation of P^H of Rupsha River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean	7.60	7.52	Optimum P^H for aquaculture Fish eggs could be hatched, but deformed young were often produced between P^H 3.8 - 10
Std Deviation	0.01	0.03	Limit of P^H for resistant fish species is 4-10.1
Variance	0.00	0.00	Range tolerated by trout is P^H 4.1- 9.5 Best range for the growth of algae is P^H 7.5-8.4.
Minimum	7.59	7.50	Food canning when minimum P^H 7.5 Freezing when minimum P^H 7.5
Maximum	7.61	7.56	Washing clothes when P^H 6-6.8 Rayon manufacturing when P^H 7.8-8.3 Tanning leather when P^H 6-8

Source : CWQB, 1963.

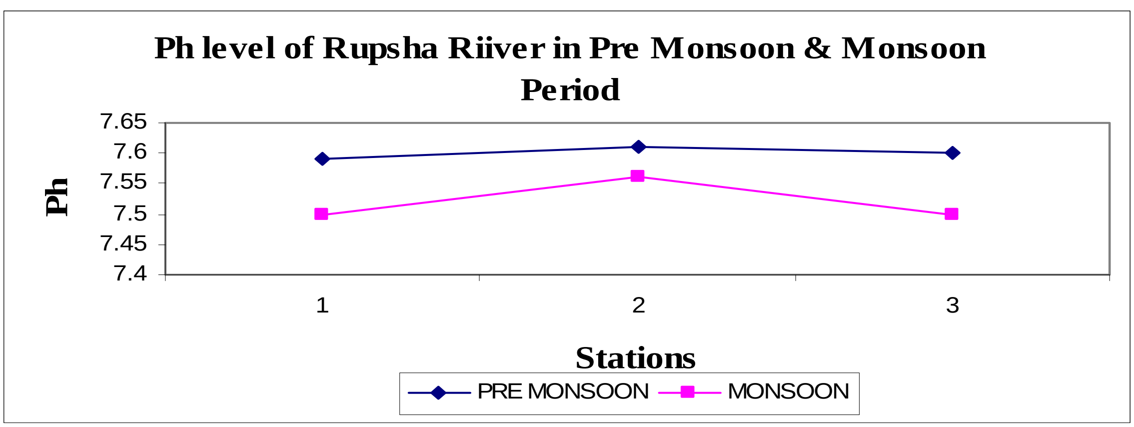

Figure 5.5.7: Graphical representation of P^H of Rupsha River.

(v) Chloride content

Table 5.5.8 Statistical presentation of Chloride of Rupsha River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	5986.10	52.17	Recommended for aquaculture Fish and aquatic life is 0.01 mg/l. Max fish can tolerate 0.37 mg/l. Minimum requirement for High-grade paper is 0.3 mg/l For surface irrigation 4-10 mg/l (Slight to moderate), > 10 mg/l (Severe).
Std Deviation	5.05	0.76	
Variance	25.48	0.58	
Minimum (mg/l)	5980.30	51.50	
Maximum (mg/l)	5989.50	53.00	

Source : EPA, 1976.

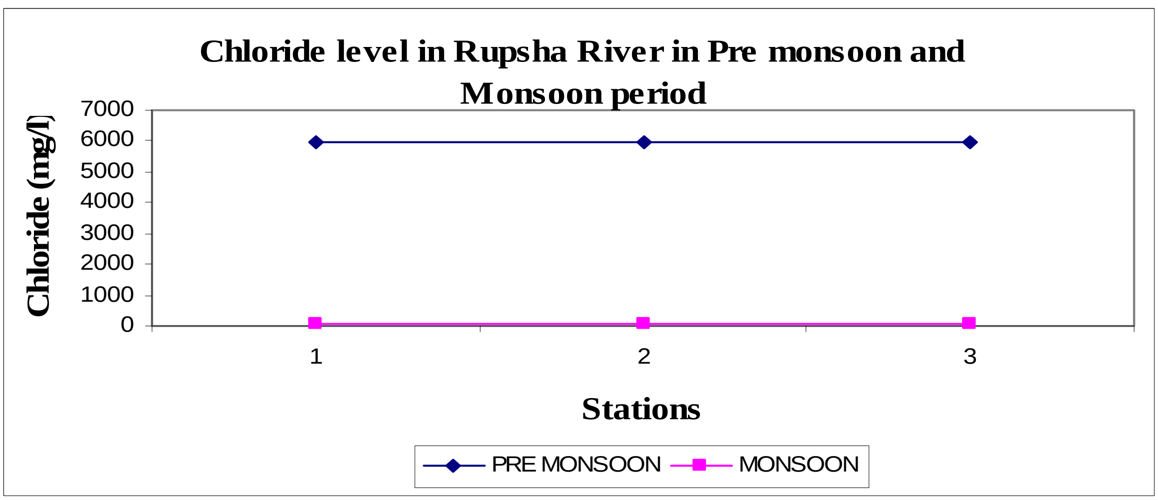

Figure 5.5.8: Graphical representation of Chloride level of Rupsha River.

(iii) T- Alkalinity

Table 5.5.9 Statistical presentation of T-Alkalinity of Rupsha River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	53.65	49.25	Recommended max alkalinity for,

Table 5.5.9 (Continue)

Std Deviation	24.30	23.89	Carbonated beverages 85 mg/l Food products (canning) 300 mg/l Fruit juice 100 mg/l Pulp and paper making 50 mg/l Textile mill products 50-200 mg/l Rayon manufacture 50 mg/l Limit for fish culture is 50-400 mg/l
Variance	20.06	114.08	
Minimum (mg/l)	47.50	40.00	
Maximum (mg/l)	58.00	58.50	

Source: (i) CWQB, 1963.

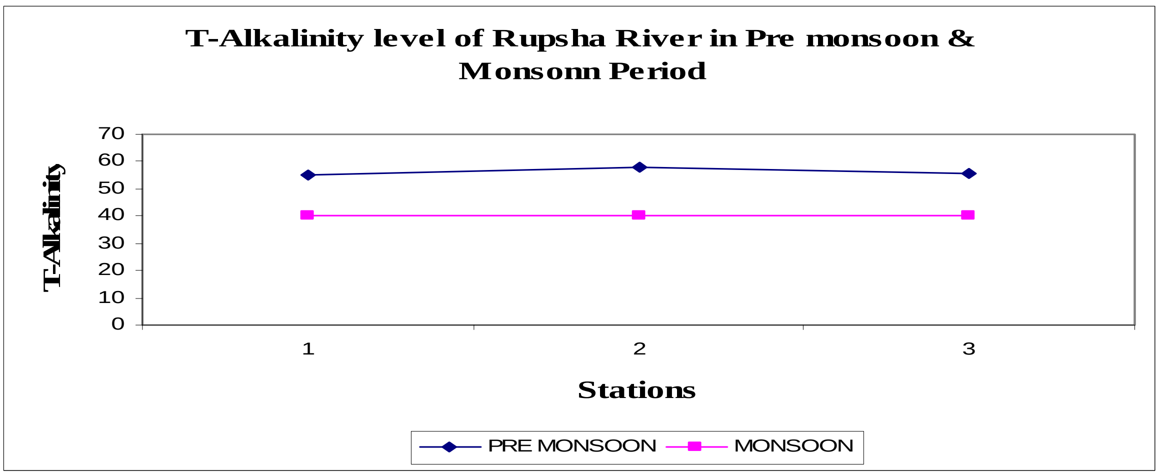

Figure 5.5.9: Graphical representation of T-Alkalinity of Rupsha River

(iv) Dissolved Oxygen

Table 5.5.10 Statistical presentation of Dissolved Oxygen of Rupsha River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	5.23	5.00	Usable for Irrigation when ≥ 5 mg/l. Fisheries when ≥ 5 mg/l. Recreational activity ≥ 5 mg/l Drinking purpose at ≥ 6 mg/l Cooling industries at ≥ 5 mg/l.
Std Deviation	0.25	0.00	
Variance	0.06	0.00	
Minimum (mg/l)	5.00	5.00	
Maximum (mg/l)	5.50	5.00	

Source: ECR 1997.

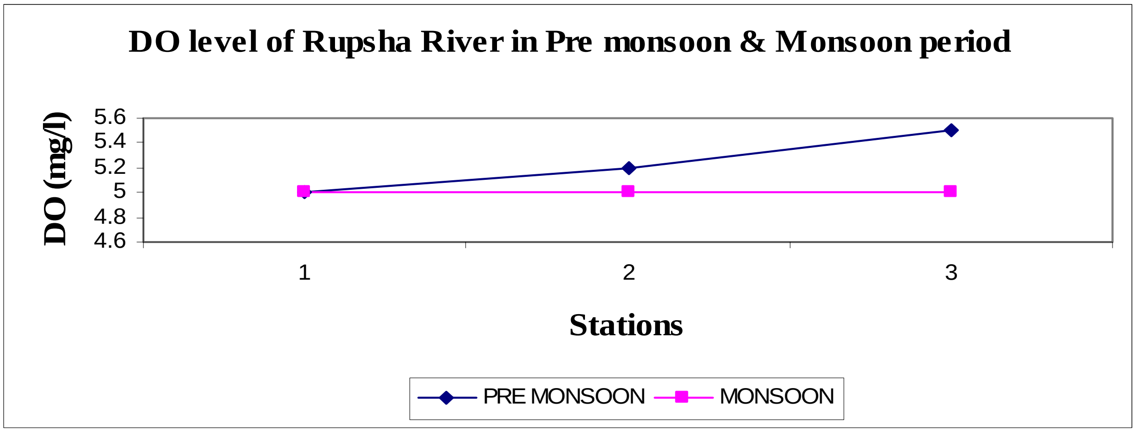

Figure 5.5.10: Graphical representation of DO of Rupsha River.

(v) BOD

Table 5.5.11 Statistical presentation of BOD of Rupsha River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	2.73	1.40	Usable for Irrigation when ≤ 2mg/l. Fisheries when ≤ 6mg/l. Recreational activity ≤ 3mg/l. Drinking purpose ≤ 2mg/l after disinfection. Cooling industries ≤ 10mg/l.
Std Deviation	0.40	0.00	
Variance	0.16	0.00	
Min (mg/l)	2.50	1.40	
Max (mg/l)	1.10	1.20	

Source : ECR 1997

(vi) COD

Table 5.5.12: Statistical presentation of COD of Rupsha River

Statistics	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	37.67	20.00	

Table 5.5.12 (Continue)

Std Deviation	2.52	0.00	Usable for bathing purpose when COD is 180-270 mg/l .
Variance	6.33	0.00	
Min (mg/l)	35.00	20.00	
Max (mg/l)	40.00	20.00	

Source : Wintgens et al 2005.

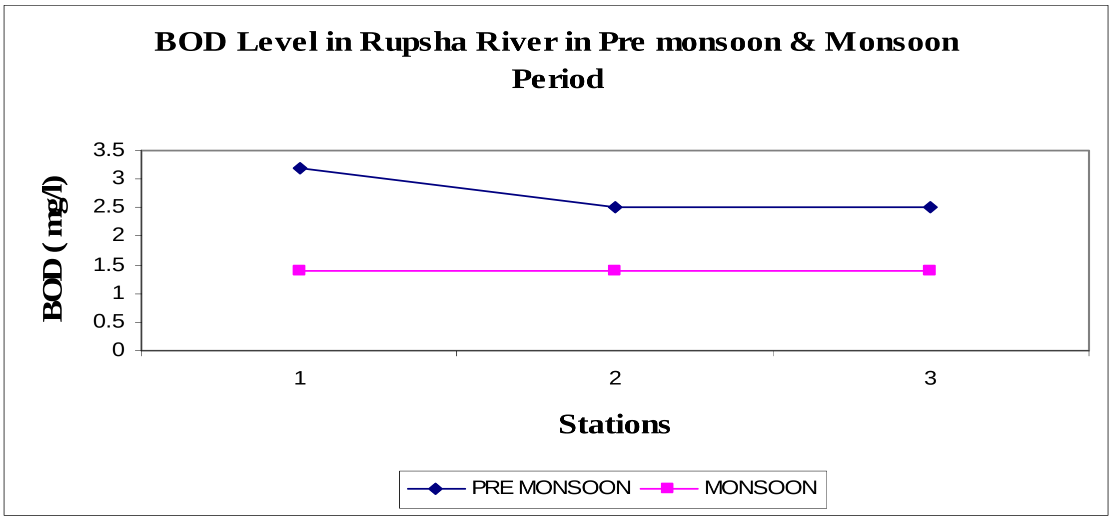

Figure 5.5.11: Graphical representation of BOD Rupsha River.

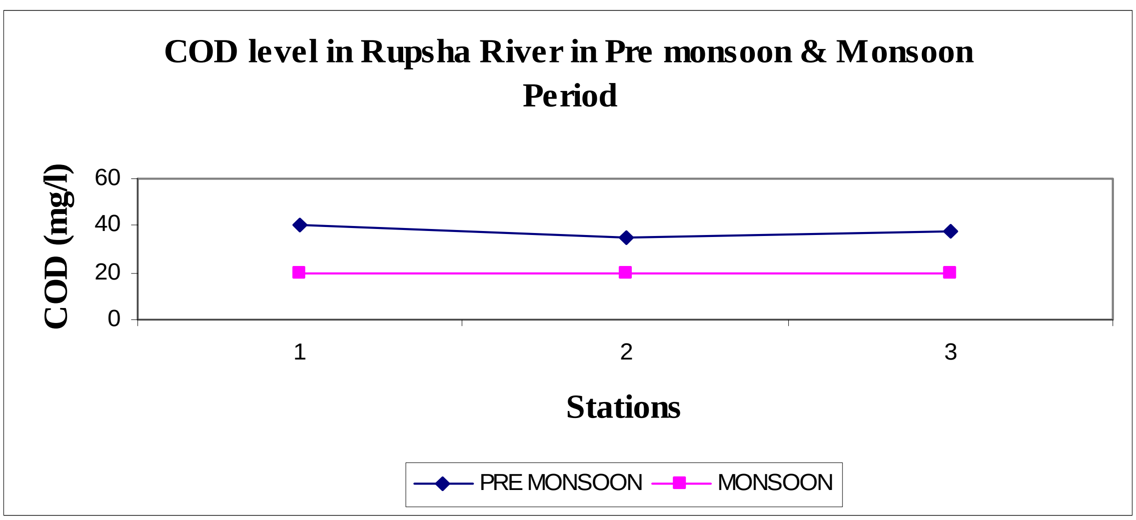

Figure 5.5.12: Graphical representation of COD of Rupsha River.

The mean values of the various chemical parameters of the Rupsha River water are presented. The mean value of water pH at different stations of the river was found as 7.60 (Pre Monsoon) and 7.52 (Monsoon). The value of pH was normal compared with the standard level as the optimum value of water pH is 6.5-8.5 or around 7 for the drinking purpose. as well as aquatic organisms and the tolerable range is between 6 and 8.5 (ECR 1997). The P^H value of Rupsha River water is also fit for fish culture and algae growth as well as industrial and manufacturing processes like Food canning, freezing, Rayon manufacturing and Tanning leather. But this water needs to be pretreated in case of washing clothes.

The mean values of dissolve oxygen (DO) were 5.23 mg/l (Pre Monsoon), 5.00 mg/l (Monsoon) at various stations throughout the experimental period. Sampling result at the pre monsoon and monsoon period revealed that the values of DO were slightly low. Rupsha River water is fit for Irrigation, fish culture, recreational activity and Cooling industries But this water needs to be pretreated in case of use it for drinking purpose after disinfection. DO is very important for identifying a suitable aquatic body and also to estimate productivity of an aquatic system (Romesh and Anbu, 1996; Davies, *et al.*, 2008). The low oxygen of this river water was due to the excess dumping (domestic and urban sewage, industrial effluents, agricultural wastes etc.). The major effect of sewage in water is that it reduces oxygen content of water as the organic matter content of sewage is higher (Ragothaman and Trivedy, 2002).

The mean value of biochemical oxygen demand (BOD) are 2.73 mg/l (Pre Monsoon) and 1.40 mg/l (Monsoon) and chemical oxygen demand (COD) at different sampling stations were 37.67 mg/l (Pre Monsoon), 20.00 mg/l (Monsoon) respectively. BOD and COD levels were observed higher at the Pre monsoon and Monsoon period. A standard value of COD for drinking purposes is 4 mg/L and For bathing is 180-270 mg/L while in the case of biochemical oxygen demand (BOD), standard for drinking purpose is 0.2 mg/L, sewage effluent 20 mg/L (Wintgens *et al.,* 2005; Jalil and Njiru, 2010). Oxygen being the basic requirement of almost all plant and animal life, its presence in sufficient quantities is important to support and sustain life. All organic matters undergo biodegradation and exhibit a biochemical oxygen demand (BOD) or a chemical oxygen demand (COD) as oxygen is required for their degradation (Khatri, 1984). The typical sources include sewage from domestic and animal source, industrial wastes, natural decaying vegetation, decay of dead plants and animals. This type of water pollution becomes a severe problem when the oxygen required for biodegradation or chemical oxidation is greater than the available oxygen in the ecosystem. The estimation of BOD gives an indication of the amount of pollution in a body of water. The high amount of BOD indicates large bacterial and fungal population. Owing to metabolic activities of these organisms, the dissolved oxygen gets reduced and the area is found without oxygen. Aquatic organisms such as fishes either evade this area or are killed (Khatri, 1985). After above analysis we found that Rupsha River water is suitable for irrigation, fish culture, recreational activities, drinking purpose (after disinfection) and cooling purpose in industries.

5.6 Parameterization of water quality parameter of Pashur River

5.6.1 Physical parameter

Among all physical properties the concern of these study was focused on Physical parameters such as temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid for Pashur River.

(i) Temperature

Table 5.6.1: Statistical presentation of Temperature of Pashur River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (^{0}C)	31.17	29.33	Optimum Temp for Carp fish is 32 ^{0}C Diatoms grow best at 15-25 ^{o}C,
Std Deviation	0.29	0.58	
Variance	0.08	0.33	

Table 5.6.1 (Continue)

Minimum (^{0}C)	31.00	29.00	Green algae grow best at 25-35 ^{o}C, Blue-green algae at 30-40 ^{o}C.
Maximum (^{0}C)	31.50	30.00	

Source: (i) CWQB, 1963. (ii) EPA, 1976.

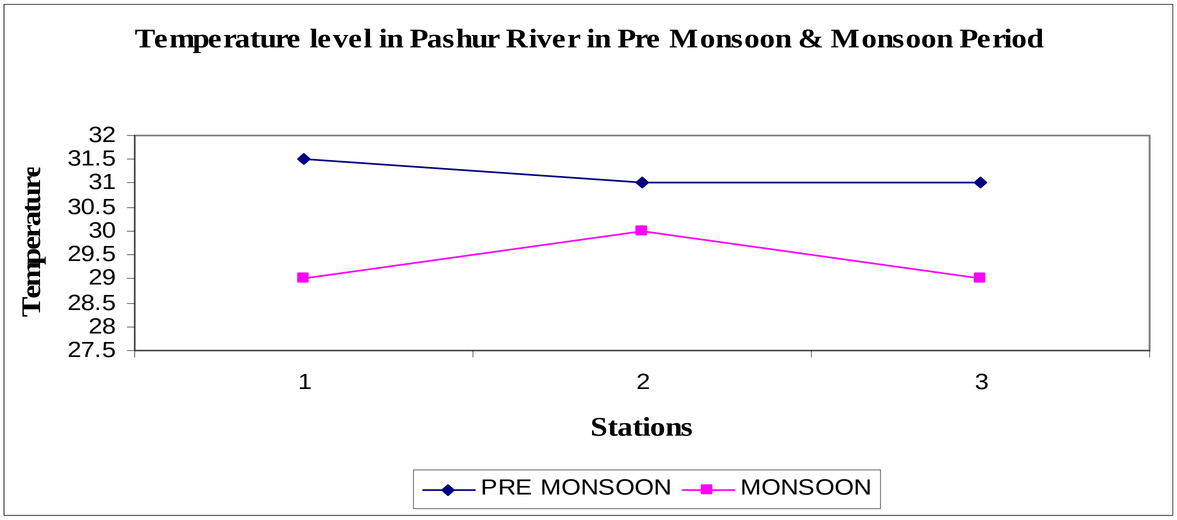

Figure 5.6.1: Graphical representation of PH of Pashur River.

(ii) Turbidity

Table 5.6.2: Statistical presentation of Turbidity of Pashur River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (NTU)	60.67	59.67	Amount of fish 162 lb/ acre for 25 NTU, 94 lb/ acre for 25 -100 NTU, 29 lb/ acre for over 100 NTU. Usable for Beverages if turbidity is 1-2 NTU Food products for 10 NTU Water used in boilers for 1-20 NTU
Std Deviation	0.76	1.53	
Variance	0.58	104974.33	
Minimum (mg/l)	60.00	58.00	

Table 5.6.2 (Continue)

Maximum (mg/l)	61.50	61.00	(varies with type of boiler) High grade paper for 5-25 NTU Water used for cooling at 50 NTU. Tanning leather for 20 NTU

Source : EPA, 1976.

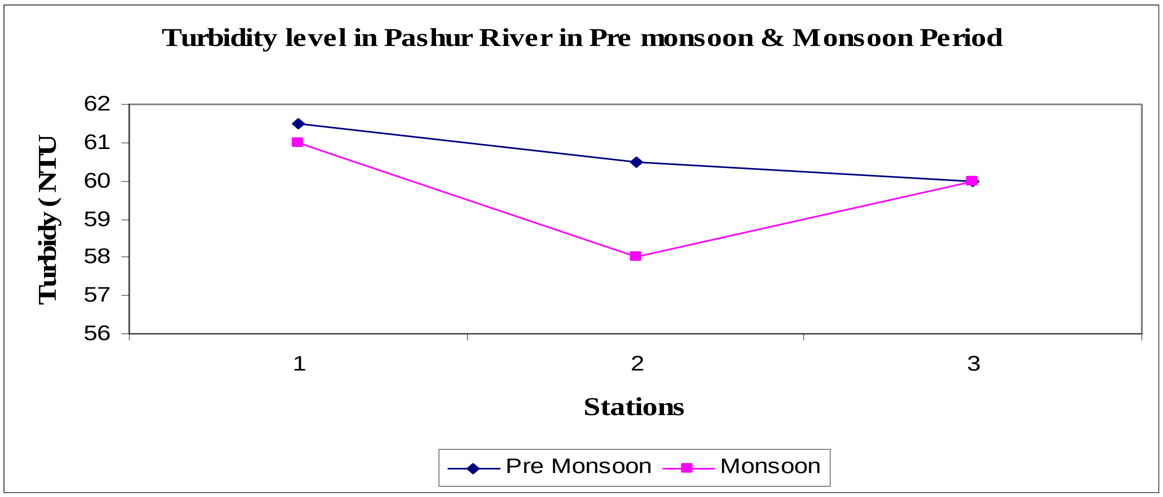

Figure 5.6.2: Graphical representation of Turbidity content of Pashur River.

(iii)T- Alkalinity

Table 5.6.3 Statistical presentation of EC of Pashur River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (dS/m)	1.67	1.21	Three categories of EC is specified by FAO for irrigation. None (<0.7 dS/m) , Slight to moderate (0.7 to 3.0 dS/m), Severe (> 3.0 dS/m).
Std Deviation	0.02	0.01	
Variance	0.00	0.00	
Min (dS/m)	1.64	1.20	
Max (dS/m)	1.69	1.21	

Source : Ayres and Westcot 1985.

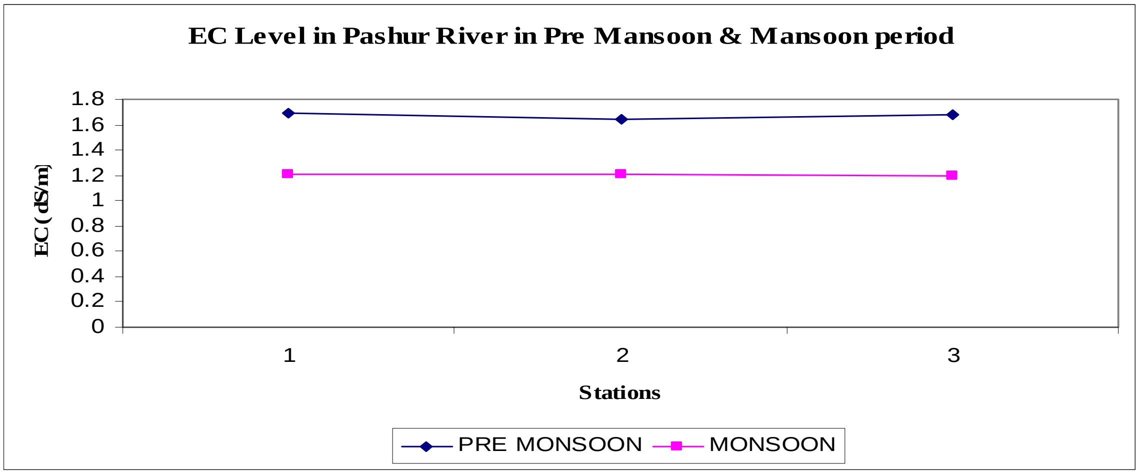

Figure 5.6.3: Graphical representation of EC of Pashur River.

(iv) Total Solid

Table 5.6.4 Statistical presentation of Total Solid of Pashur River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	811.67	616.67	Compared with the standards of suspended and dissolved solids.
Std Deviation	10.02	11.55	
Variance	100.33	133.33	
Minimum (mg/l)	802.00	610.00	
Maximum (mg/l)	822.00	630.00	

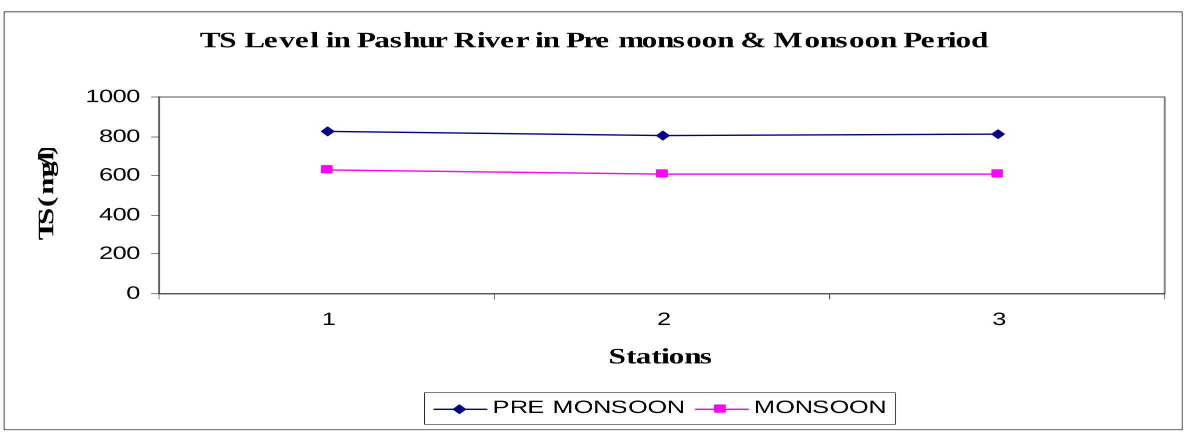

Figure 5.6.4: Graphical representation of TS of Pashur River at different station.

(v) Total Dissolved Solid

Table 5.6.5 Statistical presentation of Total Dissolved Solid of Pashur River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	735.33	573.33	Three categories of TDS is specified by FAO for irrigation. None (< 450 mg/l) Slight to moderate (450-2000 mg/l) Severe (> 2000 mg/l).
Std Deviation	9.81	12.58	
Variance	96.33	158.33	
Min (mg/l)	724.00	560.00	
Max (mg/l)	741.00	585.00	

Source : Ayres and Westcot 1985.

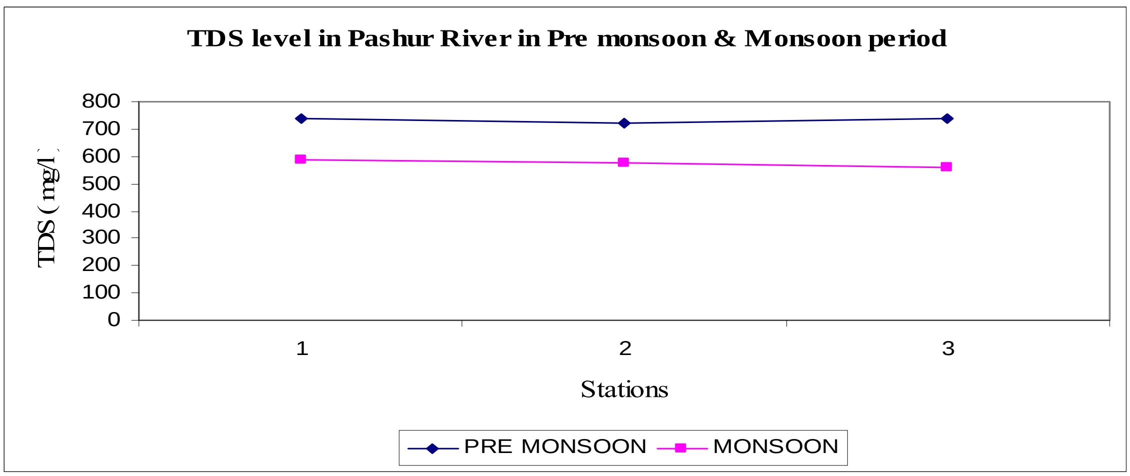

Figure 5.6.5: Graphical representation of TDS of Pashur River at different sampling station.

(vi) Suspended Solid

Table 5.6.6 Statistical presentation of Suspended Solid of Pashur River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	76.33	43.33	

Table 5.6.6 (Continue)

Std Deviation	5.69	2.89	SS for fish culture is <1500 ppm. For drinking water, allowable concentration (maximum) Bangladesh standard 10 mg/l WHO standard is 10 mg/l.
Variance	32.33	8.33	
Minimum (mg/l)	70.00	40.00	
Maximum (mg/l)	81.00	45.00	

Source : ECR 1997.

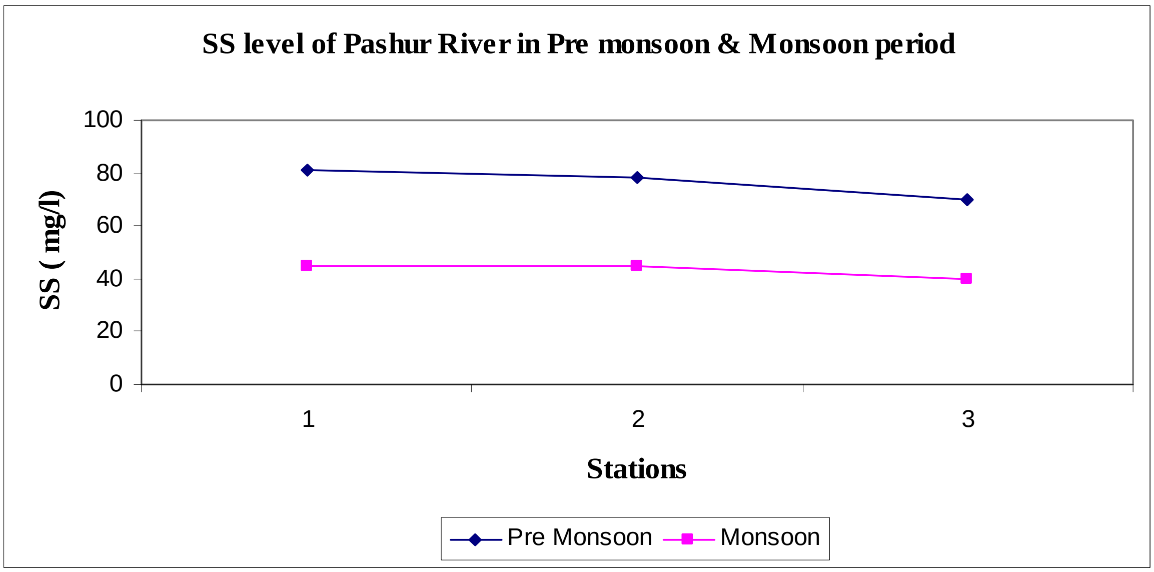

Figure 5.6.6: Graphical representation of SS of Pashur River at different sampling station

Some aspects of physical water quality parameters of Pashur River for Pre Monsoon and Monsoon period have been presented. The average value of water temperature were 31.17^{0}C (Pre Monsoon) and 29.33 ^{0}C (Monsoon), Temperature of Pashur River water showed that it might be tolerable for aquaculture like Carp fish, Diatoms, Green algae and Blue-green algae.

Turbidity of Pashur River water were seen to be 60.67 NTU (Pre Monsoon) and 59.67 NTU (Monsoon), SS were 76.33mg/l (Pre Monsoon) and 43.33 mg/l (Monsoon) and TDS were 735.33 mg/l (Pre Monsoon) and 573.33 mg/l (Monsoon) respectively. Turbidity of water mainly caused by silt, clay, waste materials, heavy particles, dumps etc. Turbidity always indicated the amount of various particles present in water which includes both the total dissolved and suspended solids present in water (Onyema, 2007). The value of different physical water quality parameters showed a higher rate in Pre Monsoon period than in Monsoon Period. These values decrease gradually as a result of more surface water flow in the river during monsoon period. Production of fish culture of Pashur River is seen to be favorable to produce 94 lb/acre of fish. Water of Pashur River is usable for cooling purpose. Pashur River water needs to be pretreated before using in beverage industries, food products, boiler, pulp paper industries and tanning leather.

The mean value of EC of Pashur River were seen to be 1.67 dS/m (Pre monsoon) 1.21 dS/m (Monsoon). That indicates the inorganic mineral content is high. The results of the present study clearly indicate that the water of Pashur River was carrying higher value of EC and not suitable for maintaining the normal functioning of irrigation and aquatic organisms. The value of EC is with in the slight to moderate restriction category according to FAO.

The standard values of SS and TDS were seen to be 10 mg/L and 1000 mg/L for the inland surface water of Bangladesh (Alam, *et al.*, 2007). After analysis the mean value of SS were found to be 76.33 mg/l (Pre Monsoon) and 43.33 mg/l (Monsoon) and TDS were 735.33 mg/l (Pre Monsoon) and 573.33 mg/l (Monsoon). The amount of SS and TDS were considerably high in Pre Monsoon period but at the same time SS and TDS was very low in the unit volume of water in Monsoon period. So in monsoon period Pashur River water is favorable for any purpose. But in Pre Monsoon period both SS and TDS is very high. So in Pre Monsoon period Pashur River Water needs pre treatment before use. The heavy particles present in the waste materials become settled on the river bottom and the remaining lighter particles are carried out with water in the form of suspended and dissolved forms. Higher amount of various solids present in water have a negative impact on the productivity and maintaining good water quality as these reduce the light penetration in water.

5.6.2 Chemical parameter

There are different chemical properties which can indicate the status of river water quality but for the study properties like P^H, chloride, alkalinity or T-alkalinity, hardness, DO, BOD, COD for Pashur River were considered.

(i) P^H

Table 5.6.7 Statistical presentation of P^H of Pashur River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean	7.84	7.83	Optimum P^H for aquaculture Fish eggs could be hatched, but deformed young were often produced between P^H 3.8 - 10 Limit of P^H for resistant fish species is 4-10.1 Range tolerated by trout is P^H 4.1- 9.5 Best range for the growth of algae is P^H 7.5-8.4. Food canning when minimum P^H 7.5 Freezing when minimum P^H 7.5 Washing clothes when P^H 6-6.8 Rayon manufacturing when P^H 7.8-8.3 Tanning leather when P^H 6-8
Std Deviation	0.03	0.03	
Variance	0.00	0.00	
Minimum	7.80	7.80	
Maximum	7.86	7.86	

Source : CWQB, 1963.

(vi) Chloride content

Table 5.6.8 Statistical presentation of Chloride of Pashur River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	221.67	154.00	Recommended for aquaculture

Table 5.6.8 (Continue)

Std Deviation	7.64	2.65	Fish and aquatic life is 0.01 mg/l. Max fish can tolerate 0.37 mg/l. Minimum requirement for High-grade paper is 0.3 mg/l For surface irrigation 4-10 mg/l (Slight to moderate), > 10 mg/l (Severe).
Variance	58.33	7.00	
Minimum (mg/l)	215.00	152.00	
Maximum (mg/l)	230.00	157.00	

Source : EPA, 1976.

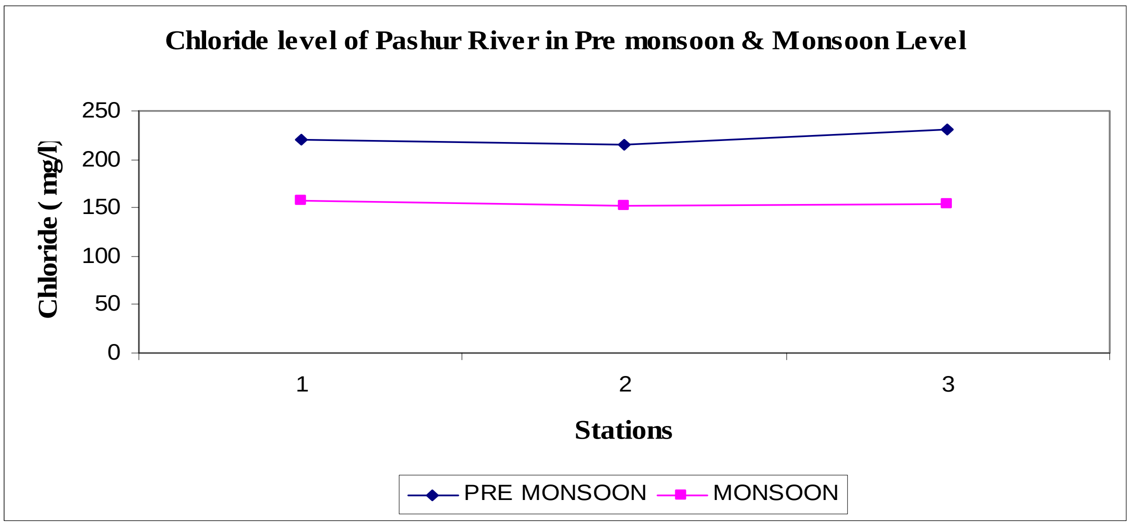

Figure 5.6.8: Graphical representation of Chloride content of Pashur River.

(iii)T- Alkalinity

Table 5.6.9 Statistical presentation of T-Alkalinity of Pashur River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	45.50	44.75	Recommended max alkalinity for, Carbonated beverages 85 mg/l Food products (canning) 300 mg/l
Std Deviation	25.58	24.88	

Table 5.6.9 (Continue)

Variance	320.50	291.58	Fruit juice 100 mg/l Pulp and paper making 50 mg/l Textile mill products 50-200 mg/l Rayon manufacture 50 mg/l Limit for fish culture is 50-400 mg/l
Minimum (mg/l)	30.00	30.00	
Maximum (mg/l)	61.50	61.00	

Source: (i) CWQB, 1963

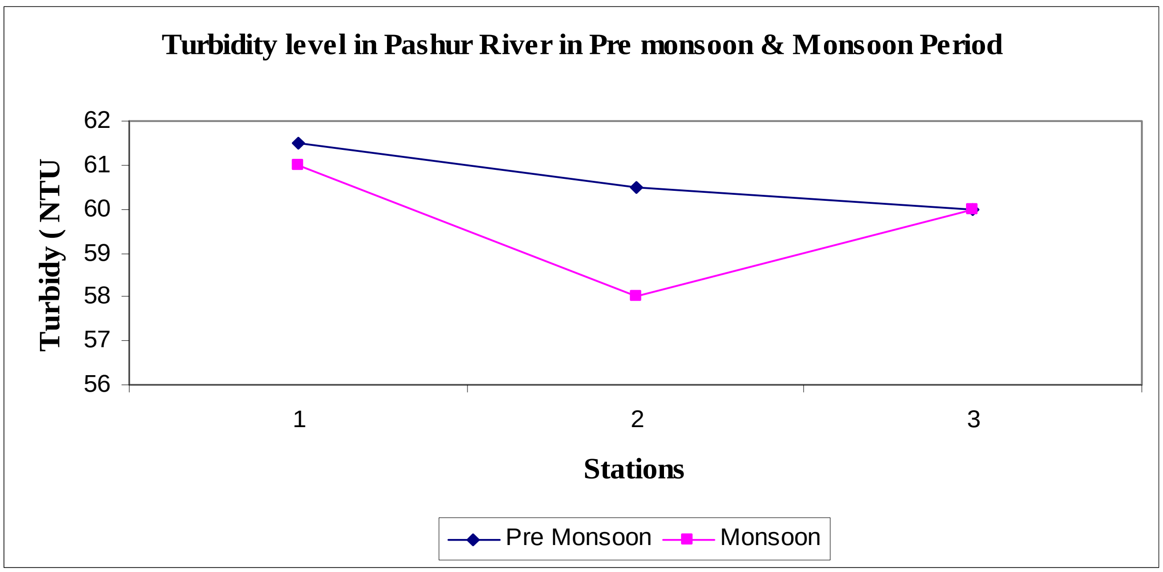

Figure 5.6.9: Graphical representation of T-Alkalinity of Pashur River.

(iv) Dissolved Oxygen

Table 5.6.10 Statistical presentation of Dissolved Oxygen of Pashur River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	5.80	5.83	Usable for Irrigation when ≥ 5 mg/l.
Std Deviation	0.00	0.06	

Table 5.6.9 (Continue)

Variance	0.00	0.00	Fisheries when ≥ 5 mg/l. Recreational activity ≥ 5 mg/l Drinking purpose ≥ 6 mg/l after disinfection. Cooling industries ≥ 5 mg/l.
Minimum (mg/l)	5.80	5.80	
Maximum (mg/l)	5.80	5.90	

Source: ECR 1997.

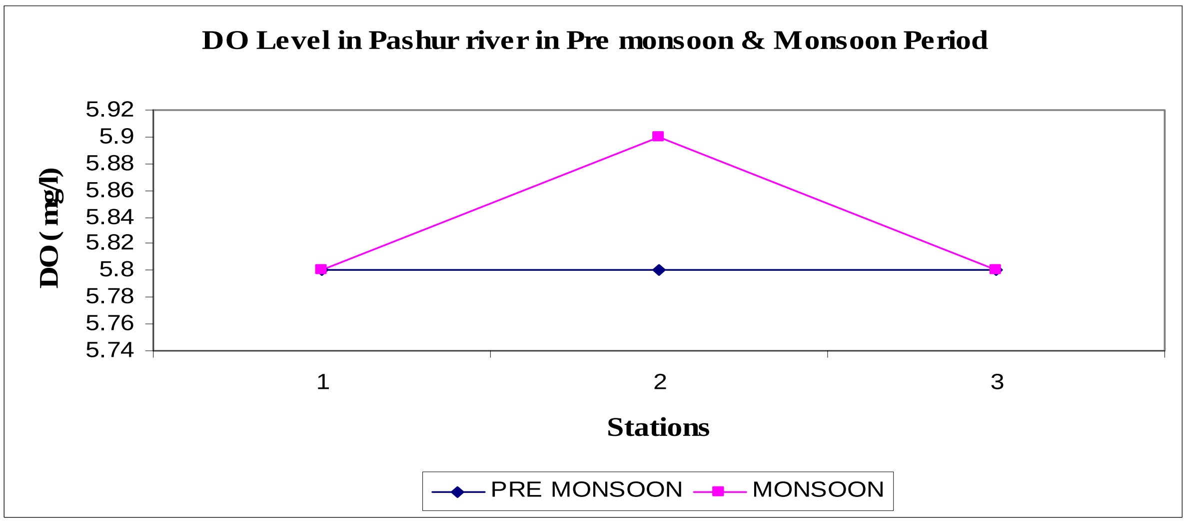

Figure 5.6.10: Graphical representation of DO of Pashur River.

(vi) BOD

Table 5.6.11 Statistical presentation of BOD of Pashur River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	1.25	0.77	Usable for Irrigation when ≤ 2mg/l. Fisheries when ≤ 6mg/l. Recreational activity ≤ 3mg/l. Drinking purpose ≤ 2mg/l Cooling industries ≤ 10mg/l.
Std Deviation	0.00	0.06	
Variance	0.00	0.00	
Min (mg/l)	1.25	0.70	
Max (mg/l)	1.25	0.80	

Source : ECR 1997

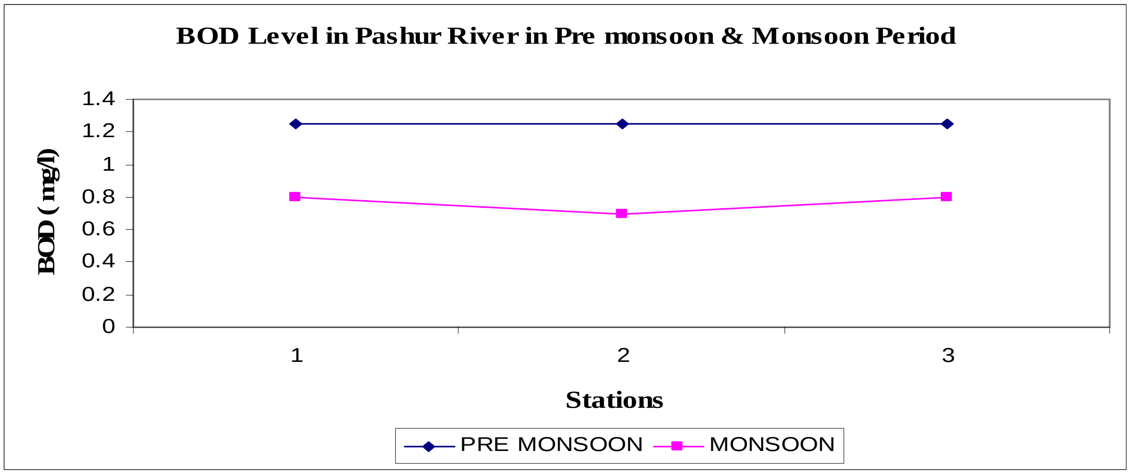

Figure 5.6.11: Graphical representation of BOD of Pashur River.

(vi) COD

Table 5.6.12: Statistical presentation of COD of Pashur River

Statistics	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	27.00	Usable for bathing purpose when COD is 180-270 mg/l .
Std Deviation	Not Available	1.73	
Variance	Not Available	3.00	
Min (mg/l)	Not Available	25.00	
Max (mg/l)	Not Available	28.00	

Source : ECR 1997.

The mean values of the various chemical parameters of the Pashur River water are presented. The mean value of water pH at different stations of the river was found as 7.84 (Pre Monsoon) and 7.83 (Monsoon). The value of pH was normal compared with the standard level as the optimum value of water pH is 6.5-8.5 or around 7 for the drinking purpose. as well as aquatic organisms and the tolerable range is between 6 and 8.5 (ECR 1997). The P^H value of Pashur River water is also fit for fish culture and algae growth as well as industrial and manufacturing processes like Food canning, freezing, Rayon manufacturing and Tanning leather. But this water needs to be pretreated in case of washing clothes.

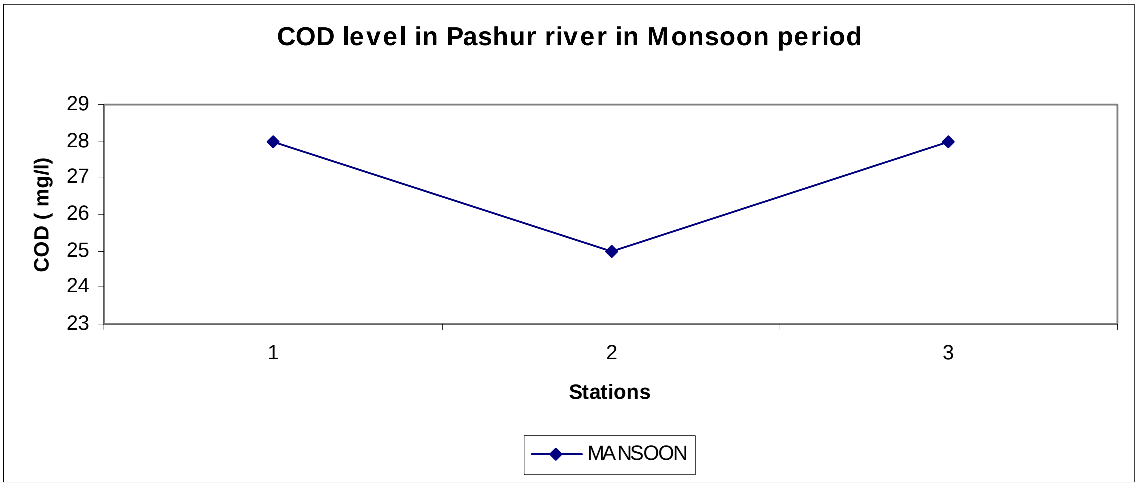

Figure 5.6.12: Graphical representation of COD of Pashur River.

The mean values of dissolve oxygen (DO) were 5.80 mg/l (Pre Monsoon), 5.83 mg/l (Monsoon) at various stations throughout the experimental period. Sampling result at the pre monsoon and monsoon period revealed that the values of DO were slightly low. Pashur River water is fit for Irrigation, fish culture, recreational activity and Cooling industries But this water needs to be pretreated in case of use it for drinking purpose after disinfection. DO is very important for identifying a suitable aquatic body and also to estimate productivity of an aquatic system (Romesh and Anbu, 1996; Davies, *et al.*, 2008). The low oxygen of this river water was due to the excess dumping (domestic and urban sewage, industrial effluents, agricultural wastes etc.). The major effect of sewage in water is that it reduces oxygen content of water as the organic matter content of sewage is higher (Ragothaman and Trivedy, 2002). The mean value of biochemical oxygen demand (BOD) are 1.25mg/l (Pre Monsoon) and 0.77 mg/l (Monsoon) and chemical oxygen demand (COD) at different sampling stations were 0 mg/l (Pre Monsoon), 27.00 mg/l (Monsoon) respectively. BOD and COD levels were observed higher at the Pre monsoon and Monsoon period. A standard value of COD for drinking purposes is 4 mg/L and For bathing is 180-270 mg/L while in the case of biochemical oxygen demand (BOD), standard for drinking purpose is 0.2mg/L, sewage effluent 20 mg/L (Wintgens *et* *al*, 2005; Jalil and Njiru, 2010). Oxygen being the basic requirement of almost all plant and animal life, its presence in sufficient quantities is important to support and sustain life. All organic matters undergo biodegradation and exhibit a biochemical oxygen demand (BOD) or a chemical oxygen demand (COD) as oxygen is required for their degradation (Khatri, 1984). The typical sources include sewage from domestic and animal source, industrial wastes, natural decaying vegetation, decay of dead plants and animals. This type of water pollution becomes a severe problem when the oxygen required for biodegradation or chemical oxidation is greater than the available oxygen in the ecosystem. The estimation of BOD gives an indication of the amount of pollution in a body of water. The high amount of BOD indicates large bacterial and fungal population. Owing to metabolic activities of these organisms, the dissolved oxygen gets reduced and the area is found without oxygen. Aquatic organisms such as fishes either evade this area or are killed (Khatri, 1985). After above analysis we found that Pashur River water is suitable for irrigation, fish culture, recreational activities, drinking purpose (after disinfection) and cooling purpose in industries.

5.7 Parameterization of water quality parameter of Kakshially River

5.7.1 Physical parameter

Among all physical properties the concern of these study was focused on Physical parameters such as temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid for Kakshially River.

(i) Temperature

Table 5.7.1: Statistical presentation of Temperature of Kakshially River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (^{0}C)	Not Available	27.08	Optimum Temp for
Std Deviation	Not Available	0.20	

Table 5.7.1 (Continue)

Variance	Not Available	0.04	Carp fish is 32 ^{0}C Diatoms grow best at 15-25 ^{o}C, Green algae grow best at 25-35 ^{o}C, Blue-green algae at 30-40 ^{o}C.
Minimum (^{0}C)	Not Available	27.00	
Maximum (^{0}C)	Not Available	27.50	

Source: (i) CWQB, 1963. (ii) EPA, 1976.

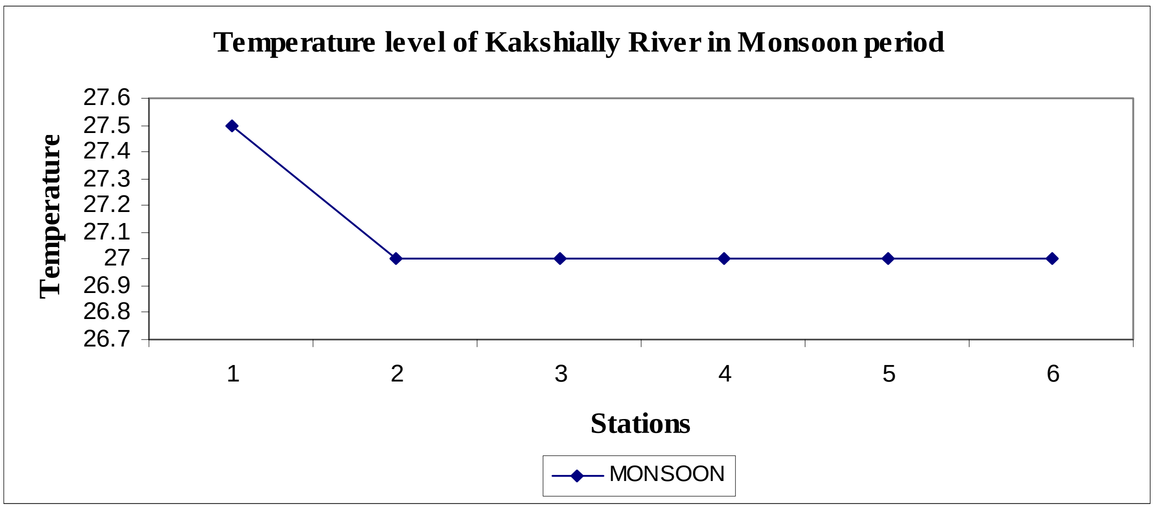

Figure 5.7.1: Graphical representation of temperature of Kakshially River.

(ii) Turbidity

Table 5.7.2: Statistical presentation of Turbidity of Kakshially River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (NTU)	Not Available	52.33	Amount of fish 162 lb/ acre for 25 NTU, 94 lb/ acre for 25 -100 NTU, 29 lb/ acre for over 100 NTU. Usable for Beverages if turbidity is 1-2 NTU Food products 10 NTU
Std Deviation	Not Available	2.75	
Variance	Not Available	110887.42	

Table 5.7.2 (Continue)

Minimum (NTU)	Not Available	49.50	Water used in boilers 1-20 NTU (varies with type of boiler) High grade paper 5-25 NTU Water used for cooling 50 NTU. Tanning leather 20 NTU
Maximum (NTU)	Not Available	55.00	

Source: CWQB, 1963.

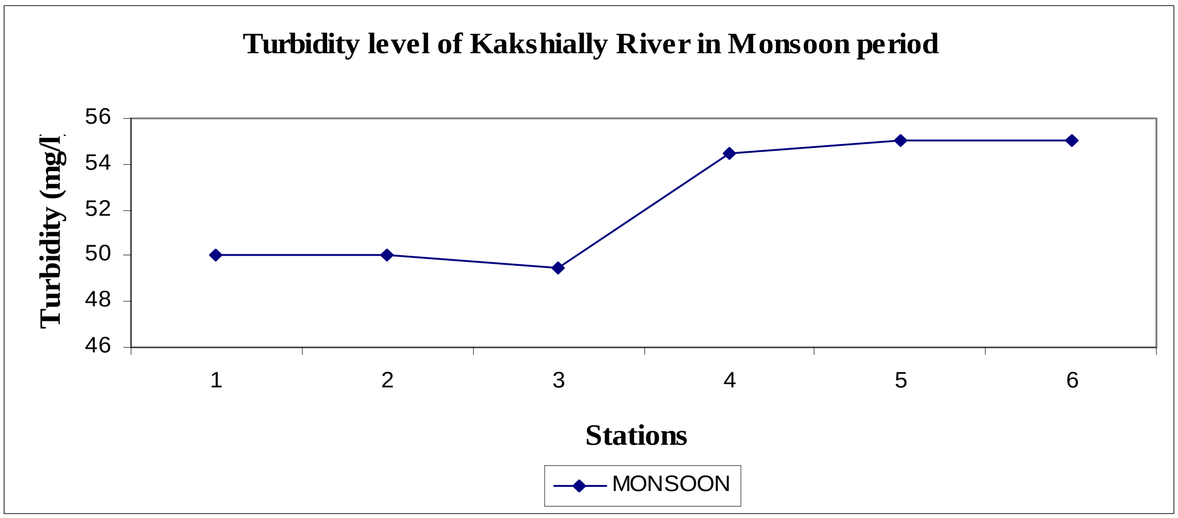

Figure 5.7.2: Graphical representation of Turbidity of Kakshially River.

(iii) Electric Conductivity

Table 5.7.3: Statistical presentation of Electric Conductivity of Kakshially River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (dS/m)	Not Available	1.34	Three categories of EC is specified by FAO for irrigation. None (<0.7 dS/m) , Slight to moderate (0.7 to 3.0 dS/m) Severe (> 3.0 dS/m).
Std Deviation	Not Available	0.06	
Variance	Not Available	0.00	
Min (dS/m)	Not Available	1.25	
Max (dS/m)	Not Available	1.40	

Source : Ayres and Westcot 1985.

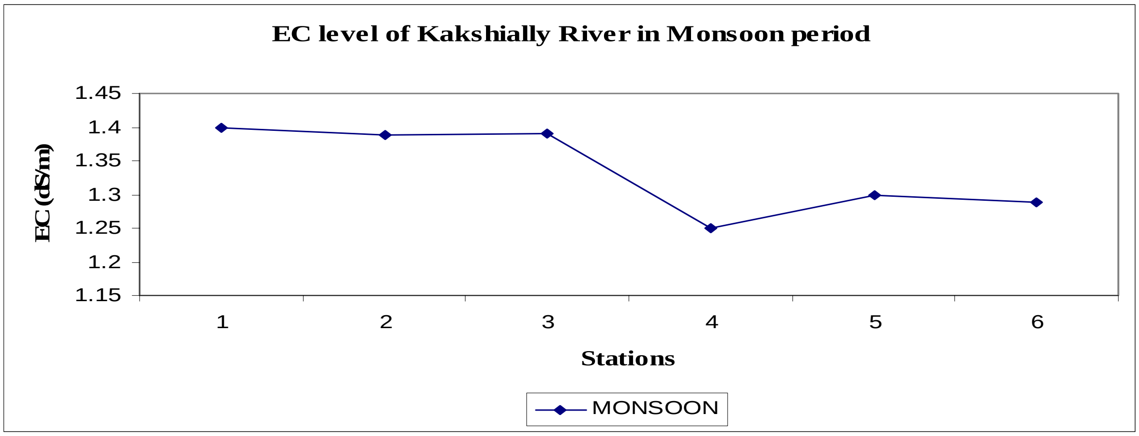

Figure 5.7.3: Graphical representation of EC of Kakshially River.

(iv) Total Solid

Table 5.7.4 Statistical presentation of Total Solid of Kakshially River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	693.83	Compared with the standards of suspended and dissolved solids.
Std Deviation	Not Available	55.24	
Variance	Not Available	3051.37	
Minimum (mg/l)	Not Available	621.00	
Maximum (mg/l)	Not Available	784.00	

(v) Total Dissolved Solid

Table 5.7.5 Statistical presentation of Total Dissolved Solid of Kakshially River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	653.17	Categories by FAO for irrigation.
Std Deviation	Not Available	45.17	None (< 450 mg/l) ,
Variance	Not Available	2040.57	Slight to moderate (450-2000 mg/l),
Min(mg/l)	Not Available	610.00	Severe (> 2000 mg/l).

Table 5.7.5 (Continue)

Max(mg/l)	Not Available	726.00	

Source : Ayres and Westcot 1985.

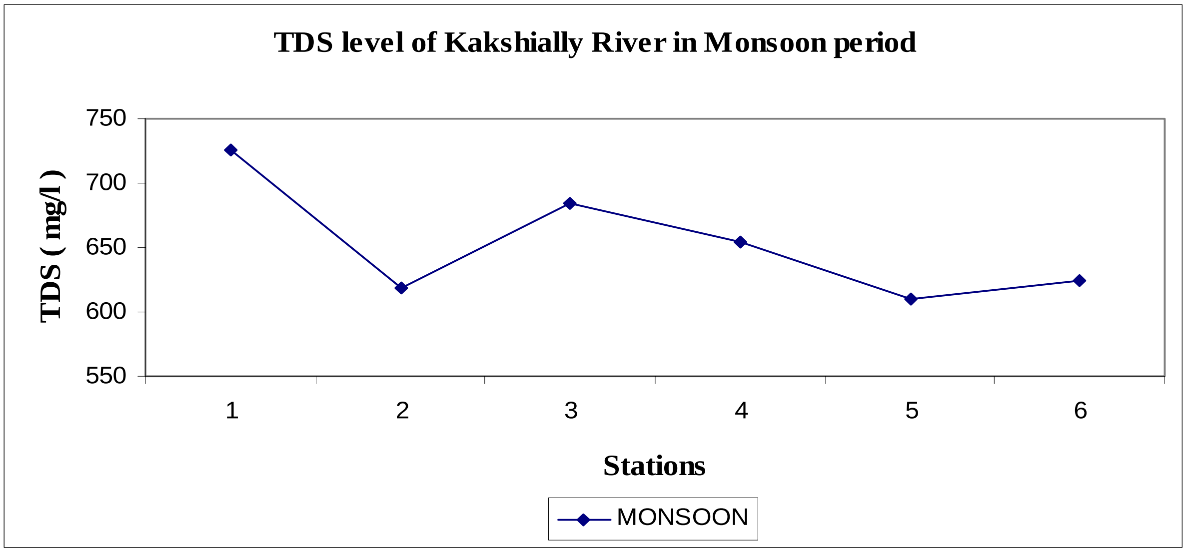

Figure 5.7.5: Graphical representation of TDS of Kakshially River.

(vi) Suspended Solid

Table 5.7.6 Statistical presentation of Suspended Solid of Kakshially River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	57.33	SS for fish culture is <1500 ppm.
Std Deviation	Not Available	9.07	For drinking water, allowable
Variance	Not Available	82.27	concentration (maximum)
Min (mg/l)	Not Available	40.00	Bangladesh standard 10 mg/l
Max (mg/l)	Not Available	66.00	WHO standard is 10 mg/l.

Source : ECR 1997.

Some aspects of physical water quality parameters of Kakshially River for Pre Monsoon and Monsoon period have been presented. The average value of water temperature were

27.08 ^{0}C (Monsoon), Temperature of Kakshially River water showed that it might be tolerable for aquaculture like Carp fish, Diatoms, Green algae and Blue-green algae.

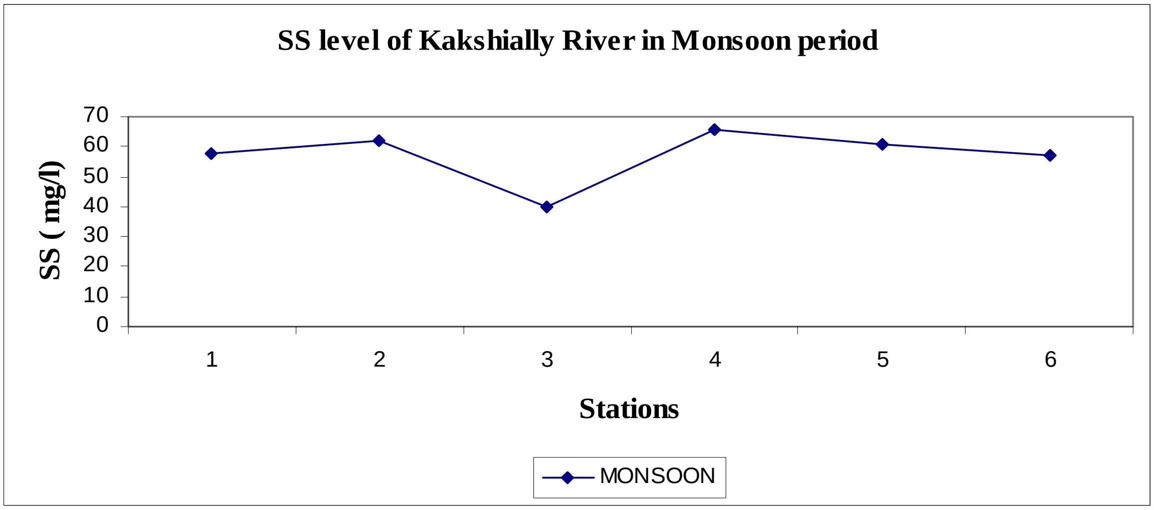

Figure 5.7.6: Graphical representation of SS of Kakshially River.

Turbidity of Kakshially River water were seen to be 52.33 NTU (Monsoon), SS were 57.33mg/l (Monsoon) and TDS were 653.17mg/l (Monsoon) respectively. Turbidity of water mainly caused by silt, clay, waste materials, heavy particles, dumps etc. Turbidity always indicated the amount of various particles present in water which includes both the total dissolved and suspended solids present in water (Onyema, 2007). Production of fish culture of Kakshially River is seen to be favorable to produce 94 lb/acre of fish. Water of Kakshially River is usable for cooling purpose. Kakshially River water needs to be pretreated before using in beverage industries, food products, boiler, pulp paper industries and tanning leather.

The mean value of EC of Kakshially River were seen to be 1.34 dS/m (Monsoon). That indicates the inorganic mineral content is high. The results of the present study clearly indicate that the water of Kakshially River was carrying higher value of EC and not suitable for maintaining the normal functioning of aquatic organisms or irrigation. The value of EC of Kakshially river is with in the slight to moderate category of restriction according to FAO.

The standard values of SS and TDS were seen to be 10 mg/L and 1000 mg/L for the inland surface water of Bangladesh (Alam, *et al.*, 2007). After analysis the mean value of SS were found to be 57.33mg/l (Monsoon) and TDS were 653.17mg/l (Monsoon). The amount of TDS falls into slight to moderate category in Monsoon period. So in monsoon period Kakshially River water needs pre treatment before use. The heavy particles present in the waste materials become settled on the river bottom and the remaining lighter particles are carried out with water in the form of suspended and dissolved forms. Higher amount of various solids present in water have a negative impact on the productivity and maintaining good water quality as these reduce the light penetration in water.

5.7.2 Chemical parameter

There are different chemical properties which can indicate the status of river water quality but for the study properties like P^H, chloride, alkalinity or T-alkalinity, hardness, DO, BOD, COD for Kakshially River were considered.

(i) P^H

Table 5.7.7 Statistical presentation of P^H of Kakshially River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean	Not Available	7.63	Optimum P^H for aquaculture

Table 5.7.7 (Continue)

Std Deviation	Not Available	0.05	Fish eggs could be hatched, but deformed young were often produced between P^H 3.8 - 10 Limit of P^H for resistant fish species is 4-10.1 Range tolerated by trout is P^H 4.1- 9.5 Best range for the growth of algae is P^H 7.5-8.4. Food canning when minimum P^H 7.5 Freezing when minimum P^H 7.5 Washing clothes when P^H 6-6.8 Rayon manufacturing when P^H 7.8-8.3 Tanning leather when P^H 6-8
Variance	Not Available	0.00	
Minimum	Not Available	7.60	
Maximum	Not Available	7.70	

Source : CWQB, 1963.

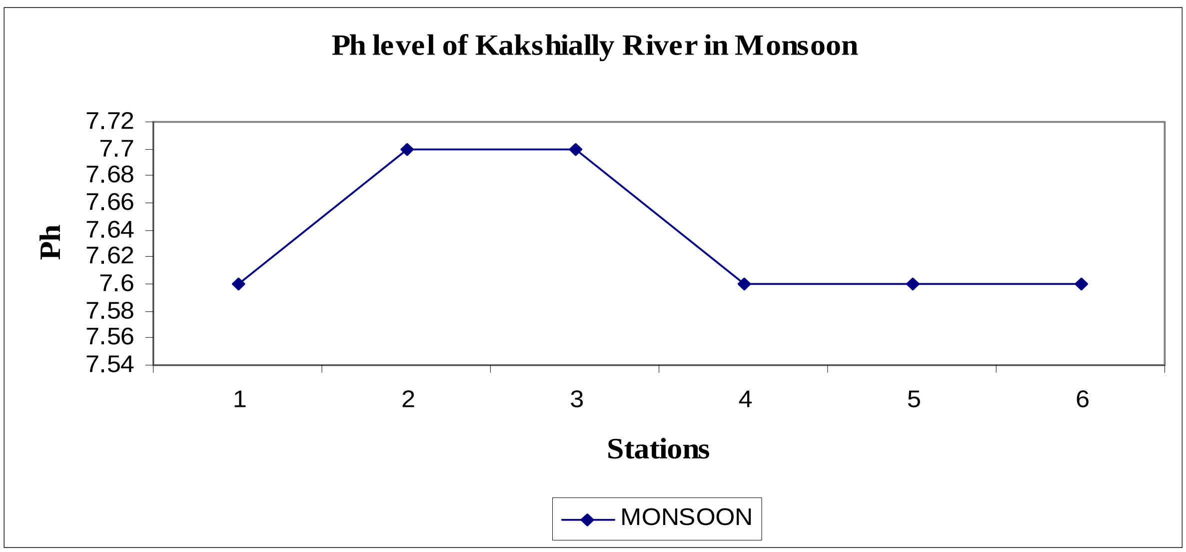

Figure 5.7.7: Graphical representation of P^H of Kakshially River.

(vii) Chloride content

Table 5.7.8 Statistical presentation of Chloride content of Kakshially River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	Not Available	151.67	Recommended for aquaculture

Table 5.7.8 (Continue)

Std Deviation	Not Available	2.58	Fish and aquatic life is 0.01 mg/l. Maximum fish can tolerate 0.37 mg/l. Minimum requirement for High-grade paper is 0.3 mg/ For surface irrigation 4-10 mg/l (Slight to moderate), > 10 mg/l (Severe).
Variance	Not Available	6.67	
Minimum (mg/l)	Not Available	150.00	
Maximum (mg/l)	Not Available	155.00	

Source : EPA, 1976.

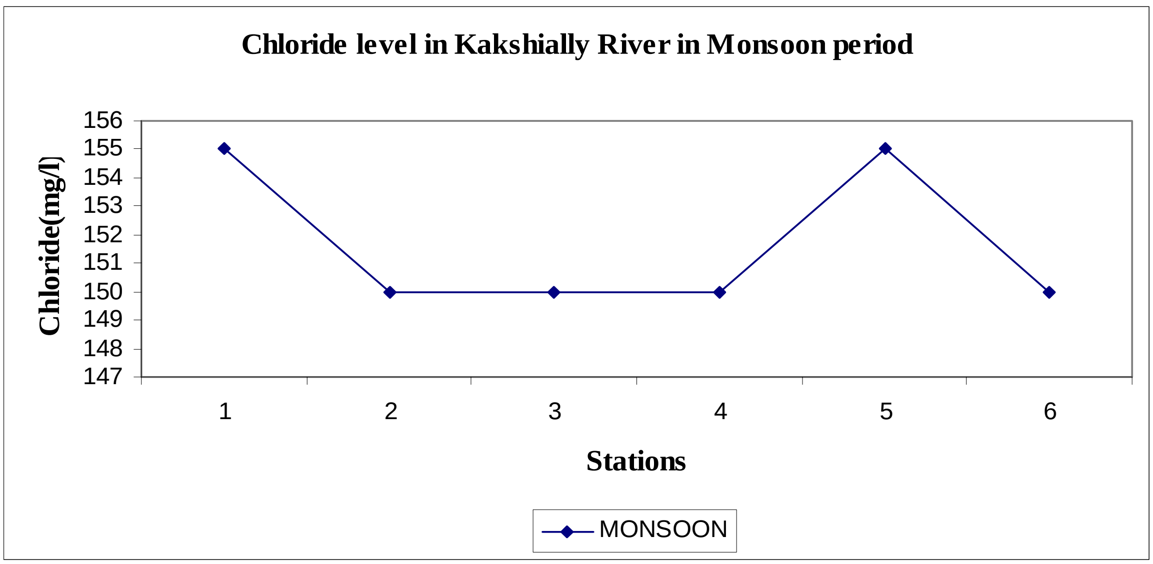

Figure 5.7.8: Graphical representation of Chloride content of Kakshially River.

(iii) T- Alkalinity

Table 5.7.9 Statistical presentation of T-Alkalinity of Kakshially River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	37.86	Recommended max alkalinity for,

Table 5.7.9 (Continue)

Std Deviation	Not Available	15.57	Carbonated beverages 85 mg/l Food products (canning) 300 mg/l Fruit juice 100 mg/l Pulp and paper making 50 mg/l Textile mill products 50-200 mg/l Rayon manufacture 50 mg/l Limit for fish culture is 50-400 mg/l
Variance	Not Available	73.81	
Minimum (mg/l)	Not Available	30.00	
Maximum (mg/l)	Not Available	50.00	

Source: (i) CWQB, 1963.

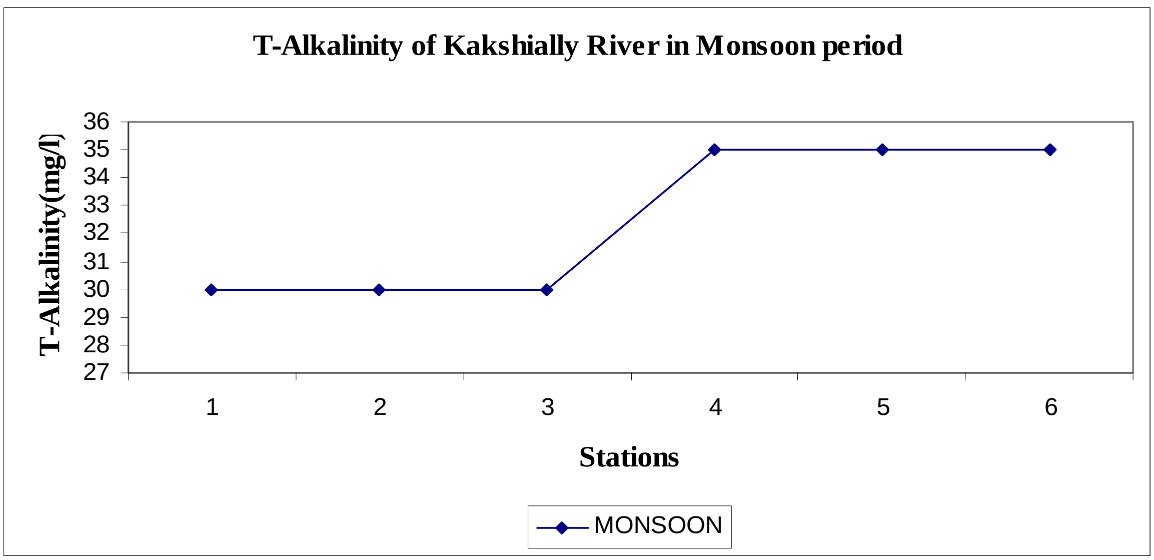

Figure 5.7.9: Graphical representation of T-Alkalinity of Kakshially River.

(iv) Dissolved Oxygen

Table 5.7.10 Statistical presentation of Dissolved Oxygen of Kakshially River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	5.47	Usable for

Table 5.7.10 (Continue)

Std Deviation	Not Available	0.10	Irrigation when DO ≥ 5 mg/l. Fisheries when DO ≥ 5 mg/l. Recreational act. DO ≥ 5 mg/l Drinking purpose at DO ≥ 6 mg/l Cooling industries at DO ≥ 5 mg/l.
Variance	Not Available	0.01	
Minimum (mg/l)	Not Available	5.30	
Maximum (mg/l)	Not Available	5.60	

Source: ECR 1997.

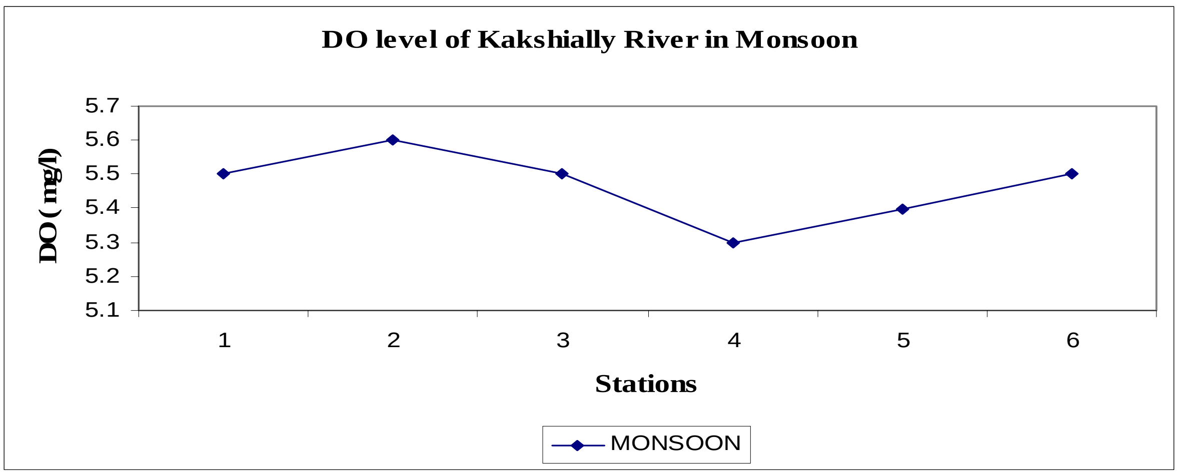

Figure 5.7.10: Graphical representation of DO of Kakshially River.

(vii) BOD

Table 5.7.11 Statistical presentation of BOD of Kakshially River. Source : ECR 1997

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	1.18	Usable for Irrigation when ≤ 2mg/l. Fisheries when ≤ 6mg/l. Recreational activity ≤ 3mg/l. Drinking purpose ≤ 2mg/l Cooling industries ≤ 10mg/l.
Std Deviation	Not Available	0.07	
Variance	Not Available	0.00	
Min (mg/l)	Not Available	1.10	
Max (mg/l)	Not Available	1.30	

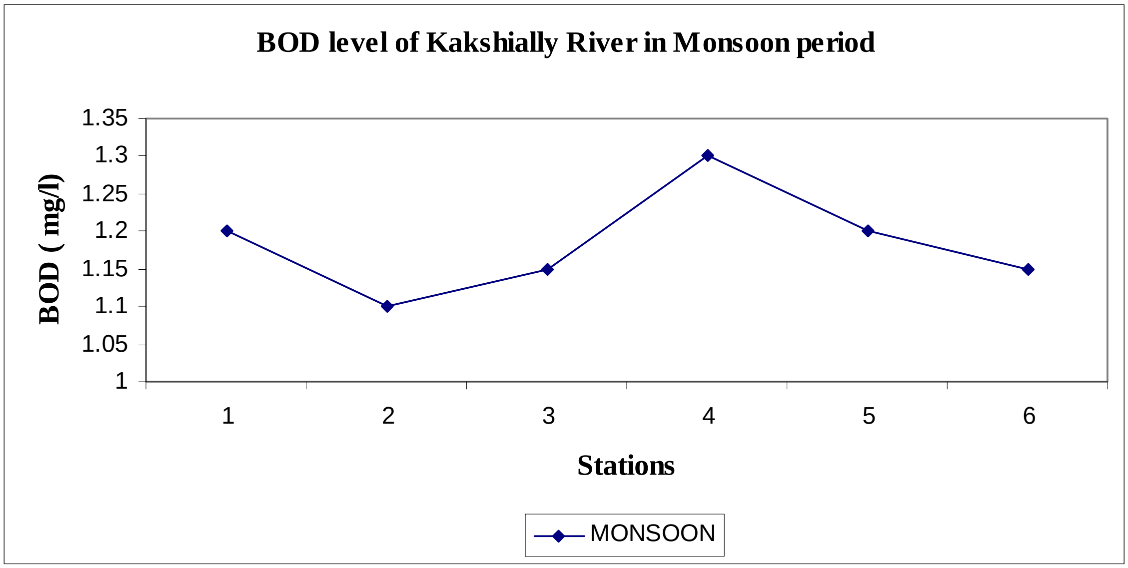

Figure 5.7.11: Graphical representation of BOD of Kakshially River.

(vi) COD

Table 5.7.12: Statistical presentation of COD of Kakshially River

Statistics	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	24.17	Usable for bathing purpose when COD is 180-270 mg/l .
Std Deviation	Not Available	4.92	
Variance	Not Available	24.17	
Min (mg/l)	Not Available	20.00	
Max (mg/l)	Not Available	30.00	

Source : Wintgens *et al.*, 2005

The mean values of the various chemical parameters of the Kakshially River water are presented. The mean value of water pH at different stations of the river was found as 7.63 (Monsoon). The value of pH was normal compared with the standard level as the optimum value of water pH is 6.5-8.5 or around 7 for the drinking purpose. as well as aquatic organisms and the tolerable range is between 6 and 8.5 (ECR 1997). The PH value of Kakshially River water is also fit for fish culture and algae growth as well as industrial and manufacturing processes like Food canning, freezing, Rayon manufacturing and Tanning leather. But this water needs to be pretreated in case of washing clothes.

The mean values of dissolve oxygen (DO) were 5.47 mg/l (Monsoon) at various stations throughout the experimental period. Sampling result at the monsoon period revealed that the values of DO are more or less ok. Kakshially River water is fit for Irrigation, fish culture, recreational activity and Cooling industries But this water needs to be pretreated in case of use it for drinking purpose after disinfection. DO is very important for identifying a suitable aquatic body and also to estimate productivity of an aquatic system (Romesh and Anbu, 1996; Davies, *et al.*, 2008). The low oxygen of this river water was due to the excess dumping (domestic and urban sewage, industrial effluents, agricultural wastes etc.). The major effect of sewage in water is that it reduces oxygen content of water as the organic matter content of sewage is higher (Ragothaman and Trivedy, 2002). The mean value of biochemical oxygen demand (BOD) are 1.18 mg/l (Monsoon) and chemical oxygen demand (COD) at different sampling stations were 24.17 mg/l (Monsoon) respectively. BOD and COD levels were observed higher at the Pre monsoon and Monsoon period. A standard value of COD for drinking purposes is 4 mg/L and For bathing is 180-270 mg/L while in the case of biochemical oxygen demand (BOD), standard for drinking purpose is 0.2mg/L, sewage effluent 20 mg/L (Wintgens *ef al*, 2005; Jalil and Njiru, 2010). Oxygen being the basic requirement of almost all plant and animal life, its presence in sufficient quantities is important to support and sustain life. All organic matters undergo biodegradation and exhibit a biochemical oxygen demand (BOD) or a chemical oxygen demand (COD) as oxygen is required for their degradation (Khatri, 1984). The typical sources include sewage from domestic and animal source, industrial wastes, natural decaying vegetation, decay of dead plants and animals. This type of water pollution becomes a severe problem when the oxygen required for biodegradation or chemical oxidation is greater than the available oxygen in the ecosystem. The estimation of BOD gives an indication of the amount of pollution in a body of water. The high amount of BOD indicates large bacterial and fungal population. Owing to metabolic activities of these organisms, the dissolved oxygen gets reduced and the area is found without oxygen. Aquatic organisms such as fishes either evade this area or are killed (Khatri, 1985). After above analysis we found that Kakshially River water is suitable for irrigation, fish culture, recreational activities, drinking purpose (after disinfection) and cooling purpose in industries.

5.8 Parameterization of water quality parameter of Mouri River

5.8.1 Physical parameter

Among all physical properties the concern of these study was focused on Physical parameters such as temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid for Mouri River.

(i) Temperature

Table 5.8.1: Statistical presentation of Temperature of Mouri River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (^{0}C)	Not Available	27.50	Optimum Temp for Carp fish is 32 ^{0}C Diatoms grow best at 15-25 ^{o}C, Green algae grow best at 25-35 ^{o}C, Blue-green algae at 30-40^{o}C
Std Deviation	Not Available	0.00	
Variance	Not Available	0.00	
Minimum (^{0}C)	Not Available	27.50	
Maximum (^{0}C)	Not Available	27.50	

Source: (i) CWQB, 1963. (ii) EPA, 1976.

(ii) Turbidity

Table 5.8.2: Statistical presentation of Turbidity of Mouri River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (NTU)	56.81	46.31	Amount of fish

Table 5.8.2 (Continue)

Std Deviation	6.64	2.43	162 lb/ acre for 25 NTU, 94 lb/ acre for 25 -100 NTU, 29 lb/ acre for over 100 NTU. Usable for Beverages if turbidity is 1-2 NTU Food products for 10 NTU Water used in boilers for 1-20 NTU (varies with type of boiler) High grade paper for 5-25 NTU Water used for cooling for 50 NTU. Tanning leather for 20 NTU
Variance	44.05	5.92	
Minimum (NTU)	47.00	45.00	
Maximum (NTU)	61.20	50.50	

Source: CWQB, 1963.

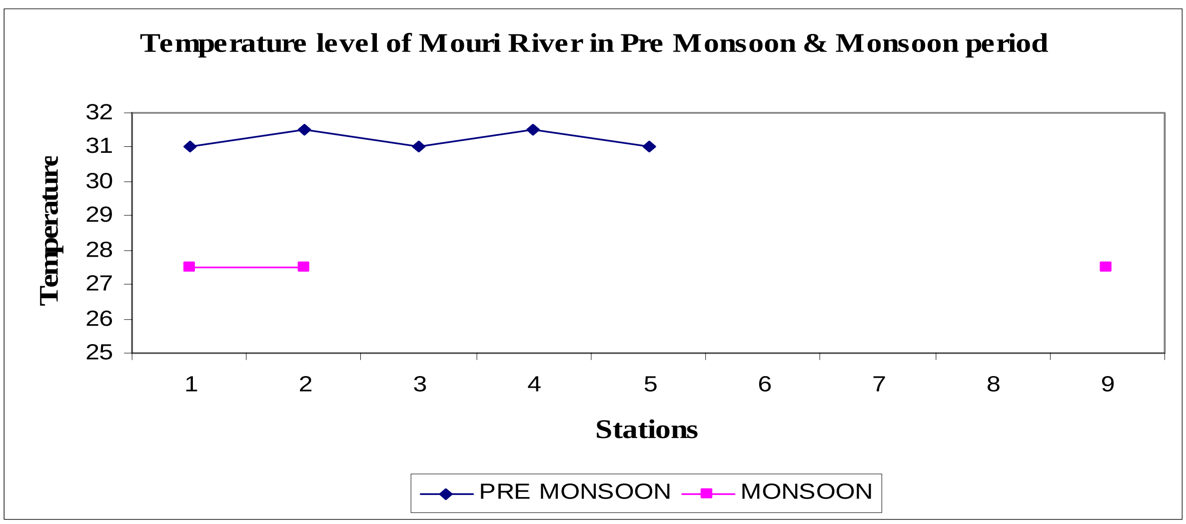

Figure 5.8.1: Graphical representation of Temperature of Mouri River.

(iii) Electric Conductivity

Table 5.8.3: Statistical presentation of Electric Conductivity of Mouri River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (dS/m)	1.9	0.53	Three categories of EC is specified by FAO for irrigation. None (<0.7 dS/m) , Slight to moderate (0.7 to 3.0 dS/m), Severe (> 3.0 dS/m).
Std Deviation	0.24	0.04	
Variance	0.06	0.00	
Min (dS/m)	1.72	0.44	
Max (dS/m)	2.25	0.57	

Source : Ayres and Westcot 1985.

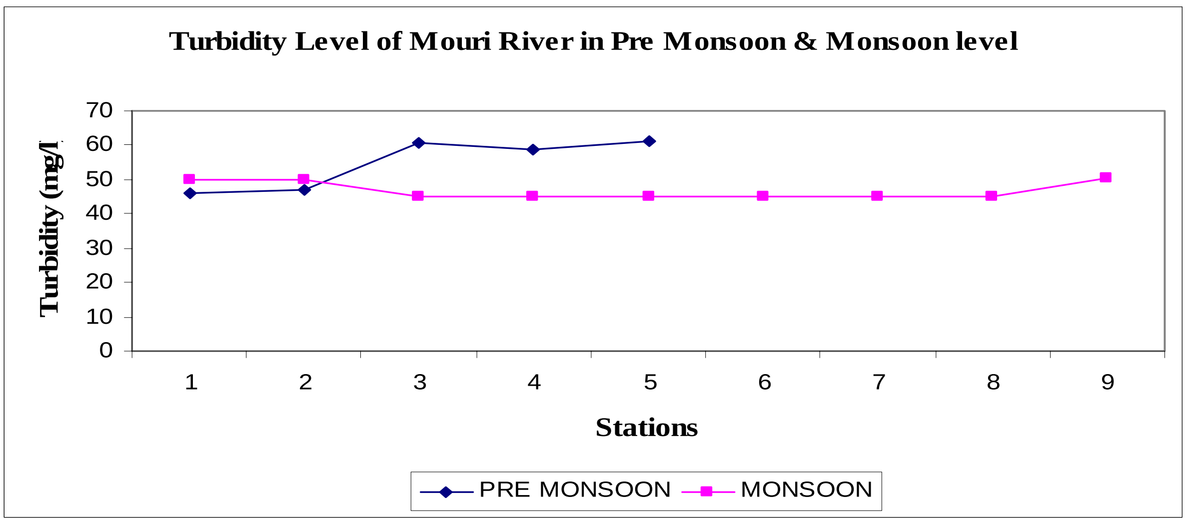

Figure 5.8.2: Graphical representation of Turbidity of Mouri River.

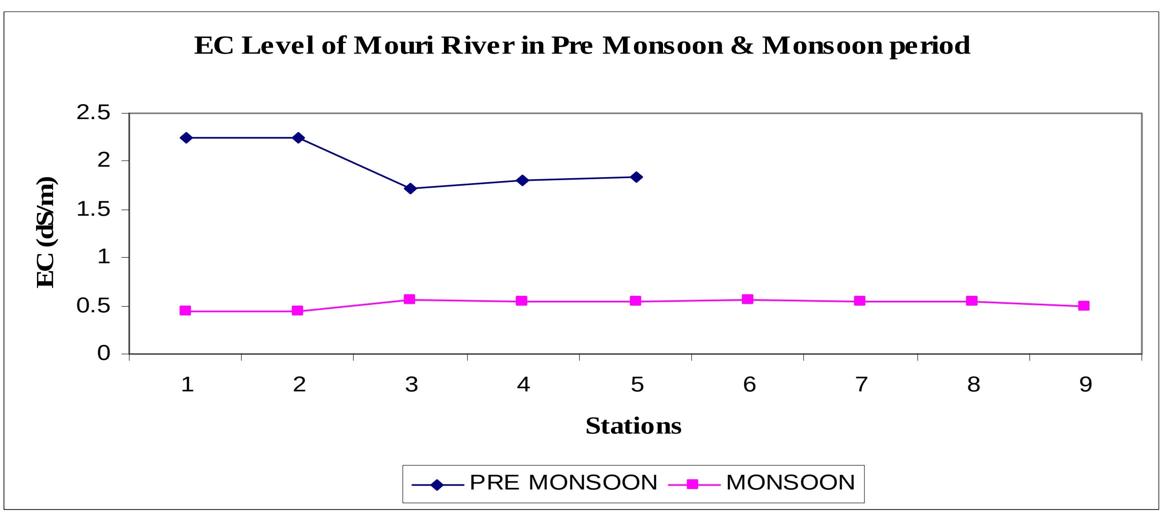

Figure 5.8.3: Graphical representation of EC of Mouri River

(iv) Total Solid

Table 5.8.4 Statistical presentation of Total Solid of Mouri River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	1383.75	326.63	Compared with the standards of suspended and dissolved solids.
Std Deviation	27.77	52.94	
Variance	770.92	2802.55	
Minimum (mg/l)	1344.00	218.00	
Maximum (mg/l)	1408.00	361.00	

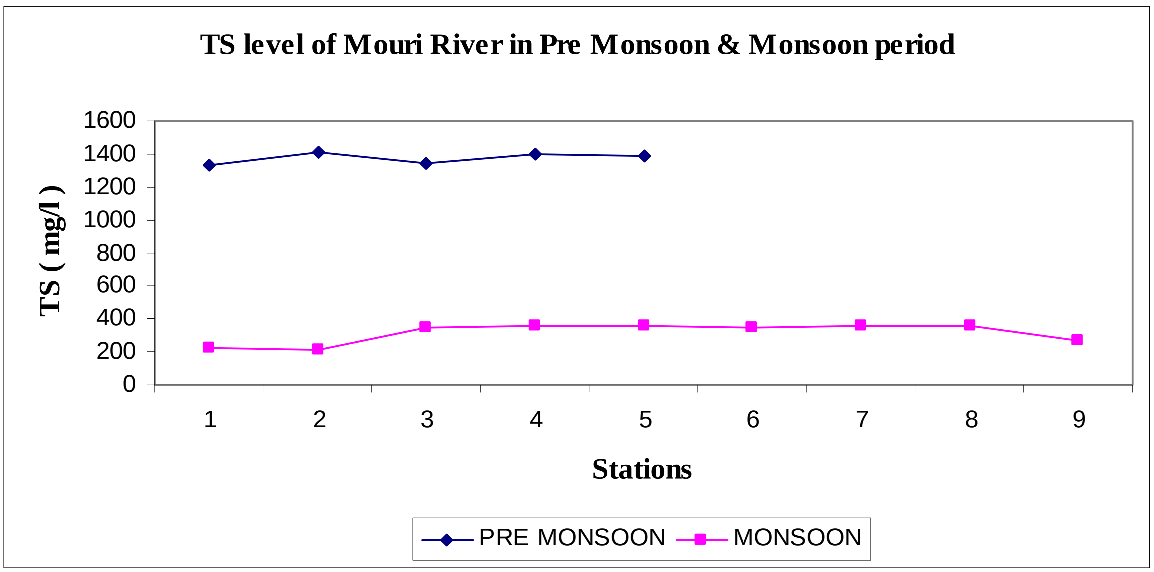

Figure 5.8.4: Graphical representation of TS of Mouri River.

(v) Total Dissolved Solid

Table 5.8.5 Statistical presentation of Total Dissolved Solid of Mouri River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	1185.00	250.25	Three categories of TDS is

Table 5.8.5 (Continue)

Std Deviation	94.17	37.50	specified by FAO for irrigation. None (< 450 mg/l) , Slight to moderate (450-2000 mg/l), Severe (> 2000 mg/l).
Variance	8868.67	1406.21	
Minimum (mg/l)	1133.00	171.00	
Maximum (mg/l)	1326.00	283.00	

Source : Ayres and Westcot 1985.

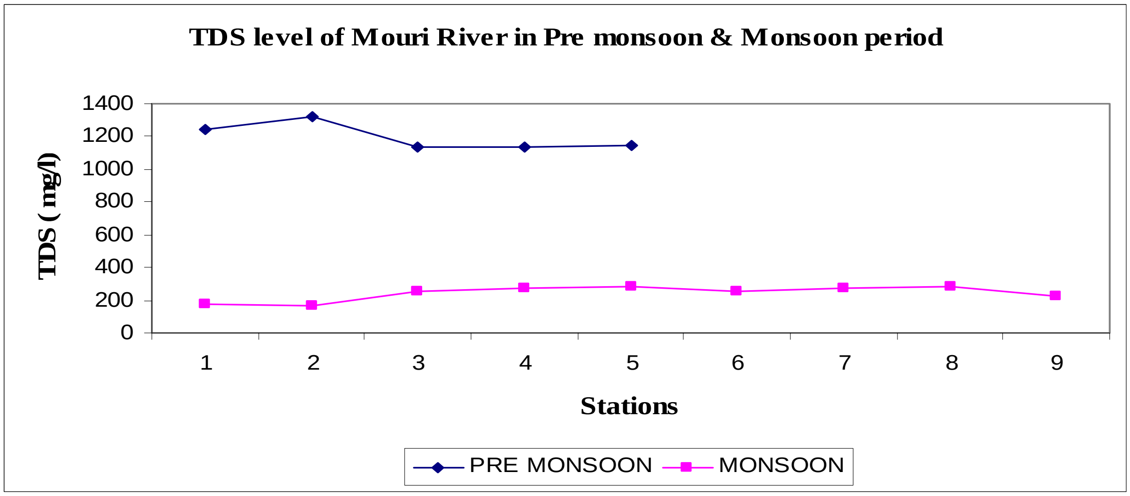

Figure 5.8.5: Graphical representation of TDS of Mouri River.

(vi) Suspended Solid

Table 5.3.6 Statistical presentation of Suspended Solid of Mouri River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	198.75	76.38	SS for fish culture is <1500 ppm. For drinking water, allowable concentration (maximum) Bangladesh standard 10 mg/l WHO standard is 10 mg/l.
Std Deviation	80.84	19.68	
Variance	6535.58	387.13	
Minimum (mg/l)	82.00	46.00	
Maximum (mg/l)	262.00	96.00	

Source: ECR 1997.

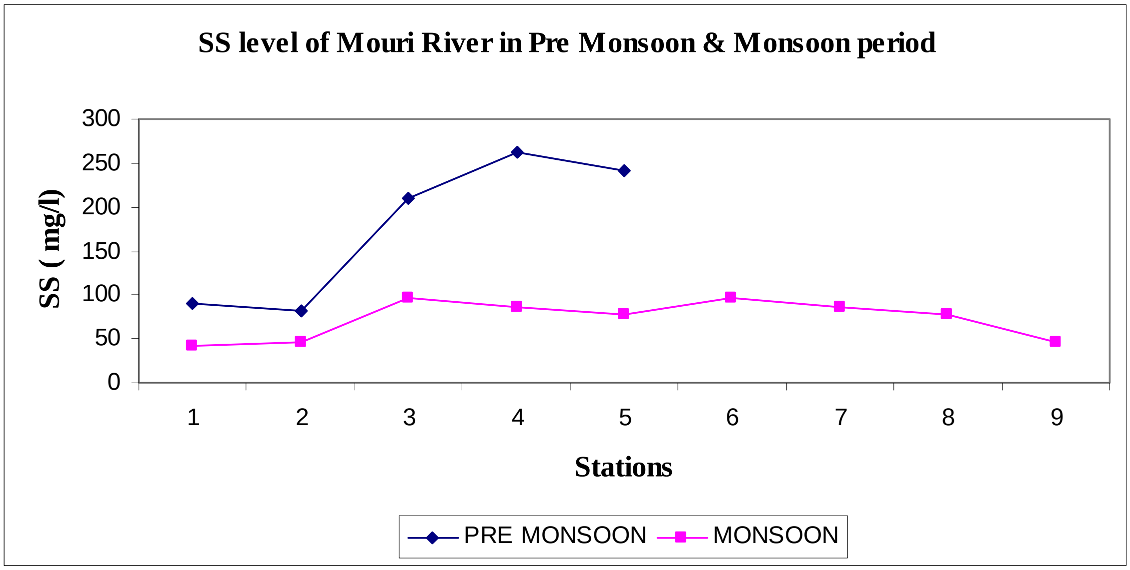

Figure 5.8.6: Graphical representation of SS of Mouri River.

Some aspects of physical water quality parameters of Mouri River for Pre Monsoon and Monsoon period have been presented. The average value of water temperature were 31.20 ^{0}C (Pre Monsoon) and 27.50 ^{0}C (Monsoon), Temperature of Mouri River water showed that it might be tolerable for aquaculture like Carp fish, Diatoms, Green algae and Blue-green algae.

Turbidity of Mouri River water were seen to be 56.81 NTU (Pre Monsoon) and 46.31 NTU (Monsoon), SS were 198.75mg/l (Pre Monsoon) and 76.38 mg/l (Monsoon) and TDS were 1185.00 mg/l (Pre Monsoon) and 250.25 mg/l (Monsoon) respectively. Turbidity of water mainly caused by silt, clay, waste materials, heavy particles, dumps etc. Turbidity always indicated the amount of various particles present in water which includes both the total dissolved and suspended solids present in water (Onyema, 2007). The value of different physical water quality parameters showed a higher rate in Pre Monsoon period than in Monsoon Period. These values decrease gradually as a result of more surface water flow in the river during monsoon period. Production of fish culture of Mouri River is seen to be favorable to produce 94 lb/acre of fish. Water of Mouri River is usable for cooling purpose. Mouri River water needs to be pretreated before using in beverage industries, food products, boiler, pulp paper industries and tanning leather.

The mean value of EC of Mouri River were seen to be 1.9 dS/m (Pre monsoon) 0.53 dS/m (Monsoon). That indicates the inorganic mineral content is high in Pre Monsoon period. Higher value of EC and not suitable for maintaining the normal functioning of aquatic organisms irrigation. But in Monsoon period this value of EC is within the no restriction category for using the water suggested by FAO. The standard values of SS and TDS were seen to be 10 mg/L and 1000 mg/L for the inland surface water of Bangladesh (Alam, *et al.,* 2007). After analysis the mean value of SS were found to be 198.75mg/l (Pre Monsoon) and 76.38 mg/l (Monsoon) and TDS were 1185.00 mg/l (Pre Monsoon) and 250.25 mg/l (Monsoon) The amount of SS and TDS were considerably high in the unit volume of water in Pre Monsoon period. In monsoon period Mouri River water is favorable for any purpose. But in Pre Monsoon period both SS and TDS is very high. So in Pre Monsoon period Mouri River Water needs pre treatment before use. The heavy particles present in the waste materials become settled on the river bottom and the remaining lighter particles are carried out with water in the form of suspended and dissolved forms. Higher amount of various solids present in water have a negative impact on the productivity and maintaining good water quality as these reduce the light penetration in water.

5.8.2 Chemical parameter

There are different chemical properties which can indicate the status of river water quality but for the study properties like P^H, chloride, alkalinity or T-alkalinity, hardness, DO, BOD, COD for Mouri River were considered.

(i) P^H

Table 5.8.7 Statistical presentation of P^H of Mouri River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean	7.21	7.25	Optimum P^H for aquaculture

Table 5.8.7 (Continue)

Std Deviation	0.04	0.03	Fish eggs could be hatched, but deformed young were often produced between P^H 3.8 - 10 Limit of P^H for resistant fish species is 4-10.1 Range tolerated by trout is P^H 4.1- 9.5 Best range for the growth of algae is P^H 7.5-8.4. Tanning leather when P^H 6-8 Food canning when minimum P^H 7.5 freezing when minimum P^H 7.5 Washing clothes when P^H 6-6.8 Rayon manufacturing when P^H 7.8-8.3
Variance	0.00	0.00	
Minimum	7.15	7.22	
Maximum	7.25	7.30	

Source: CWQB, 1963.

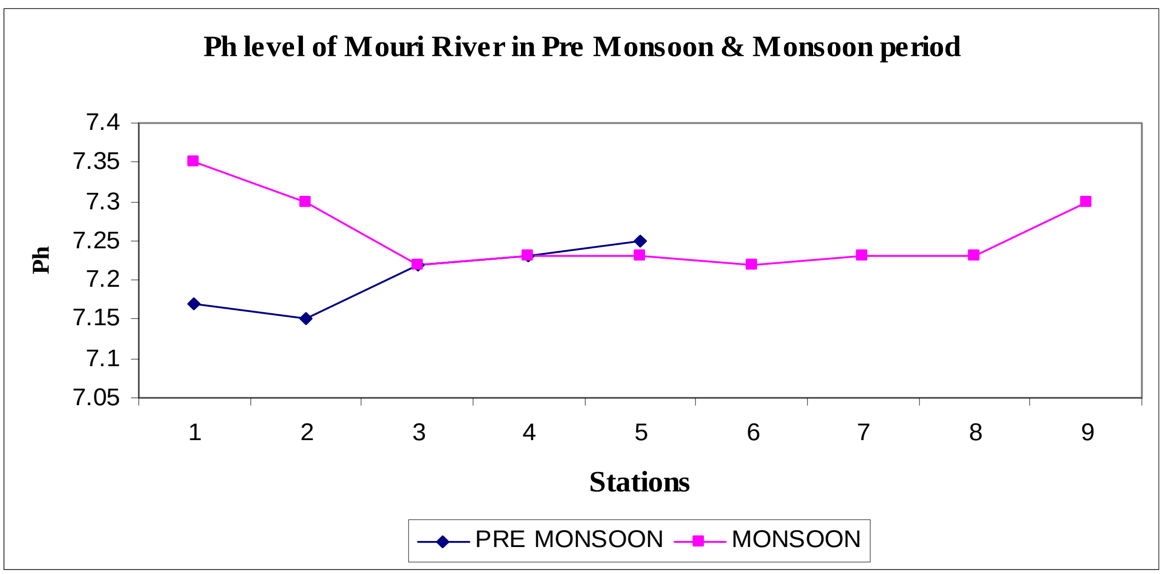

Figure 5.8.7: Graphical representation of P^H of Mouri River.

(viii) Chloride content

Table 5.8.8 Statistical presentation of Chloride of Mouri River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	543.75	51.25	Recommended for aquaculture Fish and aquatic life is 0.01 mg/l. Maximum fish can tolerate 0.37 mg/l. Minimum requirement for High-grade paper is 0.3 mg/l For surface irrigation 4-10 mg/l (Slight to moderate), > 10 mg/l (Severe).
Std Deviation	127.57	2.31	
Variance	16272.92	5.36	
Minimum (mg/l)	475.00	50.00	
Maximum (mg/l)	735.00	55.00	

Source : EPA, 1976.

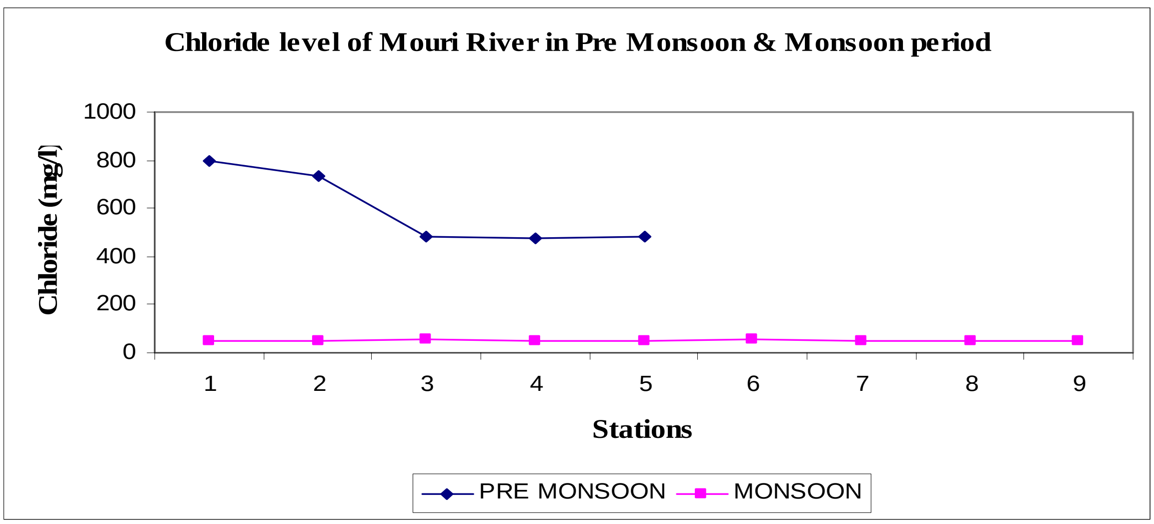

Figure 5.8.8: Graphical representation of Chloride content of Mouri River.

(iii) T- Alkalinity

Table 5.8.9 Statistical presentation of T-Alkalinity of Mouri River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	42.63	38.75	Recommended max alkalinity for,
Std Deviation	5.09	2.31	

Table 5.8.9 (Continue)

Variance	25.90	5.36	Carbonated beverages 85 mg/l Food products (canning) 300 mg/l Fruit juice 100 mg/l Pulp and paper making 50 mg/l Textile mill products 50-200 mg/l Rayon manufacture 50 mg/l Limit for fish culture is 50-400 mg/l
Minimum (mg/l)	35.00	35.00	
Maximum (mg/l)	45.50	40.00	

Source : CWQB, 1963.

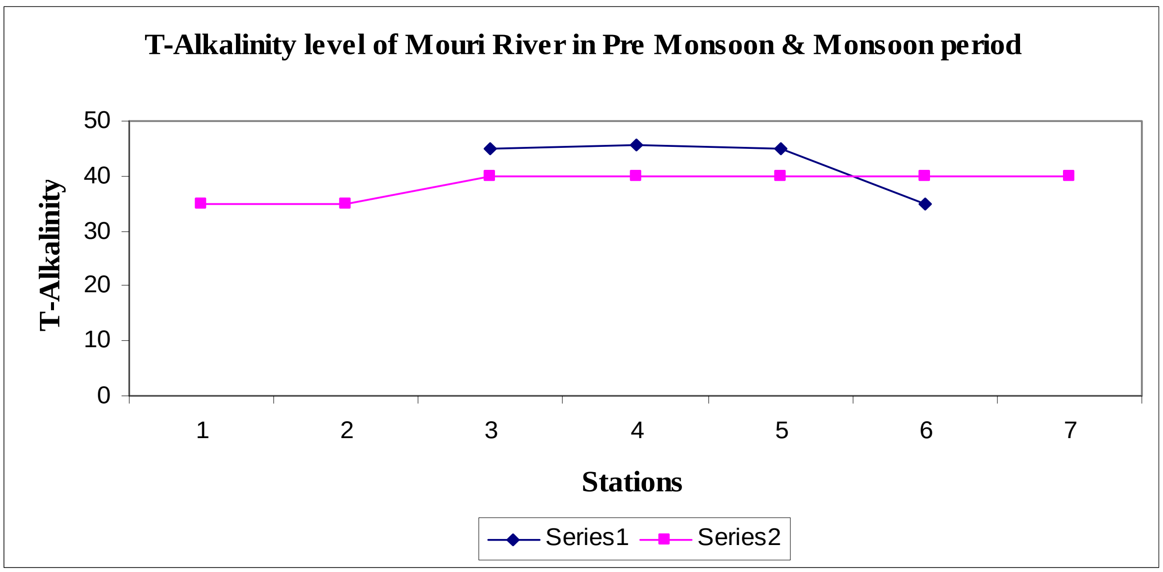

Figure 5.8.9: Graphical representation of T-Alkalinity of Mouri River.

(iv) Dissolved Oxygen

Table 5.8.10 Statistical presentation of Dissolved Oxygen of Mouri River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	3.18	3.93	Usable for

Table 5.8.10 (Continue)

Std Deviation	0.49	0.13	Irrigation when DO $\geq$ 5 mg/l. Fisheries when DO $\geq$ 5 mg/l. Recreational act. DO $\geq$ 5 mg/l Drinking purpose when DO $\geq$ 6 mg/l after disinfection. Cooling industries when DO $\geq$ 5 mg/l.
Variance	0.24	0.02	
Min (mg/l)	2.80	3.80	
Max (mg/l)	3.90	4.20	

Source: ECR 1997.

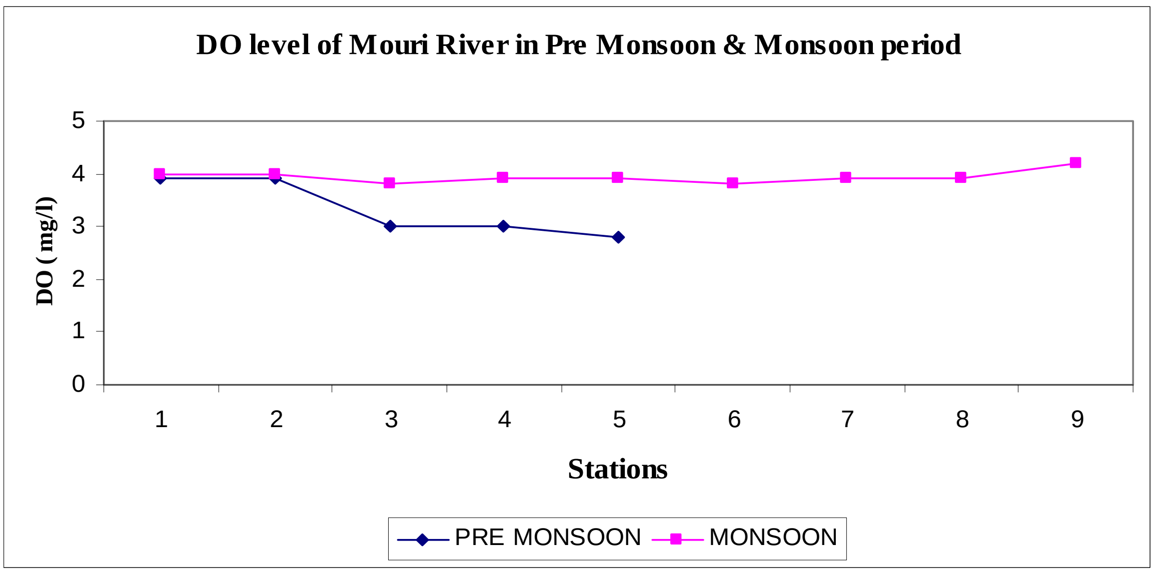

Figure 5.8.10: Graphical representation of DO of Mouri River.

(viii) BOD

Table 5.8.11 Statistical presentation of BOD of Mouri River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	12.13	1.77	Usable for

Table 5.8.11 (Continue)

Std Deviation	10.59	0.08	Irrigation when ≤ 2mg/l. Fisheries when ≤ 6mg/l. Recreational activity ≤ 3mg/l. Drinking purpose ≤ 2mg/l after disinfection. Cooling industries ≤ 10mg/l
Variance	112.23	0.01	
Min (mg/l)	6.50	1.70	
Max (mg/l)	28.00	1.90	

Source : ECR 1997

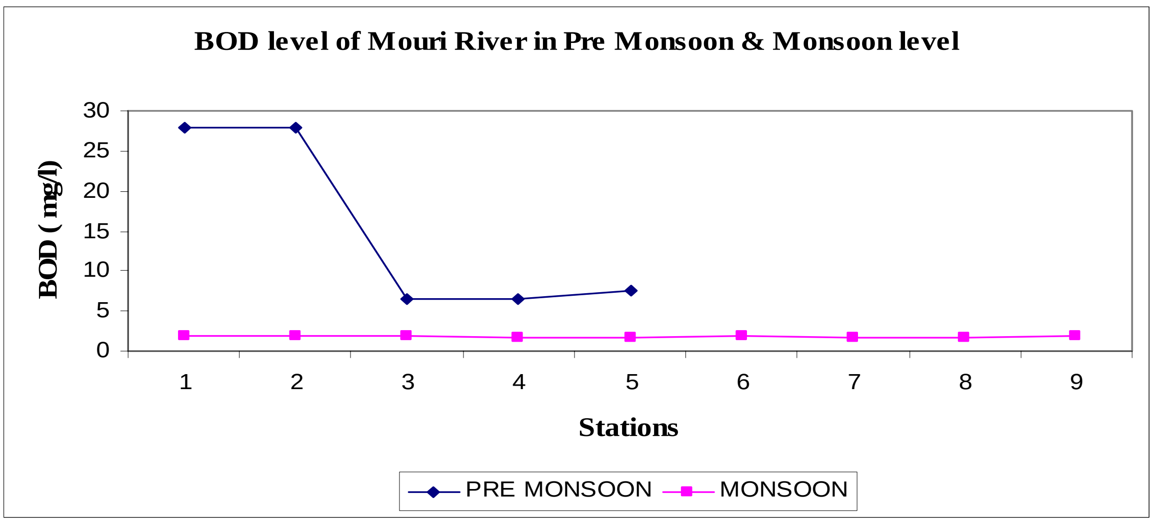

Figure 5.8.11: Graphical representation of BOD of Mouri River.

(vi) COD

Table 5.8.12: Statistical presentation of COD of Mouri River

Statistics	Pre-Monsoon	Monsoon	Remark
Mean	570.75	271.25	
Std Deviation	99.25	2.76	Usable for bathing purpose when COD is 180-270 mg/l .
Variance	9850.92	7.64	
Minimum	422.00	268.00	
Maximum	625.00	275.00	

Source : Wintgens *et al.*, 2005

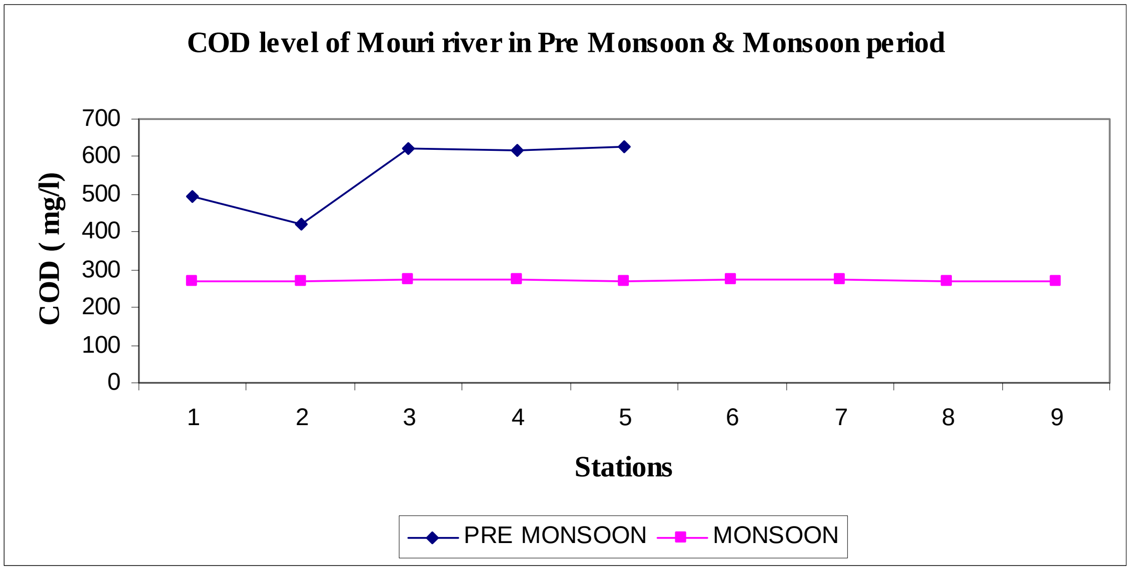

Figure 5.8.12: Graphical representation of COD of Mouri River at different sampling station.

The mean values of the various chemical parameters of the Mouri River water are presented. The mean value of water pH at different stations of the river was found as 7.21 (Pre Monsoon) and 7.25 (Monsoon). The value of pH was normal compared with the standard level as the optimum value of water pH is 6.5-8.5 or around 7 for the drinking purpose. as well as aquatic organisms and the tolerable range is between 6 and 8.5 (ECR 1997). The P^H value of Mouri River water is also fit for fish culture and algae growth as well as industrial and manufacturing processes like Food canning, freezing, Rayon manufacturing and Tanning leather. But this water needs to be pretreated in case of washing clothes.

The mean values of dissolve oxygen (DO) were 3.18 mg/l (Pre Monsoon), 3.93 mg/l (Monsoon) at various stations throughout the experimental period. Sampling result at the pre monsoon and monsoon period revealed that the values of DO were slightly low. Mouri River water is not fit for Irrigation, fish culture, recreational activity and Cooling industries But this water needs to be pretreated in case of use it for drinking purpose after disinfection. DO is very important for identifying a suitable aquatic body and also to estimate productivity of an aquatic system (Romesh and Anbu, 1996; Davies, *et al.*, 2008). The low oxygen of this river water was due to the excess dumping (domestic and urban sewage, industrial effluents, agricultural wastes etc.). The major effect of sewage in water is that it reduces oxygen content of water as the organic matter content of sewage is higher (Ragothaman and Trivedy, 2002).

The mean value of biochemical oxygen demand (BOD) are 12.13 mg/l (Pre Monsoon) and 1.77 mg/l (Monsoon) and chemical oxygen demand (COD) at different sampling stations were 570.75 mg/l (Pre Monsoon), 271.25 mg/l (Monsoon) respectively. BOD and COD levels were observed higher at the Pre monsoon and Monsoon period. A standard value of COD for drinking purposes is 4 mg/L and For bathing is 180-270 mg/L while in the case of biochemical oxygen demand (BOD), standard for drinking purpose is 0.2mg/L, sewage effluent 20 mg/L (Wintgens *et al*, 2005; Jalil and Njiru, 2010). Oxygen being the basic requirement of almost all plant and animal life, its presence in sufficient quantities is important to support and sustain life. All organic matters undergo biodegradation and exhibit a biochemical oxygen demand (BOD) or a chemical oxygen demand (COD) as oxygen is required for their degradation (Khatri, 1984). The typical sources include sewage from domestic and animal source, industrial wastes, natural decaying vegetation, decay of dead plants and animals. This type of water pollution becomes a severe problem when the oxygen required for biodegradation or chemical oxidation is greater than the available oxygen in the ecosystem. The estimation of BOD gives an indication of the amount of pollution in a body of water. The high amount of BOD indicates large bacterial and fungal population. Owing to metabolic activities of these organisms, the dissolved oxygen gets reduced and the area is found without oxygen. Aquatic organisms such as fishes either evade this area or are killed (Khatri, 1985). After above analysis we found that in Monsoon period Mouri River water is suitable for irrigation, fish culture, recreational activities, drinking purpose (after disinfection) and cooling purpose in industries.

5.9 Parameterization of water quality parameter of Kopotakhkho River

5.9.1 Physical parameter

Among all physical properties our concern Physical parameters were temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid for Kopotakhkho River.

(i) Temperature

Table 5.9.1 Statistical presentation of Temperature of Kopotakhkho River.

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (^{0}C)	Not Available	27.00	Optimum Temp for Carp fish is 32 ^{0}C Diatoms grow best at 15-25 ^{o}C, Green algae grow best at 25-35 ^{o}C, Blue-green algae at 30-40 ^{o}C.
Std Deviation	Not Available	0.00	
Variance	Not Available	0.00	
Minimum (^{0}C)	Not Available	27.00	
Maximum (^{0}C)	Not Available	27.00	

Source: (i) CWQB, 1963. (ii) EPA, 1976.

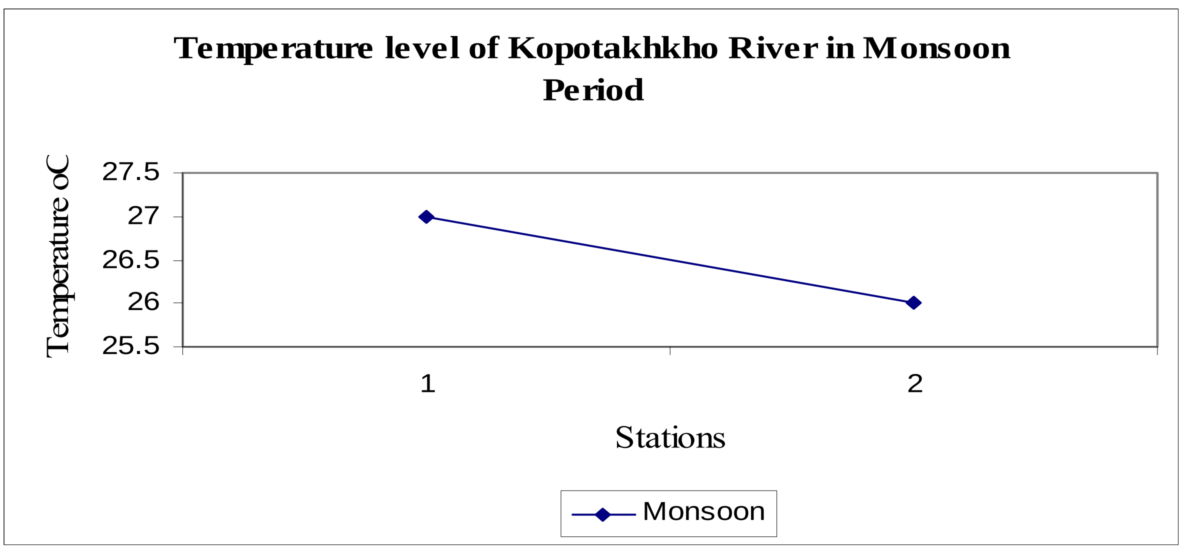

Figure 5.9.1: Graphical representation of temperature of Kopotakhkho River.

(ii) Turbidity

Table 5.9.2 Statistical presentation of Turbidity of Kopotakhkho River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (NTU)	Not Available	82.95	Amount of fish 162 lb/ acre for 25 NTU, 94 lb/ acre for 25 -100 NTU, 29 lb/ acre for over 100 NTU. Usable for Beverages if turbidity is 1-2 NTU Food products for 10 NTU Water used in boilers for 1-20 NTU (varies with type of boiler) High grade paper for 5-25 NTU Water used for cooling for 50 NTU. Tanning leather for 20 NTU
Std Deviation	Not Available	3.61	
Variance	Not Available	13.00	
Minimum (NTU)	Not Available	80.40	
Maximum (NTU)	Not Available	85.50	

Source: CWQB, 1963.

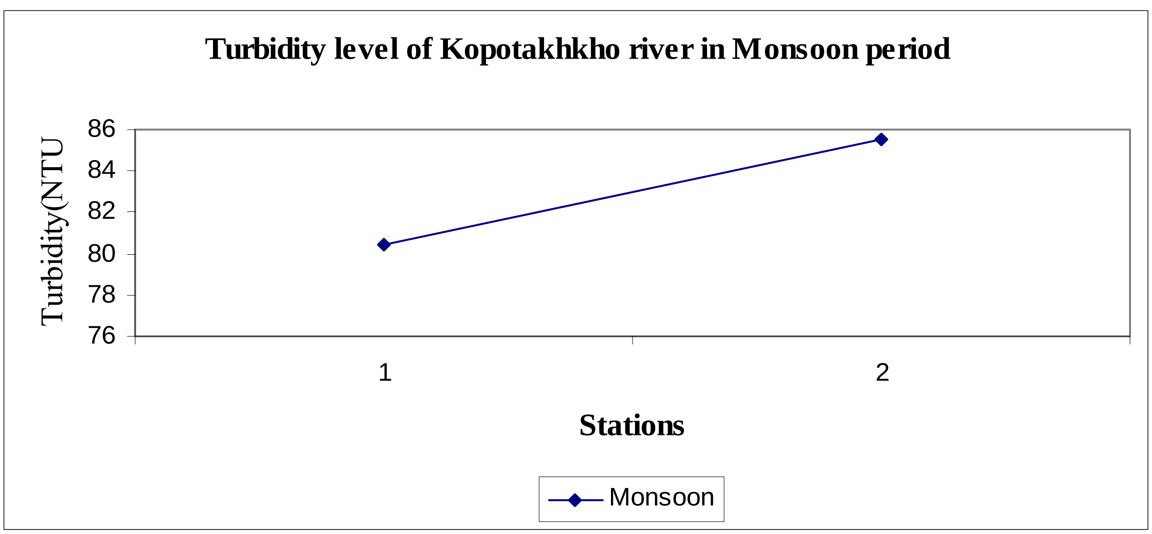

Figure 5.9.2: Graphical representation of Turbidity of Kopotakhkho River.

(iii) Electric Conductivity

Table 5.9.3 Statistical presentation of Electric Conductivity of Kopotakhkho River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (dS/m)	Not Available	53.25	Three categories of EC is specified by FAO for irrigation. None (<0.7 dS/m) , Slight to moderate (0.7 to 3.0 dS/m), Severe (> 3.0 dS/m).
Std Deviation	Not Available	1.77	
Variance	Not Available	3.13	
Min (dS/m)	Not Available	52.00	
Max (dS/m)	Not Available	54.50	

Source : Ayres and Westcot 1985.

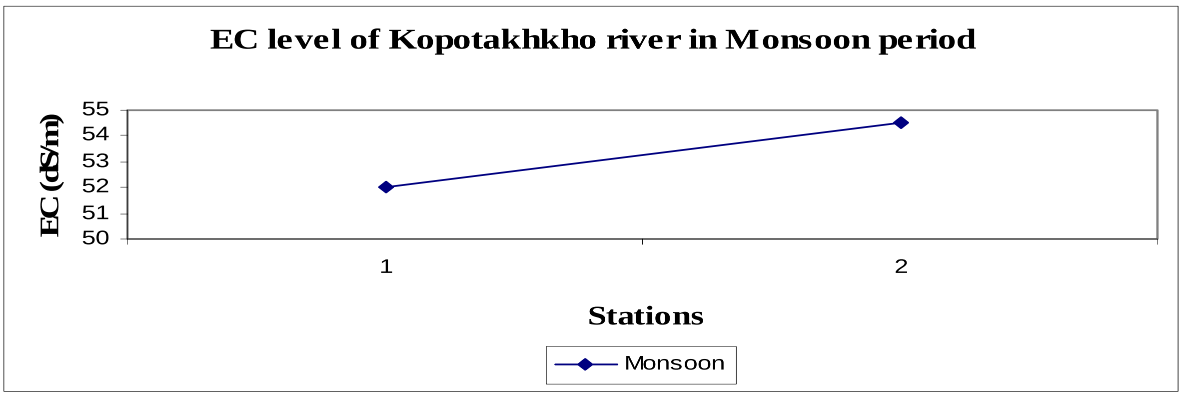

Figure 5.9.3: Graphical representation of EC of Kopotakhkho River.

(iv) Total Solid

Table 5.9.4 Statistical presentation of Total Solid of Kopotakhkho River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	28990.00	Compared with the standards of suspended and dissolved solids.
Std Deviation	Not Available	1159.66	
Variance	Not Available	1344800.00	
Minimum (mg/l)	Not Available	28170.00	
Maximum (mg/l)	Not Available	28990.00	

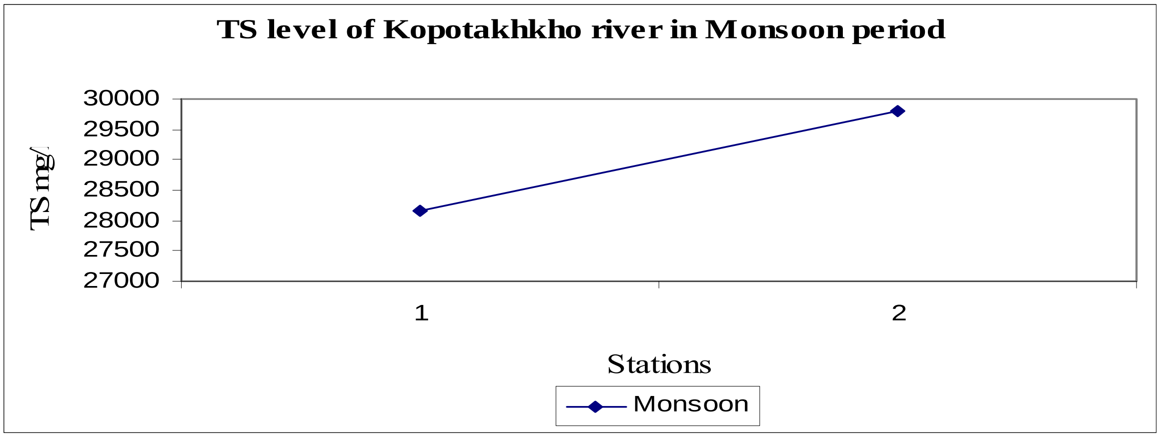

Figure 5.9.4: Graphical representation of TS of Kopotakhkho River.

(v) Total Dissolved Solid

Table 5.9.5 Statistical presentation of Total Dissolved Solid of Kopotakhkho River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	28852.50	Three categories of TDS is specified by FAO for irrigation. None (< 450 mg/l) , Slight to moderate (450-2000 mg/l), Severe (> 2000 mg/l).
Std Deviation	Not Available	1205.62	
Variance	Not Available	1453512.50	
Min (mg/l)	Not Available	28000.00	
Max(mg/l)	Not Available	29705.00	

Source : Ayres and Westcot 1985.

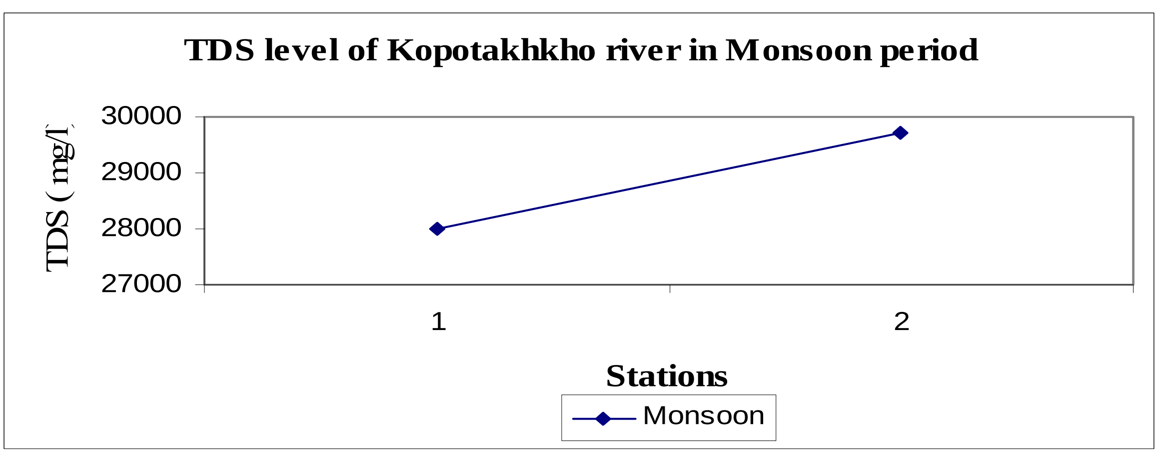

Figure 5.9.5: Graphical representation of TDS of Kopotakhkho River.

(vi) Suspended Solid

Table 5.9.6 Statistical presentation of Suspended Solid of Kopotakhkho River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	137.50	SS for fish culture is <1500 ppm. For drinking water, allowable concentration (maximum) Bangladesh standard 10 mg/l WHO standard is 10 mg/l.
Std Deviation	Not Available	45.96	
Variance	Not Available	2112.50	
Minimum (mg/l)	Not Available	105.00	
Maximum (mg/l)	Not Available	170.00	

Source : ECR 1997.

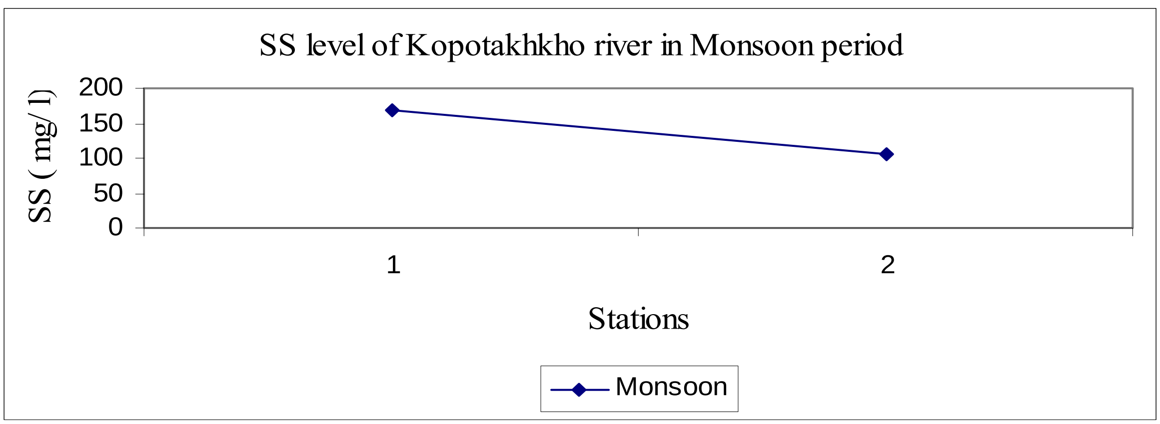

Figure 5.9.6: Graphical representation of SS of Kopotakhkho River.

Some aspects of physical water quality parameters of Kopotakhkho River for Pre Monsoon and Monsoon period have been presented. The average value of water temperature was 27.00 ^{0}C (Monsoon), Temperature of Kopotakhkho River water showed that it might be tolerable for aquaculture like Carp fish, Diatoms, Green algae and Blue-green algae. Turbidity of Kopotakhkho River water were seen to be 82.95 NTU (Monsoon), SS were 137.50 mg/l (Monsoon) and TDS was 28852.50 mg/l (Monsoon) respectively. Turbidity of water mainly caused by silt, clay, waste materials, heavy particles, dumps etc. Turbidity always indicated the amount of various particles present in water which includes both the total dissolved and suspended solids present in water

(Onyema, 2007). The value of different physical water quality parameters showed a higher rate in Pre Monsoon period than in Monsoon Period. These values decrease gradually as a result of more surface water flow in the river during monsoon period. Production of fish culture of Kopotakhkho River is seen to be favorable to produce 94 lb/acre of fish. Water of Kopotakhkho River is usable for cooling purpose. Kopotakhkho River water needs to be pretreated before using in beverage industries, food products, boiler, pulp paper industries and tanning leather.

The mean value of EC of Kopotakhkho River were seen to be 53.25 dS/m (Monsoon). That indicates the inorganic mineral content is high. The results of the present study clearly indicate that the water of Kopotakhkho River was carrying higher value of EC and not suitable for maintaining the normal functioning of aquatic organisms or irrigation and needs to be pretreated before using for drinking and industrial purposes. The standard values of SS and TDS were seen to be 10 mg/L and 1000 mg/L for the inland surface water of Bangladesh (Alam, *et al.,* 2007). After analysis the mean value of SS were 137.50 mg/l (Monsoon) and TDS was 28852.50 mg/l (Monsoon) respectively. The amount of SS and TDS were considerably high and falls in severe restriction category suggested by FAO. So in monsoon period Kopotakhkho River water needs pre treatment before use. The heavy particles present in the waste materials become settled on the river bottom and the remaining lighter particles are carried out with water in the form of suspended and dissolved forms. Higher amount of various solids present in water have a negative impact on the productivity and maintaining good water quality as these reduce the light penetration in water. As the data of Pre monsoon period was not available, so it was not possible to analyze Pre Monsoon data.

5.9.2 Chemical parameter

There are different chemical properties which can indicate the status of river water quality but for the study properties like P^H, chloride, alkalinity or T-alkalinity, hardness, DO, BOD, COD for Kopotakhkho River were considered.

(i) P^H

Table 5.9.7 Statistical presentation of P^H of Kopotakhkho River

<table>
<tr><th>Statistical Parameters</th><th>Pre-Monsoon</th><th>Monsoon</th><th>Remark</th></tr>
<tr><td>Mean</td><td>Not Available</td><td>7.65</td><td rowspan="5">Optimum P^H for aquaculture
Fish eggs could be hatched, but deformed young were often produced between P^H 3.8 - 10
Limit of P^H for resistant fish species is 4-10.1
Range tolerated by trout is P^H 4.1- 9.5
Best range for the growth of algae is P^H 7.5-8.4.
Food canning when minimum P^H 7.5
Freezing when minimum P^H 7.5
Washing clothes when P^H 6-6.8
Rayon manufacturing when P^H 7.8-8.3
Tanning leather when P^H 6-8</td></tr>
<tr><td>Std Deviation</td><td>Not Available</td><td>0.07</td></tr>
<tr><td>Variance</td><td>Not Available</td><td>0.00</td></tr>
<tr><td>Minimum</td><td>Not Available</td><td>7.60</td></tr>
<tr><td>Maximum</td><td>Not Available</td><td>7.70</td></tr>
</table>

Source : CWQB, 1963.

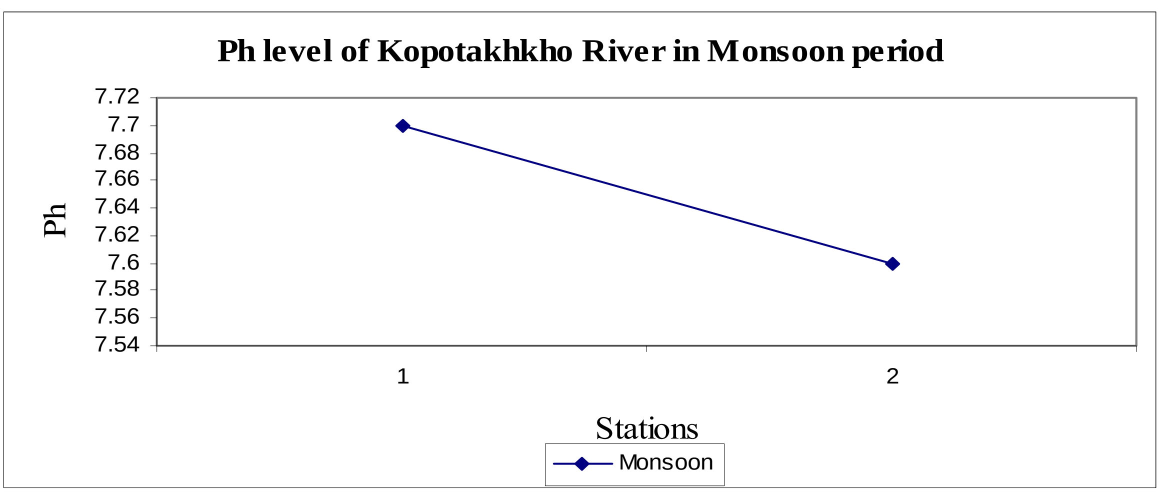

Figure 5.9.7: Graphical representation of Ph of Kopotakhkho River.

(ii) Chloride content

Table 5.9.8 Statistical presentation of Chloride of Kopotakhkho River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	12900.00	Recommended for aquaculture Fish and aquatic life is 0.01 mg/l. Maximum fish can tolerate 0.37 mg/l. Minimum requirement for High-grade paper is 0.3 mg/ For surface irrigation 4-10 mg/l (Slight to moderate), > 10 mg/l (Severe).
Std Deviation	Not Available	848.53	
Variance	Not Available	720000.00	
Minimum (mg/l)	Not Available	12300.00	
Maximum (mg/l)	Not Available	13500.00	

Source : EPA, 1976.

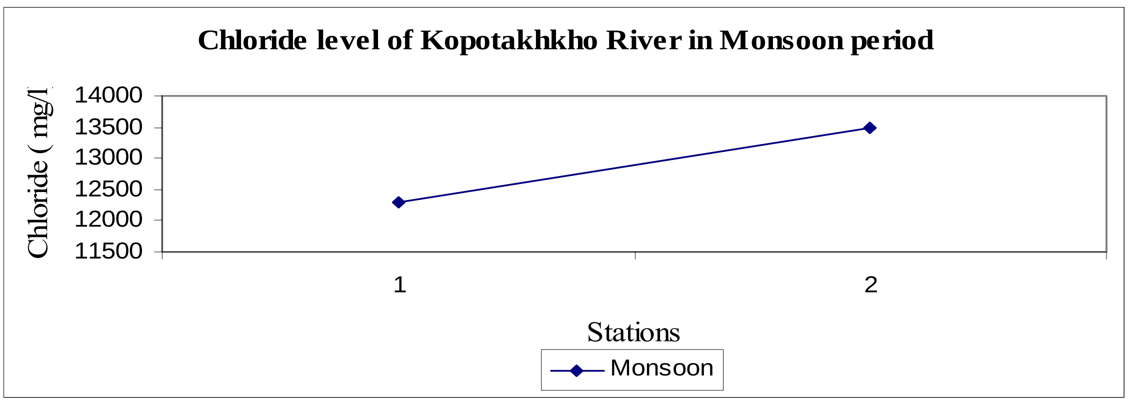

Figure 5.9.8: Graphical representation of Chloride content of Kopotakhkho River.

(iii) T- Alkalinity

Table 5.9.9 Statistical presentation of T-Alkalinity of Kopotakhkho River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	35.50	Recommended max alkalinity for, Carbonated beverages 85 mg/l Food products (canning) 300 mg/l Fruit juice 100 mg/l
Std Deviation	Not Available	0.71	
Variance	Not Available	0.50	

Table 5.9.9 (Continue)

Minimum (mg/l)	Not Available	35.00	Pulp and paper making 50 mg/l Textile mill products 50-200 mg/l Rayon manufacture 50 mg/l Limit for fish culture is 50-400 mg/l
Maximum (mg/l)	Not Available	36.00	

Source: (i) CWQB, 1963.

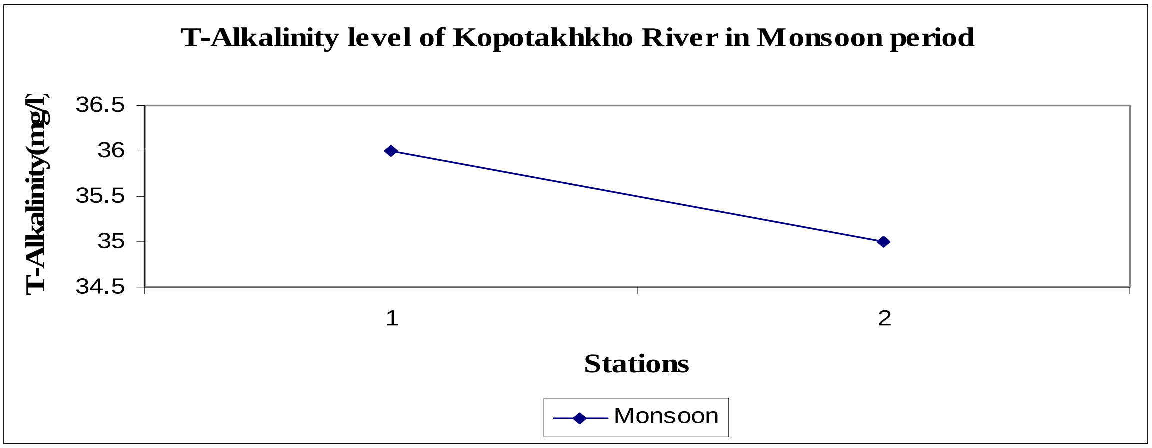

Figure 5.9.9: Graphical representation of T-Alkalinity of Kopotakhkho River.

(iv) Dissolved Oxygen

Table 5.9.10 Statistical presentation of Dissolved Oxygen of Kopotakhkho River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	Not Available	4.05	Usable for Irrigation when DO ≥ 5 mg/l. Fisheries when DO ≥ 5 mg/l. Recreational act. DO ≥ 5 mg/l Drinking purpose when DO ≥ 6 mg/l Cooling industries when DO ≥ 5 mg/l.
Std Deviation	Not Available	0.07	
Variance	Not Available	0.01	
Minimum (mg/l)	Not Available	4.00	
Maximum (mg/l)	Not Available	4.10	

Source: ECR 1997.

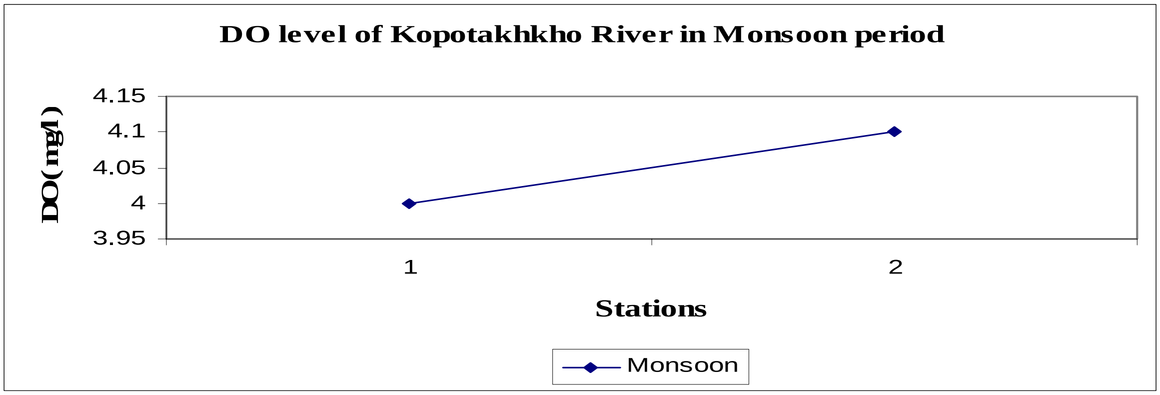

Figure 5.9.10: Graphical representation of DO of Kopotakhkho River.

(ix) BOD

Table 5.9.11 Statistical presentation of BOD of Kopotakhkho River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**	
Mean (mg/l)	Not Available	1.25	Usable for	
Std Deviation	Not Available	0.07	Irrigation when	≤ 2mg/l.
Variance	Not Available	0.00	Fisheries when	≤ 6mg/l.
Min (mg/l)	Not Available	1.20	Recreational activity	≤ 3mg/l.
Max (mg/l)	Not Available	1.30	Drinking purpose	≤ 2mg/l
			Cooling industries	≤ 10mg/l.

Source : ECR 1997

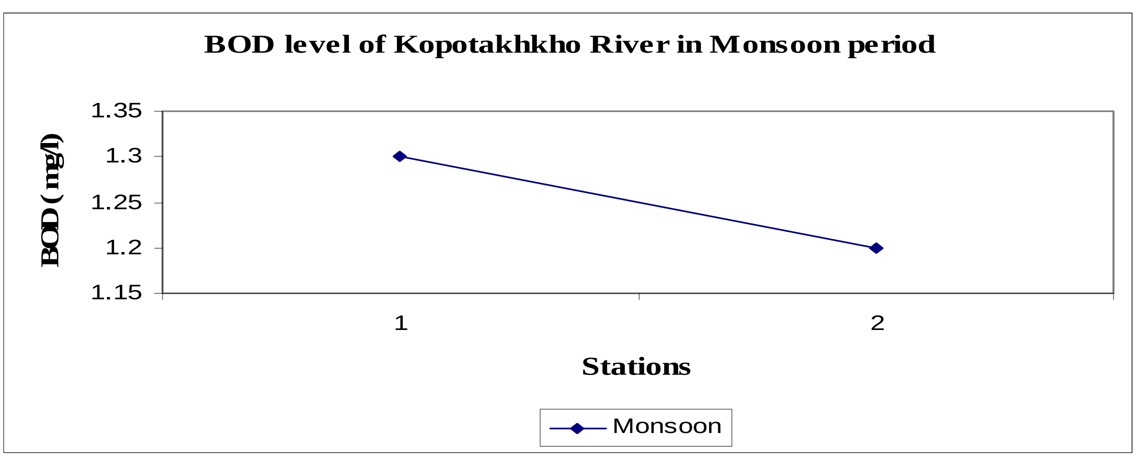

Figure 5.9.11: Graphical representation of BOD of Kopotakhkho River.

(vi) COD

Table 5.9.12: Statistical presentation of COD of Kopotakhkho River

Statistics	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	1075.00	Usable for bathing purpose when COD is 180-270 mg/l .
Std Deviation	Not Available	35.36	
Variance	Not Available	1250.00	
Min (mg/l)	Not Available	1050.00	
Max (mg/l)	Not Available	1100.00	

Source : Wintgens *et al.*, 2005

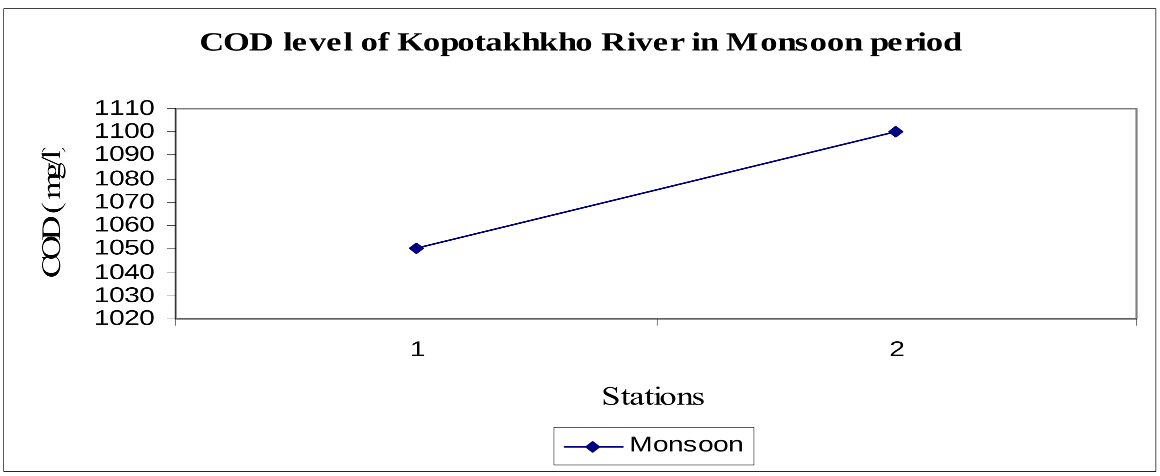

Figure 5.9.12: Graphical representation of COD of Kopotakhkho River at different sampling station.

The mean values of the various chemical parameters of the Kopotakhkho River water are presented. The mean value of water pH at different stations of the river was found as 7.65 (Monsoon). The value of pH was normal compared with the standard level as the optimum value of water pH is 6.5-8.5 or around 7 for the drinking purpose. as well as aquatic organisms and the tolerable range is between 6 and 8.5 (ECR 1997). The P^H

value of Kopotakhkho River water is also fit for fish culture and algae growth as well as industrial and manufacturing processes like Food canning, freezing, Rayon manufacturing and Tanning leather. But this water needs to be pretreated in case of washing clothes.

The mean values of dissolve oxygen (DO) were 4.05 mg/l (Monsoon) at various stations throughout the experimental period. Sampling result at the pre monsoon and monsoon period revealed that the values of DO were slightly low. Kopotakhkho River water is fit for Irrigation, fish culture, recreational activity and Cooling industries But this water needs to be pretreated in case of use it for drinking purpose after disinfection. DO is very important for identifying a suitable aquatic body and also to estimate productivity of an aquatic system (Romesh and Anbu, 1996; Davies, *et al.*, 2008). The low oxygen of this river water was due to the excess dumping (domestic and urban sewage, industrial effluents, agricultural wastes etc.). The major effect of sewage in water is that it reduces oxygen content of water as the organic matter content of sewage is higher (Ragothaman and Trivedy, 2002). The mean value of biochemical oxygen demand (BOD) are 1.25 mg/l (Monsoon) and chemical oxygen demand (COD) at different sampling stations were 1075.00 mg/l (Monsoon) respectively. BOD and COD levels were observed higher at the Pre monsoon and Monsoon period. A standard value of COD for drinking purposes is 4 mg/L and For bathing is 180-270 mg/L while in the case of biochemical oxygen demand (BOD), standard for drinking purpose is 0.2mg/L, sewage effluent 20 mg/L (Wintgens *et al*, 2005; Jalil and Njiru, 2010). Oxygen being the basic requirement of almost all plant and animal life, its presence in sufficient quantities is important to support and sustain life. All organic matters undergo biodegradation and exhibit a biochemical oxygen demand (BOD) or a chemical oxygen demand (COD) as oxygen is required for their degradation (Khatri, 1984). The typical sources include sewage from domestic and animal source, industrial wastes, natural decaying vegetation, decay of dead plants and animals. This type of water pollution becomes a severe problem when the oxygen required for biodegradation or chemical oxidation is greater than the available oxygen in the ecosystem. The estimation of BOD gives an indication of the amount of pollution in a body of water. The high amount of BOD indicates large bacterial and fungal population. Owing to metabolic activities of these organisms, the dissolved oxygen gets reduced and the area is found without oxygen. Aquatic organisms such as fishes either evade this area or are killed (Khatri, 1985). After above analysis we found that Kopotakhkho River water is suitable for irrigation, fish culture, recreational activities, drinking purpose (after disinfection) and cooling purpose in industries.

5.10 Parameterization of water quality parameter of Mathavanga River

5.10.1 Physical parameter

Among all physical properties the concern of these study was focused on Physical parameters such as temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid for Mathavanga River.

(i) Temperature

Table 5.10.1: Statistical presentation of Temperature of Mathavanga River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (^{0}C)	32.17	Not Available	Optimum Temp for Carp fish is 32 ^{0}C Diatoms grow best at 15-25 ^{o}C, Green algae grow best at 25-35 ^{o}C, Blue-green algae at 30-40^{o}C
Std Deviation	2.17	Not Available	
Variance	4.69	Not Available	
Min (^{0}C)	30.00	Not Available	
Max (^{0}C)	35.00	Not Available	

Source: (i) CWQB, 1963. (ii) EPA, 1976.

(ii) Turbidity

Table 5.10.2: Statistical presentation of Turbidity of Mathavanga River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (NTU)	73.61	Not Available	Amount of fish 162 lb/ acre for 25 NTU, 94 lb/ acre for 25 -100 NTU, 29 lb/ acre for over 100 NTU. Usable for Beverages if turbidity is 1-2 NTU Food products for 10 NTU Water used in boilers for 1-20 NTU (varies with type of boiler) High grade paper for 5-25 NTU Water used for cooling for 50 NTU. Tanning leather for 20 NTU
Std Deviation	86.81	Not Available	
Variance	7536.29	Not Available	
Minimum (NTU)	18.00	Not Available	
Maximum (NTU)	265.00	Not Available	

Source: CWQB, 1963.

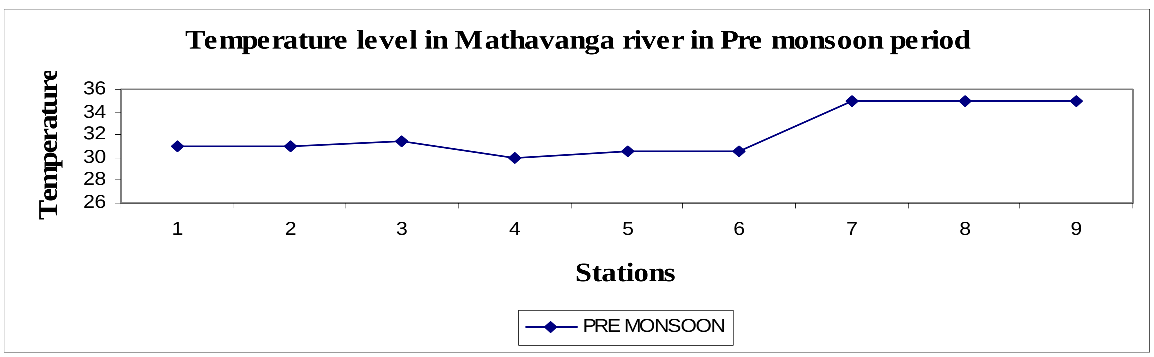

Figure 5.10.1: Graphical representation of temperature of Mathavanga River.

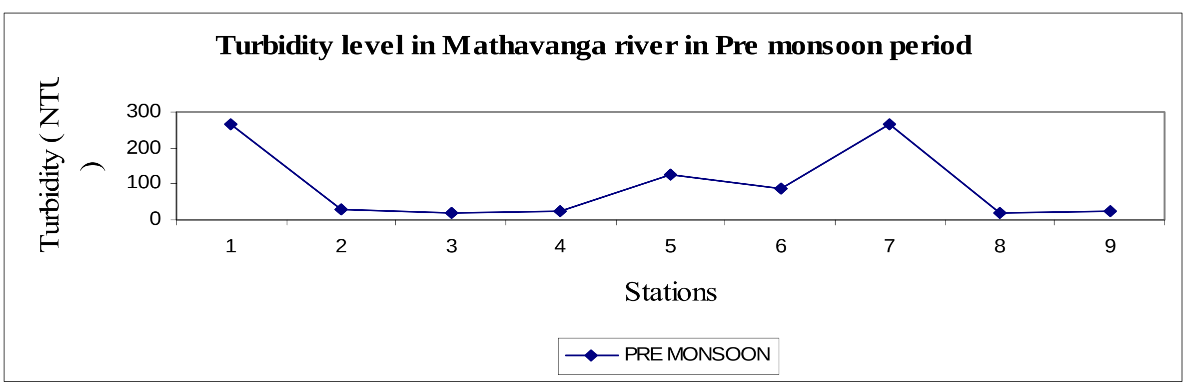

Figure 5.10.2: Graphical representation of Turbidity of Mathavanga River.

(iii) Electric Conductivity

Table 5.10.3: Statistical presentation of Electric Conductivity of Mathavanga River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (dS/m)	1.01	Not Available	Three categories of EC is specified by FAO for irrigation. None (<0.7 dS/m) , Slight to moderate (0.7 to 3.0 dS/m), Severe (> 3.0 dS/m).
Std Deviation	0.28	Not Available	
Variance	0.08	Not Available	
Min (dS/m)	0.52	Not Available	
Max (dS/m)	1.38	Not Available	

Source : Ayres and Westcot 1985.

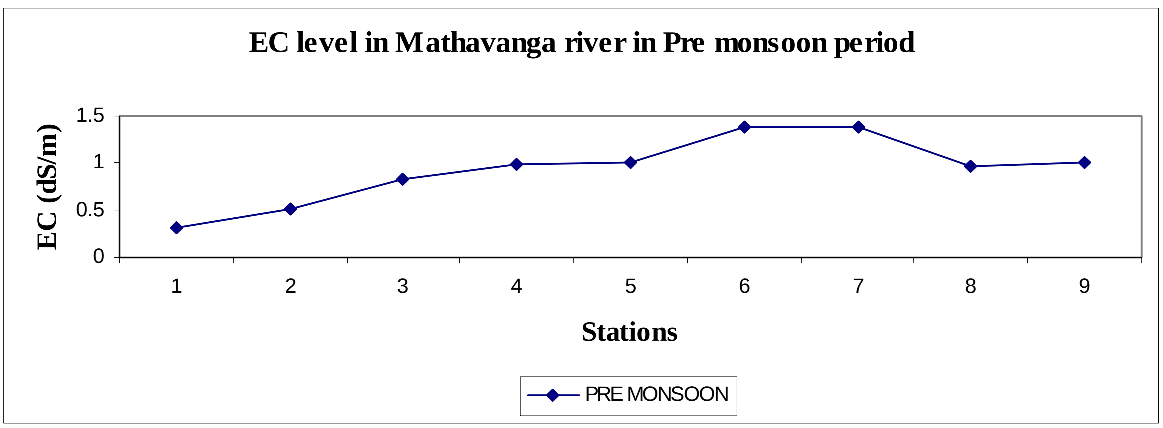

Figure 5.10.3: Graphical representation of EC of Mathavanga River.

(iv) Total Solid

Table 5.10.4 Statistical presentation of Total Solid of Mathavanga River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	1732.13	Not Available	

Table 5.10.4 (Continue)

Std Deviation	2491.00	Not Available	Compared with the standards of suspended and dissolved solids.
Variance	6205058.70	Not Available	
Minimum (mg/l)	483.00	Not Available	
Maximum (mg/l)	7877.00	Not Available	

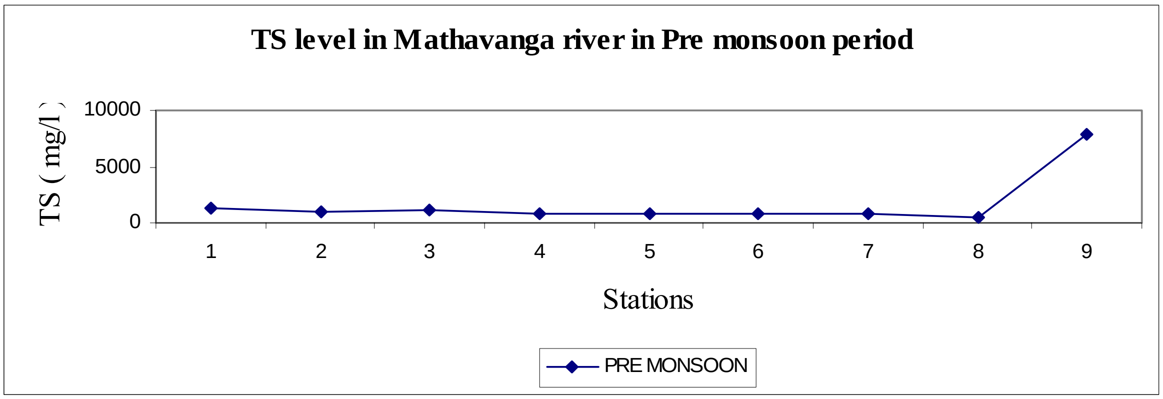

Figure 5.10.4: Graphical representation of TS of Mathavanga River.

(v) Total Dissolved Solid

Table 5.10.5 Statistical presentation of Total Dissolved Solid of Mathavanga River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	660.88	Not Available	Three categories of TDS is specified by FAO for irrigation. None (< 450 mg/l) , Slight to moderate (450-2000 mg/l), Severe (> 2000 mg/l).
Std Deviation	230.48	Not Available	
Variance	53120.41	Not Available	
Min (mg/l)	463.00	Not Available	
Max (mg/l)	1129.00	Not Available	

Source : Ayres and Westcot 1985.

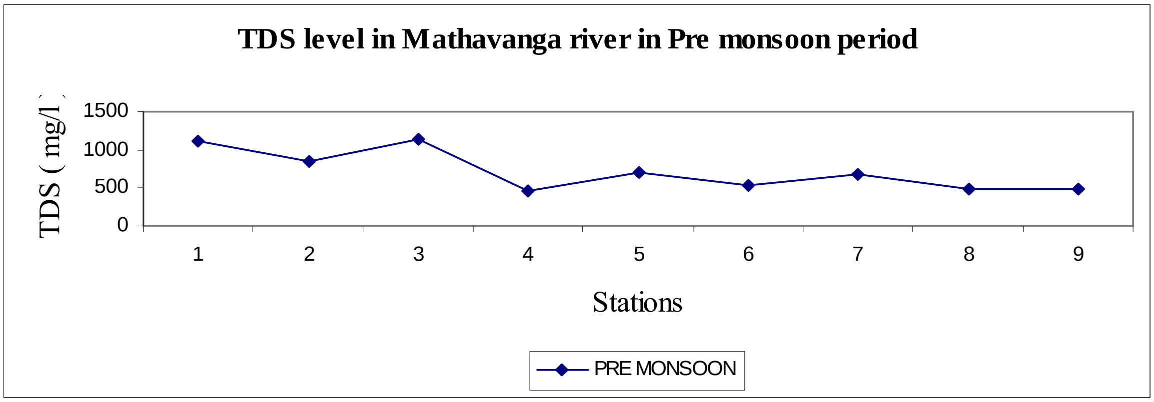

Figure 5.10.5: Graphical representation of TDS of Mathavanga River.

(vi) Suspended Solid

Table 5.10.6 Statistical presentation of Suspended Solid of Mathavanga River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	66.25	Not Available	SS for fish culture is <1500 ppm. For drinking water, allowable concentration (maximum) Bangladesh standard 10 mg/l WHO standard is 10 mg/l.
Std Deviation	38.32	Not Available	
Variance	1468.21	Not Available	
Min (mg/l)	20.00	Not Available	
Max (mg/l)	120.00	Not Available	

Source : ECR 1997.

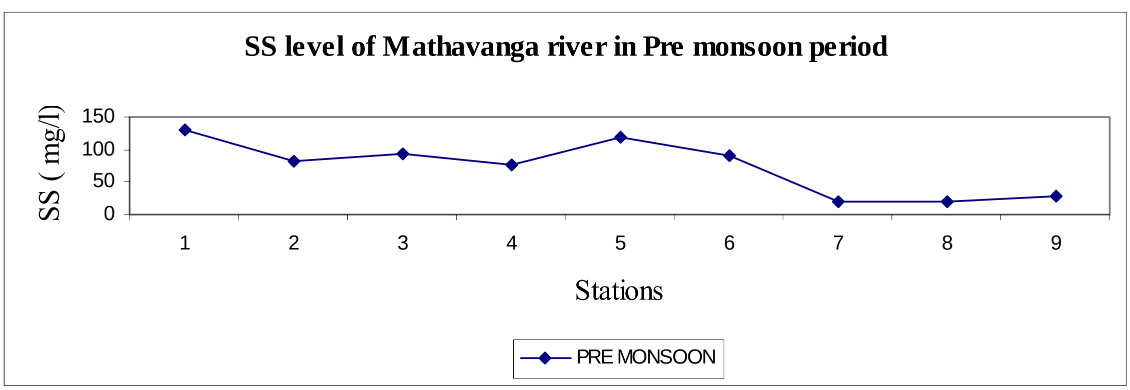

Figure 5.10.6: Graphical representation of SS of Mathavanga River

Some aspects of physical water quality parameters of Mathavanga River for Pre Monsoon period have been presented. The average value of water temperature were 32.17 ^{0}C (Pre Monsoon). Temperature of Mathavanga River water showed that it might be tolerable for aquaculture like Carp fish, Diatoms, Green algae and Blue-green algae.

Turbidity of Mathavanga River water were seen to be 73.61 NTU (Pre Monsoon), SS were 66.25 mg/l (Pre Monsoon) and TDS were 660.88 mg/l (Pre Monsoon) respectively. Turbidity of water mainly caused by silt, clay, waste materials, heavy particles, dumps etc. Turbidity always indicated the amount of various particles present in water which includes both the total dissolved and suspended solids present in water (Onyema, 2007). The value of different physical water quality parameters showed a higher rate in Pre Monsoon period than in Monsoon Period. These values decrease gradually as a result of more surface water flow in the river during monsoon period. Production of fish culture of Mathavanga River is seen to be favorable to produce 94 lb/acre of fish. Water of Mathavanga River is usable for cooling purpose. Mathavanga River water needs to be pretreated before using in beverage industries, food products, boiler, pulp paper industries and tanning leather.

The mean value of EC of Mathavanga River were seen to be 1.01 dS/m (Pre monsoon). That indicates the inorganic mineral content is high. The results of the present study clearly indicate that the water of Mathavanga River was carrying higher value of EC and not suitable for maintaining the normal functioning of aquatic organisms or irrigation and needs to be pretreated before using for drinking and industrial purposes. The standard values of SS and TDS were seen to be 10 mg/L and 1000 mg/L for the inland surface water of Bangladesh (Alam, *et al.,* 2007). After analysis the mean value of SS were 66.25 mg/l (Pre Monsoon) and TDS were 660.88 mg/l (Pre Monsoon). The amount of TDS were considerably high and falls in slight to moderate restriction category suggested by FAO. In Pre Monsoon period TDS is very high. So in Pre Monsoon period Mathavanga River Water needs pre treatment before use. The heavy particles present in the waste materials become settled on the river bottom and the remaining lighter particles are carried out with water in the form of suspended and dissolved forms. Higher amount of various solids present in water have a negative impact on the productivity and maintaining good water quality as these reduce the light penetration in water.

5.10.2 Chemical parameter

There are different chemical properties which can indicate the status of river water quality but for the study properties like P^H, chloride, alkalinity or T-alkalinity, hardness, DO, BOD, COD for Mathavanga River were considered.

(i) P^H

Table 5.10.7 Statistical presentation of P^H of Mathavanga River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean	7.46	Not Available	Optimum P^H for aquaculture Fish eggs could be hatched, but deformed young were often produced between P^H 3.8 - 10 Limit of P^H for resistant fish species is 4-10.1 Range tolerated by trout is P^H 4.1- 9.5 Best range for the growth of algae is P^H 7.5-8.4. Food canning when minimum P^H 7.5 freezing when minimum P^H 7.5 Washing clothes when P^H 6-6.8 Rayon manufacturing when P^H 7.8-8.3 Tanning leather when P^H 6-8
Std Deviation	0.53	Not Available	
Variance	0.28	Not Available	
Minimum	6.50	Not Available	
Maximum	7.90	Not Available	

Source : CWQB, 1963.

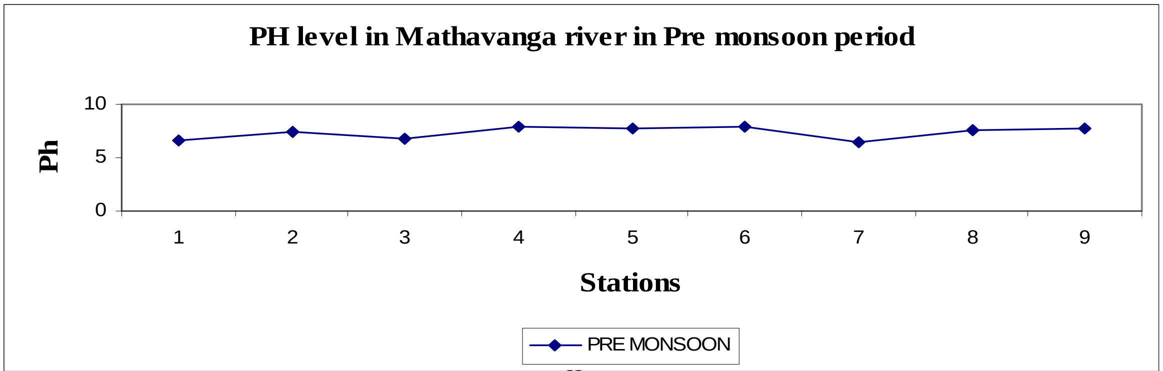

Figure 5.10.7: Graphical representation of P^H of Mathavanga River.

(ix) Chloride content

Table 5.10.8 Statistical presentation of Chloride of Mathavanga River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	77.13	Not Available	Recommended for aquaculture Fish and aquatic life is 0.01 mg/l. Maximum fish can tolerate 0.37 mg/l. Minimum requirement for High-grade paper is 0.3 mg/ For surface irrigation 4-10 mg/l (Slight to moderate), > 10 mg/l (Severe).
Std Deviation	32.91	Not Available	
Variance	1083.27	Not Available	
Minimum (mg/l)	12.00	Not Available	
Maximum (mg/l)	110.00	Not Available	

Source : EPA, 1976

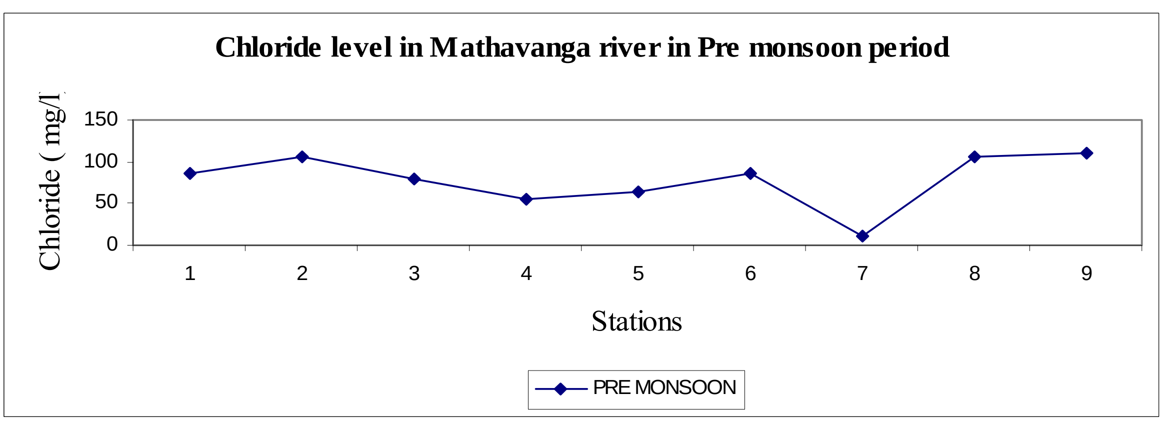

Figure 5.10.8: Graphical representation of Chloride content of Mathavanga River.

(iii) T- Alkalinity

Table 5.10.9 Statistical presentation of T-Alkalinity of Mathavanga River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	37.88	Not Available	Recommended max alkalinity for, Carbonated beverages 85 mg/l
Std Deviation	5.59	Not Available	Food products (canning) 300 mg/l
Variance	31.27	Not Available	Fruit juice 100 mg/l Pulp and paper making 50 mg/l
Minimum (mg/l)	30.00	Not Available	Textile mill products 50-200 mg/l Rayon manufacture 50 mg/l
Maximum (mg/l)	45.00	Not Available	Limit for fish culture is 50-400 mg/l

Source: (i) CWQB, 1963.

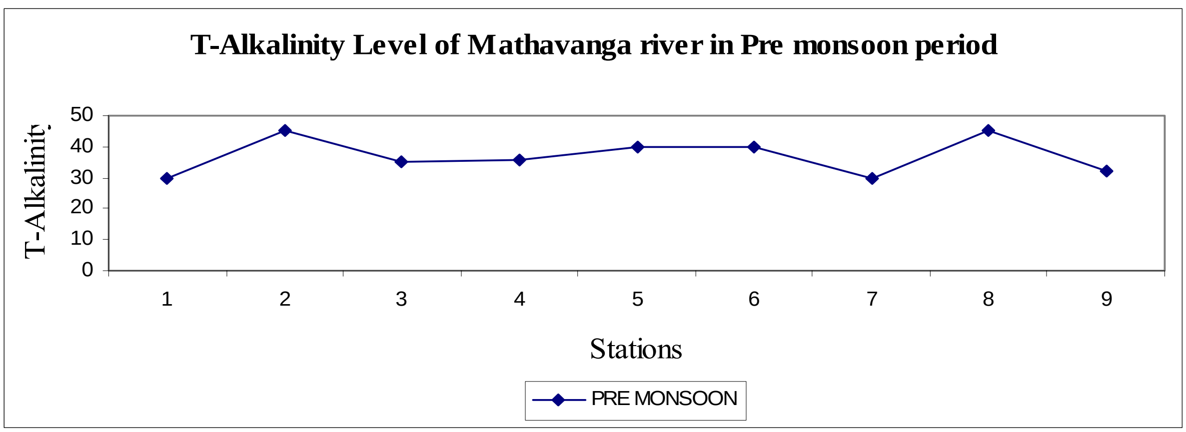

Figure 5.10.9: Graphical representation of T-Alkalinity of Mathavanga River.

(iv) Dissolved Oxygen

Table 5.10.10 Statistical presentation of Dissolved Oxygen of Mathavanga River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	4.95	Not Available	

Table 5.10.10 (Continue)

Std Deviation	0.93	Not Available	Usable for Irrigation when ≥ 5 mg/l. Fisheries when ≥ 5 mg/l. Recreational activity ≥ 5 mg/l Drinking purpose when ≥ 6 mg/l after disinfection. Cooling industries when ≥ 5 mg/l.
Variance	0.86	Not Available	
Minimum (mg/l)	3.80	Not Available	
Maximum (mg/l)	6.00	Not Available	

Source: ECR 1997.

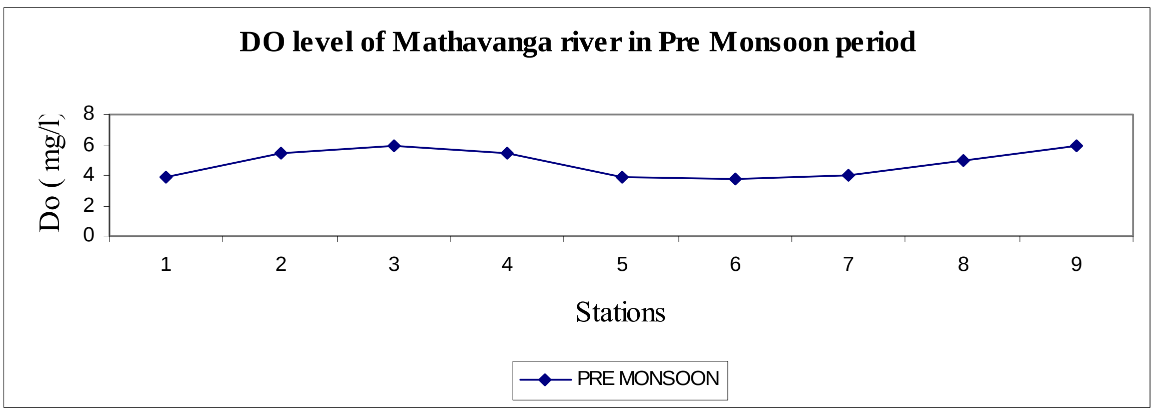

Figure 5.10.10: Graphical representation of DO of Mathavanga River.

(i) BOD

Table 5.10.11 Statistical presentation of BOD of Mathavanga River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	144.03	Not Available	Usable for Irrigation when ≤ 2mg/l. Fisheries when ≤ 6mg/l. Recreational activity ≤ 3mg/l. Drinking purpose ≤ 2mg/l after disinfection.
Std Deviation	152.08	Not Available	
Variance	23127.73	Not Available	
Min (mg/l)	1.20	Not Available	

Table 5.10.11 (Continue)

Max (mg/l)	290.00	Not Available	Cooling industries	≤ 10mg/l.

Source : ECR 1997

(vi) COD

Table 5.10.12: Statistical presentation of COD of Mathavanga River

Statistics	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	1595.00	Not Available	Usable for bathing purpose when COD is 180-270 mg/l .
Std Deviation	1571.54	Not Available	
Variance	2469742.86	Not Available	
Min (mg/l)	30.00	Not Available	
Max (mg/l)	4800.00	Not Available	

Source : Wintgens *et al.*, 2005

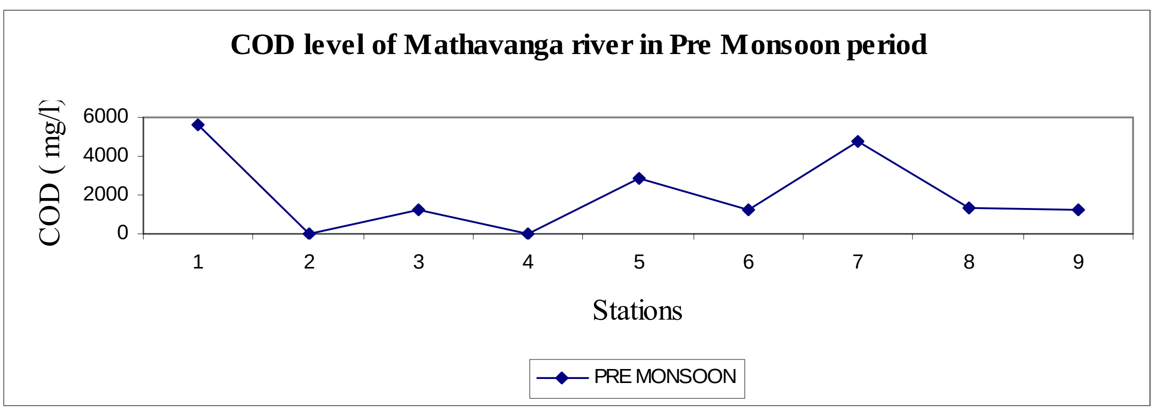

Figure 5.10.12: Graphical representation of COD of Mathavanga River at different sampling station.

The mean values of the various chemical parameters of the Mathavanga River water are presented. The mean value of water pH at different stations of the river was found as 7.46 (Pre Monsoon). The value of pH was normal compared with the standard level as the optimum value of water pH is 6.5-8.5 or around 7 for the drinking purpose. as well as aquatic organisms and the tolerable range is between 6 and 8.5 (ECR 1997). The P^H value of Mathavanga River water is also fit for fish culture and algae growth as well as industrial and manufacturing processes like Food canning, freezing, Rayon manufacturing and Tanning leather. But this water needs to be pretreated in case of washing clothes.

The mean values of dissolve oxygen (DO) were 4.95 mg/l (Pre Monsoon) at various stations throughout the experimental period. Sampling result at the pre monsoon revealed that the values of DO were slightly low. Mathavanga River water will be fit for Irrigation, fish culture, recreational activity and Cooling industries after pretreatment. This water needs also to be pretreated for drinking purpose after disinfection. DO is very important for identifying a suitable aquatic body and also to estimate productivity of an aquatic system (Romesh and Anbu, 1996; Davies, *et al.*, 2008). The low oxygen of this river water was due to the excess dumping (domestic and urban sewage, industrial effluents, agricultural wastes etc.). The major effect of sewage in water is that it reduces oxygen content of water as the organic matter content of sewage is higher (Ragothaman and Trivedy, 2002). The mean value of biochemical oxygen demand (BOD) are 144.03 mg/l (Pre Monsoon) and chemical oxygen demand (COD) at different sampling stations were 1595.00 mg/l (Pre Monsoon) respectively. BOD and COD levels were observed higher at the Pre monsoon period. A standard value of COD for drinking purposes is 4 mg/L and For bathing is 180-270 mg/L while in the case of biochemical oxygen demand (BOD), standard for drinking purpose is 0.2mg/L, sewage effluent 20 mg/L (Wintgens *et al*, 2005; Jalil and Njiru, 2010). Oxygen being the basic requirement of almost all plant and animal life, its presence in sufficient quantities is important to support and sustain life. All organic matters undergo biodegradation and exhibit a biochemical oxygen demand (BOD) or a chemical oxygen demand (COD) as oxygen is required for their degradation (Khatri, 1984). The typical sources include sewage from domestic and animal source, industrial wastes, natural decaying vegetation, decay of dead plants and animals. This type of water pollution becomes a severe problem when the oxygen required for biodegradation or chemical oxidation is greater than the available oxygen in the ecosystem. The estimation of BOD gives an indication of the amount of pollution in a body of water. The high amount of BOD indicates large bacterial and fungal population. Owing to metabolic activities of these organisms, the dissolved oxygen gets reduced and the area is found without oxygen. Aquatic organisms such as fishes either evade this area or be killed (Khatri, 1985). After above analysis we found that Mathavanga River water may not suitable for irrigation, fish culture, recreational activities, drinking purpose and cooling purpose in industries (in pre monsoon period).

5.11 Parameterization of water quality parameter of Mamundo River

5.11.1 Physical parameter

Among all physical properties the concern of these study was focused on Physical parameters such as temperature, turbidity, conductivity or electric conductivity, suspended solid, total dissolved solid, total solid for Mamundo River.

(i) Temperature

Table 5.11.1: Statistical presentation of Temperature of Mamundo River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (^{0}C)	Not Available	27.50	Optimum Temp for Carp fish is 32 ^{0}C Diatoms grow best at 15-25 ^{o}C, Green algae grow best at 25-35 ^{o}C, Blue-green algae at 30-40 ^{o}C.
Std Deviation	Not Available	0.71	
Variance	Not Available	0.50	
Minimum (^{0}C)	Not Available	27.00	
Maximum (^{0}C)	Not Available	28.00	

Source: (i) CWQB, 1963. (ii) EPA, 1976.

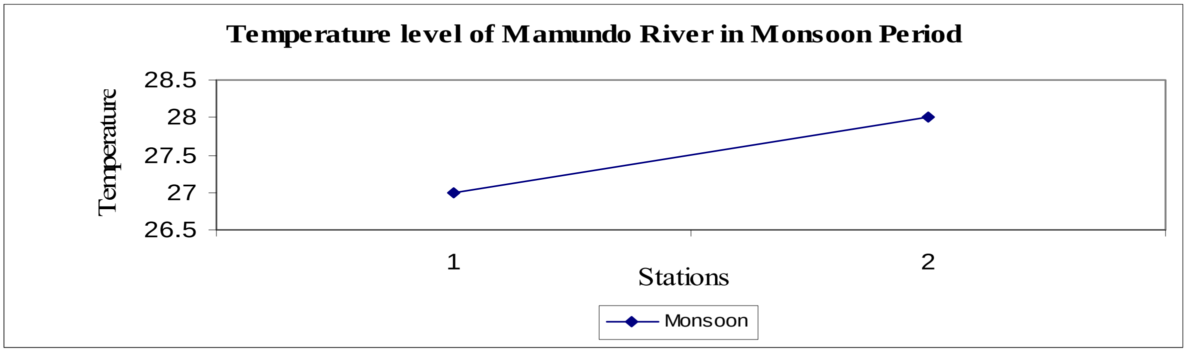

Figure 5.11.1: Graphical representation of temperature of Mamundo River.

(ii) Turbidity

Table 5.11.2: Statistical presentation of Turbidity of Mamundo River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (NTU)	Not Available	77.25	Amount of fish 162 lb/ acre for 25 NTU, 94 lb/ acre for 25 -100 NTU, 29 lb/ acre for over 100 NTU. Beverages if turbidity is 1-2 NTU Food products for 10 NTU Water used in boilers for 1-20 NTU High grade paper for 5-25 NTU Water used for cooling for 50 NTU. Tanning leather for 20 NTU
Std Deviation	Not Available	1.77	
Variance	Not Available	3.13	
Min (NTU)	Not Available	76.00	
Max (NTU)	Not Available	78.50	

Source: CWQB, 1963.

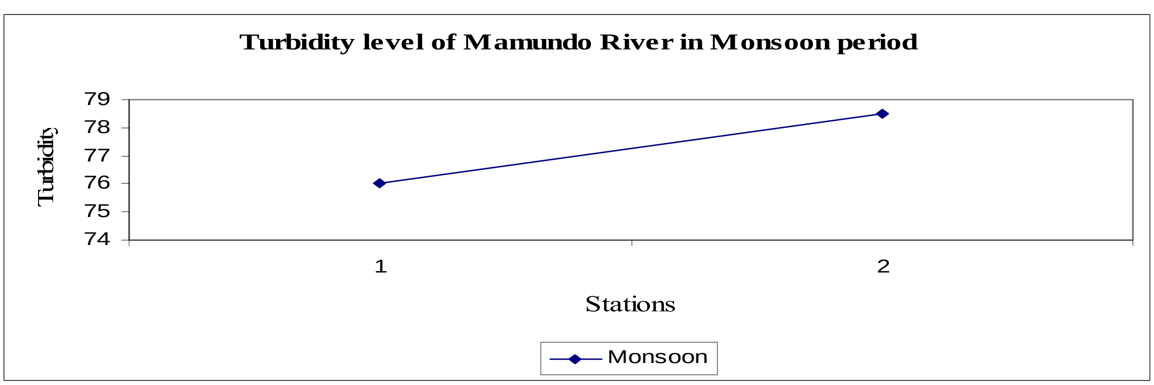

Figure 5.11.2: Graphical representation of Turbidity of Mamundo River.

(iii) Electric Conductivity

Table 5.11.3: Statistical presentation of Electric Conductivity of Mamundo River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (dS/m)	Not Available	29.37	Three categories of EC is specified by FAO for irrigation. None (<0.7 dS/m) , Slight to moderate (0.7 to 3.0 dS/m), Severe (> 3.0 dS/m).
Std Deviation	Not Available	0.80	
Variance	Not Available	0.64	
Min (dS/m)	Not Available	28.80	
Max (dS/m)	Not Available	29.93	

Source : Ayres and Westcot 1985.

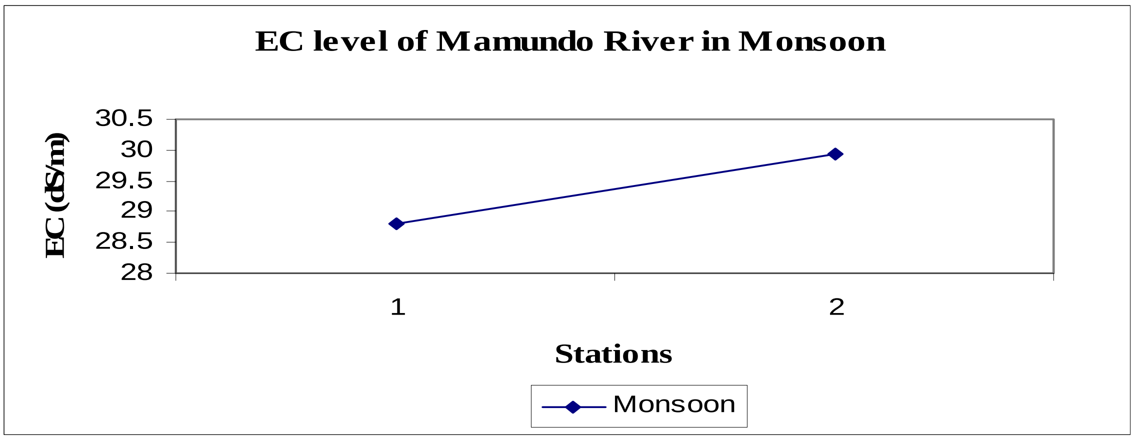

Figure 5.11.3: Graphical representation of EC of Mamundo River.

(iv) Total Solid

Table 5.11.4 Statistical presentation of Total Solid of Mamundo River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	0.00	16505.00	Compared with the standards of suspended and dissolved solids.
Std Deviation	0.00	1845.55	

Table 5.11.4 (Continue)

Variance	0.00	3406050.00	
Minimum (mg/l)	0.00	15200.00	
Maximum (mg/l)	0.00	17810.00	

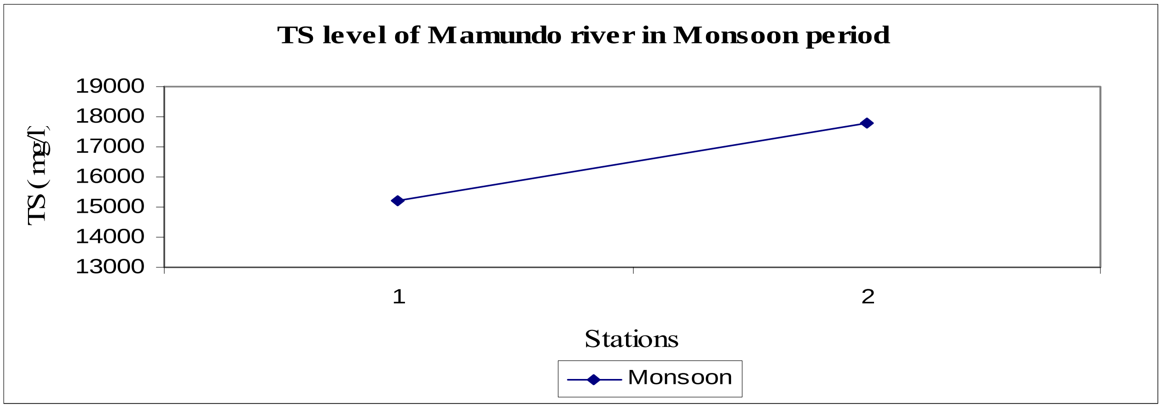

Figure 5.11.4: Graphical representation of TS of Mamundo River.

(v) Total Dissolved Solid

Table 5.11.5 Statistical presentation of Total Dissolved Solid of Mamundo River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	16399.50	Three categories of TDS is specified by FAO for irrigation. None (< 450 mg/l) Slight to moderate (450-2000 mg/l), Severe (> 2000 mg/l).
Std Deviation	Not Available	1837.77	
Variance	Not Available	3377400.50	
Minimum (mg/l)	Not Available	15100.00	
Maximum (mg/l)	Not Available	17699.00	

Source : Ayres and Westcot 1985.

(vi) Suspended Solid

Table 5.11.6 Statistical presentation of Suspended Solid of Mamundo River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	105.50	SS for fish culture is <1500 ppm.
Std Deviation	Not Available	7.78	For drinking water, allowable
Variance	Not Available	60.50	concentration (maximum)
Min (mg/l)	Not Available	100.00	Bangladesh standard 10 mg/l
Max (mg/l)	Not Available	111.00	WHO standard is 10 mg/l.

Source : ECR 1997.

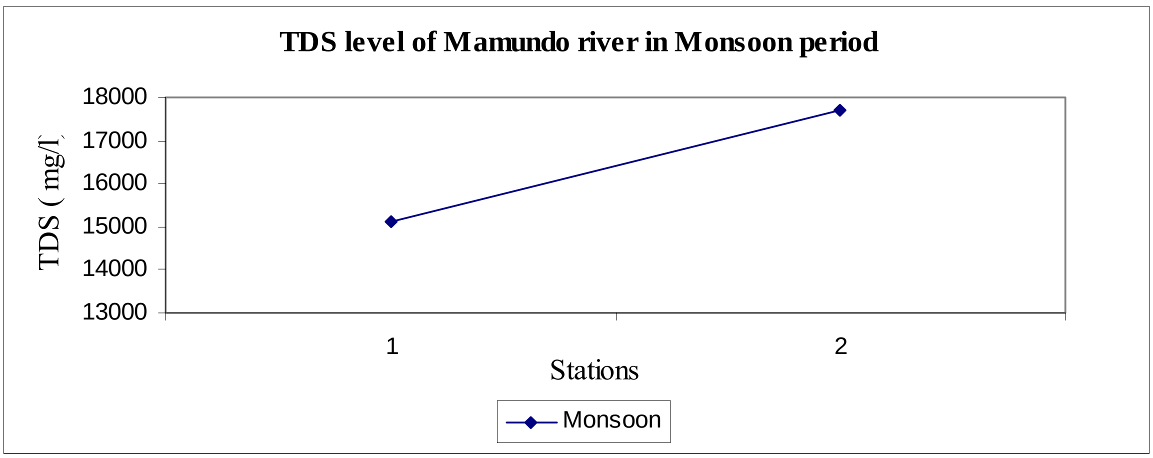

Figure 5.11.5: Graphical representation of TDS of Mamundo River.

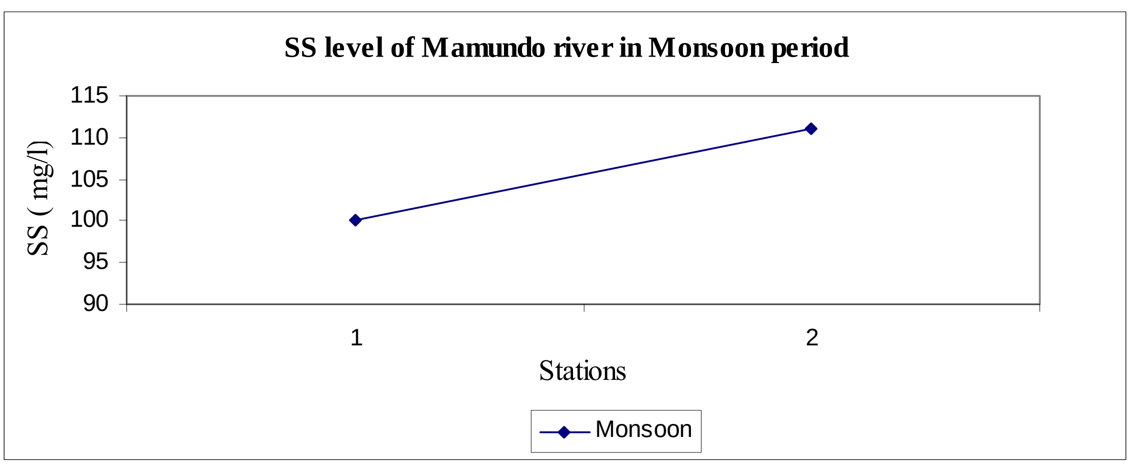

Figure 5.11.6: Graphical representation of SS of Mamundo River.

Some aspects of physical water quality parameters of Mamundo River for Pre Monsoon and Monsoon period have been presented. The average value of water temperature was 27.50 ^{0}C (Monsoon), Temperature of Mamundo River water showed that it might be tolerable for aquaculture like Carp fish, Diatoms, Green algae and Blue-green algae. Turbidity of Mamundo River water were seen to be 77.25 NTU (Monsoon), SS were 105.50 mg/l (Monsoon) and TDS was 16399.50 mg/l (Monsoon) respectively. Turbidity of water mainly caused by silt, clay, waste materials, heavy particles, dumps etc. Turbidity always indicated the amount of various particles present in water which includes both the total dissolved and suspended solids present in water (Onyema, 2007).. Production of fish culture of Mamundo River is seen to be favorable to produce 94 lb/acre of fish. Water of Mamundo River is usable for cooling purpose. Mamundo River water needs to be pretreated before using in beverage industries, food products, boiler, pulp paper industries and tanning leather.

The mean value of EC of Mamundo River were seen to be 29.37 dS/m (Monsoon). That indicates the inorganic mineral content is high. The results of the present study clearly indicate that the water of Mamundo River was carrying higher value of EC and not suitable for maintaining the normal functioning of aquatic organisms or irrigation and needs to be pretreated before using for drinking and industrial purposes. The standard values of SS and TDS were seen to be 10 mg/L and 1000 mg/L for the inland surface water of Bangladesh (Alam, *et al.,* 2007). After analysis the mean value of SS were 105.50 mg/l (Monsoon) and TDS was 16399.50 mg/l (Monsoon) respectively. The amount of TDS were considerably high and falls in severe restriction category suggested by FAO . In Monsoon period Mamundo River Water needs pre treatment before use. The heavy particles present in the waste materials become settled on the river bottom and the remaining lighter particles are carried out with water in the form of suspended and dissolved forms. Higher amount of various solids present in water have a negative impact on the productivity and maintaining good water quality as these reduce the light penetration in water.

5.11.2 Chemical parameter

There are different chemical properties which can indicate the status of river water quality but for the study properties like P^H, chloride, alkalinity or T-alkalinity, hardness, DO, BOD, COD for Mamundo River were considered.

(i) P^H

Table 5.11.7 Statistical presentation of P^H of Mamundo River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean	Not Available	7.67	Optimum P^H for aquaculture Fish eggs could be hatched, but deformed young were often produced between P^H 3.8 - 10
Std Deviation	Not Available	0.05	Limit of P^H for resistant fish species is 4-10.1 Range tolerated by trout is P^H 4.1- 9.5
Variance	Not Available	0.00	Best range for the growth of algae is P^H 7.5-8.4. Food canning when minimum P^H 7.5
Minimum	Not Available	7.63	Freezing when minimum P^H 7.5 Washing clothes when P^H 6-6.8
Maximum	Not Available	7.70	Rayon manufacturing when P^H 7.8-8.3 Tanning leather when P^H 6-8

Source : CWQB, 1963.

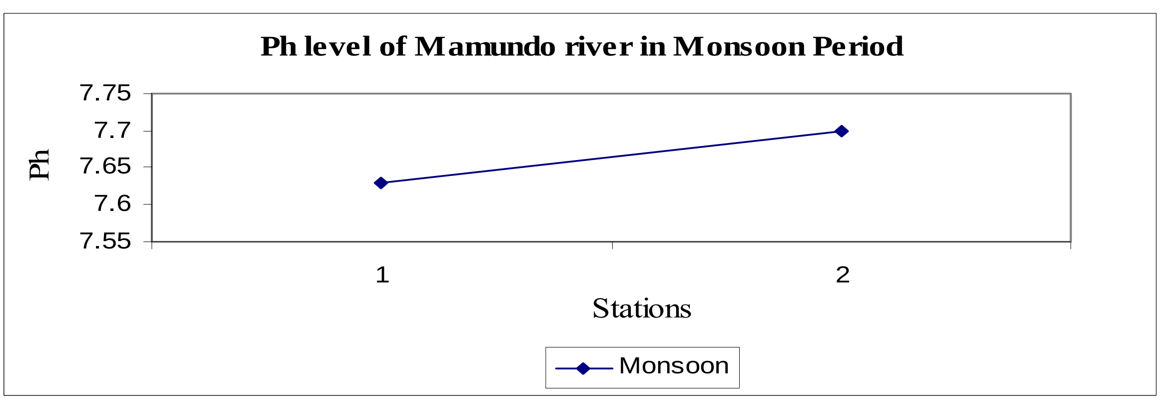

Figure 5.11.7: Graphical representation of PH of Mamundo River.

(ii) Chloride content

Table 5.11.8 Statistical presentation of Chloride of Mamundo River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	6305.00	Recommended for aquaculture Fish and aquatic life is 0.01 mg/l. Maximum fish can tolerate 0.37 mg/l. Minimum requirement for High-grade paper is 0.3 mg/ For surface irrigation 4-10 mg/l (Slight to moderate), > 10 mg/l (Severe).
Std Deviation	Not Available	289.91	
Variance	Not Available	84050.00	
Minimum (mg/l)	Not Available	6100.00	
Maximum (mg/l)	Not Available	6510.00	

Source : EPA, 1976.

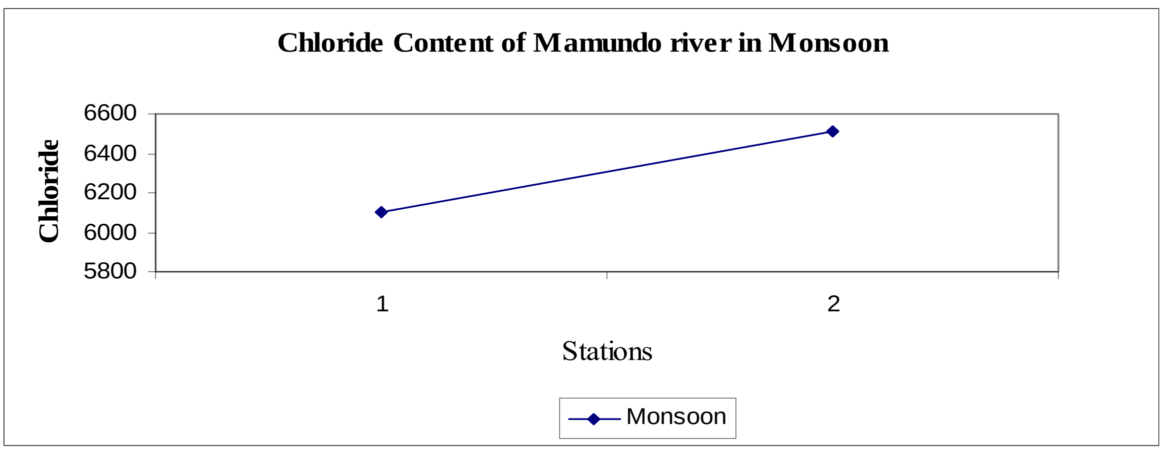

Figure 5.11.8: Graphical representation of Chloride content of Mamundo River.

(iii) T- Alkalinity

Table 5.11.9 Statistical presentation of T-Alkalinity of Mamundo River

Statistical Parameters	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	37.00	Recommended max alkalinity for,
Std Deviation	Not Available	1.41	

Table 5.11.9 (Continue)

Variance	Not Available	2.00	Carbonated beverages 85 mg/l Food products (canning) 300 mg/l Fruit juice 100 mg/l Pulp and paper making 50 mg/l Textile mill products 50-200 mg/l Rayon manufacture 50 mg/l Limit for fish culture is 50-400 mg/l
Minimum (mg/l)	Not Available	36.00	
Maximum (mg/l)	Not Available	38.00	

Source: (i) CWQB, 1963.

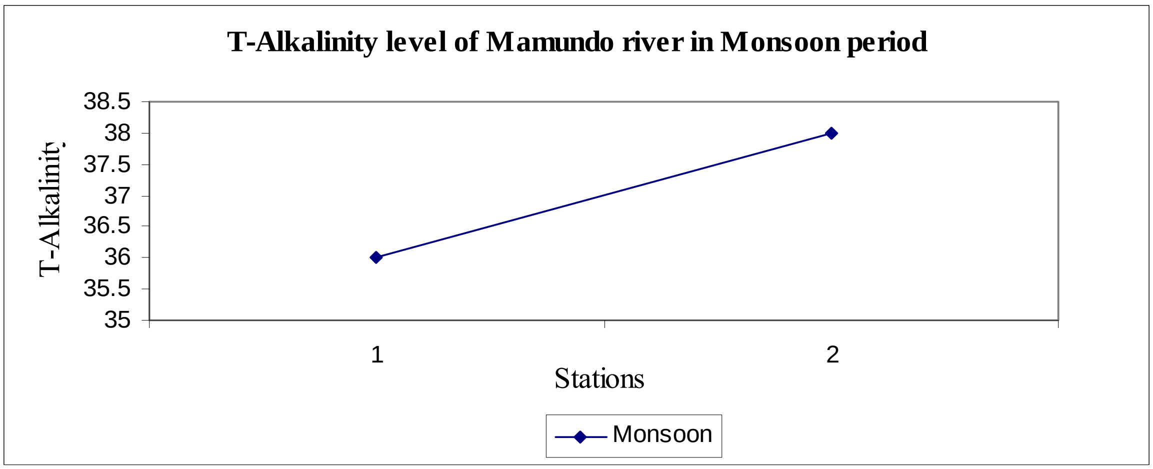

Figure 5.11.9: Graphical representation of T-Alkalinity of Mamundo River.

(iv) Dissolved Oxygen

Table 5.11.10 Statistical presentation of Dissolved Oxygen of Mamundo River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean (mg/l)	Not Available	4.05	Usable for Irrigation when ≥ 5 mg/l. Fisheries when ≥ 5 mg/l. Recreational activity ≥ 5 mg/l Drinking purpose when ≥ 6 mg/l Cooling industries when ≥ 5 mg/l
Std Deviation	Not Available	0.07	
Variance	Not Available	0.01	
Minimum (mg/l)	Not Available	4.00	
Maximum (mg/l)	Not Available	4.10	

Source: ECR 1997.

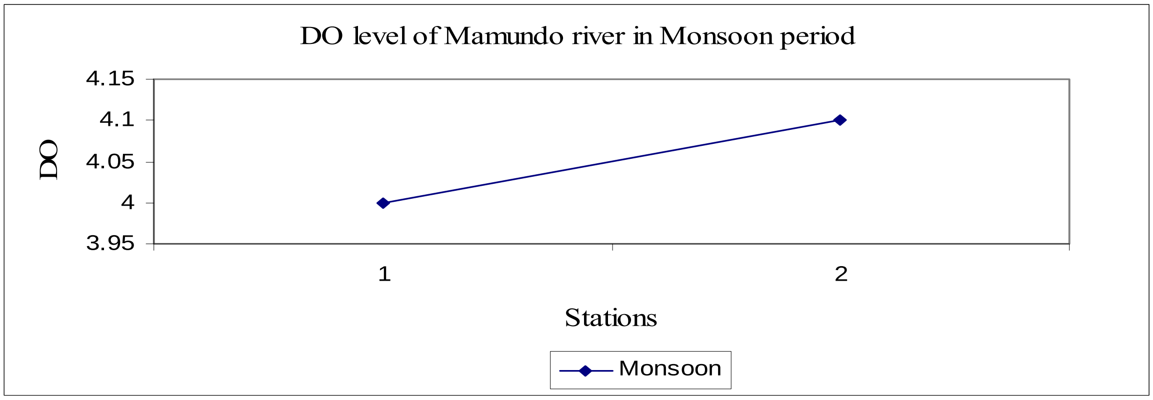

Figure 5.11.10: Graphical representation of DO of Mamundo River.

(v) BOD

Table 5.11.11 Statistical presentation of BOD of Mamundo River

Statistical Parameters	**Pre-Monsoon**	**Monsoon**	**Remark**
Mean ((mg/l)	Not Available	1.28	Irrigation when ≤ 2mg/l.
Std Deviation	Not Available	0.04	Fisheries when ≤ 6mg/l.
Variance	Not Available	0.00	Recreational activity ≤ 3mg/l.
Min (mg/l)	Not Available	1.25	Drinking purpose ≤ 2mg/l
Max (mg/l)	Not Available	1.30	Cooling industries ≤ 10mg/l.

Source : ECR 1997

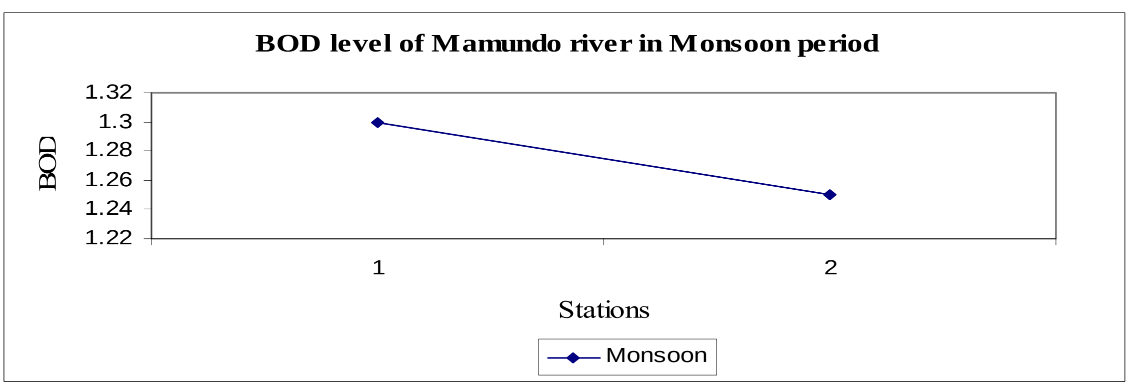

Figure 5.11.11: Graphical representation of BOD of Mamundo River.

(vi) COD

Table 5.11.12: Statistical presentation of COD of Mamundo River

Statistics	Pre-Monsoon	Monsoon	Remark
Mean (mg/l)	Not Available	1089.00	Usable for bathing purpose when COD is 180-270 mg/l .
Std Deviation	Not Available	29.70	
Variance	Not Available	882.00	
Min (mg/l)	Not Available	1068.00	
Max(mg/l)	Not Available	1110.00	

Source : Wintgens *et al.*, 2005

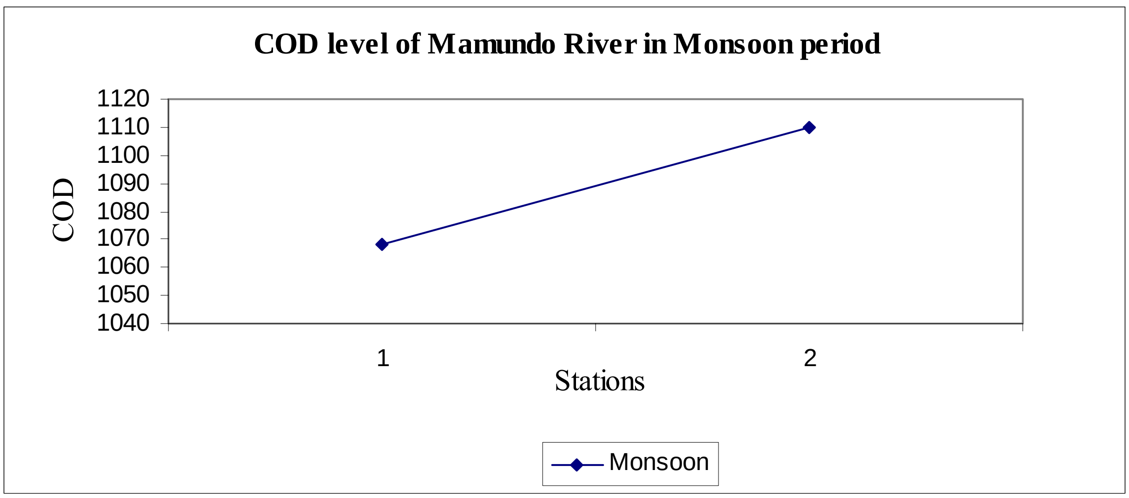

Figure 5.11.12: Graphical representation of COD of Mamundo River at different sampling station.

The mean values of the various chemical parameters of the Mamundo River water are presented. The mean value of water pH at different stations of the river was found as 7.67 (Monsoon). The value of pH was normal compared with the standard level as the optimum value of water pH is 6.5-8.5 or around 7 for the drinking purpose and as well as aquatic organisms and the tolerable range is between 6 and 8.5 (ECR 1997). The pH value of Mamundo River water is also fit for fish culture and algae growth as well as industrial and manufacturing processes like Food canning, freezing, Rayon manufacturing, tanning leather and washing clothes.

The mean values of dissolve oxygen (DO) were 4.05 mg/l (Monsoon) at various stations throughout the experimental period. Sampling result at the pre monsoon revealed that the values of DO were slightly low. Mamundo River water will be fit for Irrigation, fish culture, recreational activity and Cooling industries after pretreatment. This water needs also to be pretreated for drinking purpose after disinfection. DO is very important for identifying a suitable aquatic body and also to estimate productivity of an aquatic system (Romesh and Anbu, 1996; Davies, *et al.*, 2008). The low oxygen of this river water was due to the excess dumping (domestic and urban sewage, industrial effluents, agricultural wastes etc.). The major effect of sewage in water is that it reduces oxygen content of water as the organic matter content of sewage is higher (Ragothaman and Trivedy, 2002). The mean value of biochemical oxygen demand (BOD) are 1.28 mg/l (Monsoon) and chemical oxygen demand (COD) at different sampling stations were 1089.00 mg/l (Monsoon) respectively. BOD and COD levels were observed higher at the Pre monsoon period. A standard value of COD for drinking purposes is 4 mg/L and For bathing is 180-270 mg/L while in the case of biochemical oxygen demand (BOD), standard for drinking purpose is 0.2mg/L, sewage effluent 20 mg/L (Wintgens *et al*, 2005; Jalil and Njiru, 2010). Oxygen being the basic requirement of almost all plant and animal life, its presence in sufficient quantities is important to support and sustain life. All organic matters undergo biodegradation and exhibit a biochemical oxygen demand (BOD) or a chemical oxygen demand (COD) as oxygen is required for their degradation (Khatri, 1984). The typical sources include sewage from domestic and animal source, industrial wastes, natural decaying vegetation, decay of dead plants and animals. This type of water pollution becomes a severe problem when the oxygen required for biodegradation or chemical oxidation is greater than the available oxygen in the ecosystem. The estimation of BOD gives an indication of the amount of pollution in a body of water. The high amount of BOD indicates large bacterial and fungal population. Owing to metabolic activities of these organisms, the dissolved oxygen gets reduced and the area is found without oxygen. Aquatic organisms such as fishes either evade this area or be killed

(Khatri, 1985). After above analysis we found that Mamundo River water is suitable for irrigation, fish culture, recreational activities, drinking purpose and cooling purpose in industries (in pre monsoon period).

5.12 Summary

In this chapter all the secondary data had been analyzed discussed and results has been presented both in tabulated form and in graphical form along with the findings on nine rivers of southern region of Bangladesh. Chemical analysis was done by DoE written in Chapter-3 and statistical analysis was done by Microsoft Excel in Windows XP 2007 platform. Using this raw data further steps had been taken.

Chapter 6

CONCLUSION AND RECOMMENDATION

6.1 General

This chapter highlights the overall conclusions and recommendations for the existing water quality in the southern region of Bangladesh. This gives an overall idea about suitability about uses of water in agriculture, industries and comparison with the standard.

6.2 Conclusions

Different aspects of water quality parameters of some selected rivers of southern region of Bangladesh were determined and compared with Industrial standard in present study. Some of these rivers are used as the dumping site of wastage and industrial effluent of Khulna division. For this reason the environment of the river degraded day by day. Environmental degradation of river water in Pre monsoon period is very high than in the Monsoon period. However some conclusions can be drawn based on present study and are recommended as follows:

i. Because of high turbidity in both Pre-monsoon and Monsoon period of Bhairab, Gorai, Rupsha, Pashur, Mouri River water may need a certain degree of treatment before using in food products, boiler, pulp paper industries, tanning leather and beverage industries.

ii. Because of high turbidity of Kakshially (Monsoon), Kopotakhkho (Monsoon), Mamundo (Monsoon) river water and Mathavanga (Pre-monsoon) river water may need a certain degree of treatment before using in food products, boiler, pulp paper industries, tanning leather and beverage industries.

iii. Data of turbidity of Kakshially (Pre-monsoon), Kopotakhkho (Pre-monsoon), Mamundo (Pre-monsoon) river was not available. And data of turbidity of Mathavanga (Monsoon) river was not available

iv. Because of high turbidity of Bhairab, Gorai, Rupsha, Pashur, Kakshially, Mouri, Kopotakhkho, Mathavanga, Mamundo River water may be able to produce fish culture 94 lb/ acre in above mentioned period.

v. Depending on EC in case of Pre-monsoon period, the according to the restriction category for using water in agricultural purpose suggested by FAO

- The water of Bhairab (Pre-monsoon) and Rupsha (Pre- monsoon) falls in Severe category.
- The water of Pashur (Pre-monsoon), Mouri (Pre-monsoon) and Mathavanga (Pre-monsoon) falls into Slight to Moderate category.
- The water of Gorai river (Pre-monsoon) falls into None category.

vi. Depending on EC in case of Monsoon period, according to the restriction category for using water in agricultural purpose suggested by FAO

- The water of Bhairab (Monsoon), Rupsha (Monsoon), Gorai (Monsoon), Mouri (Monsoon) falls in None category.
- The water of Pashur (Monsoon), Kakshially (Monsoon) falls into Slight to Moderate category.
- The water of Kopotakhkho (Monsoon), Mamundo (Monsoon) river water falls into None category.

vii. Data of EC of Kakshially (Pre-monsoon), Kopotakhkho (Pre-monsoon), Mamundo (Pre-monsoon) river was not available. And data of EC of Mathavanga (Monsoon) river was not available

viii. Depending on TDS in case of Pre-monsoon period, according to the restriction category for using water in agricultural purpose suggested by FAO

- The water of Bhairab (Pre-monsoon) and Rupsha (Pre- monsoon) falls in Severe category.

- The water of Gorai (Pre-monsoon), Pashur (Pre-monsoon), Mouri (Pre-monsoon) and Mathavanga (Pre-monsoon) falls into Slight to Moderate category.

ix. Depending on TDS in case of Monsoon period, according to the restriction category for using water in agricultural purpose suggested by FAO

- The water of Bhairab (Monsoon), Rupsha (Monsoon), Gorai (Monsoon), Mouri (Monsoon) falls in None category.
- The water of Pashur (Monsoon), Kakshially (Monsoon) falls into Slight to Moderate category.
- The water of Kopotakhkho (Monsoon), Mamundo (Monsoon) river water falls into Severe category.

x. Data of TDS of Kakshially (Pre-monsoon), Kopotakhkho (Pre-monsoon), Mamundo (Pre-monsoon) river was not available. And data of TDS of Mathavanga (Monsoon) river was not available

xi. Mouri River water may not fit for Irrigation, fish culture and recreational activity due to lower value of DO

6.3 Recommendations

The study was conducted on a limited scale in a selected location. Monitoring of large number of locations with large number of sampling stations and adequate financial support may represent in actual condition of the surface water degradation of southern region of Bangladesh. However the following recommendation will help to reduce degradation of surface water in southern region of Bangladesh,

1. Public awareness concerning natural water management, water quality criteria, effect of waste water in sustainable development.
2. Regular practice of wastewater treatment before discharging it to the receiving water bodies should be ensured first.
3. In a selected industrial zone where, large number of industries is situated can develop a combined wastewater treatment plant to minimize the treatment cost.

4. Water loss or wastage must be minimized at house hold and industry level and waste water recycling process should be implemented to reduce demand for water.
5. Last but not the least there should be a continuous monitoring, at strategic points, at regular intervals to quantitatively determine the pollution load.

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Appendix – A

CATEGORY OF INDUSTRIES

(a) Types of industries under Green category:

1. Assembling and manufacturing of TV, Radio, etc.
2. Assembling and manufacturing of clocks and watches.
3. Assembling of telephones.
4. Assembling and manufacturing of toys (plastic made items excluded).
5. Book-binding.
6. Rope and mats (made of cotton, jute and artificial fibers).
7. Photography (movie and x-ray excluded).
8. Production of artificial leather goods.
9. Assembling of motorcycles, bicycles and toy cycles.
10. Assembling of scientific and mathematical instruments (excluding manufacturing).
11. Musical instruments.
12. Sports goods (excluding plastic made items).
13. Tea packaging (excluding processing).
14. Re-packing of milk powder (excluding production).
15. Bamboo and cane goods.
16. Artificial flower (excluding plastic made items).
17. Pen and ball-pen.
18. Gold ornaments (excluding production) (shops only).
19. Candle.
20. Medical and surgical instrument (excluding production).
21. Factory for production of cork items (excluding metalic items).
22. Laundry (excluding washing).

(b) Types of industries under Orange – A category :

1. Dairy Farm, 10 (ten) cattle heads or below in urban areas and 25 cattle heads or below in rural areas.
2. Poultry (up to 250 in urban areas and up to 1000 in rural areas).
3. Grinding/husking of wheat, rice, turmeric, pepper, pulses (up to 20 Horse Power).
4. Weaving and handloom.
5. Production of shoes and leather goods (capital up to 5 hundred thousand Taka).
6. Saw mill/wood sawing.
7. Furniture of wood/iron, aluminum, etc.,(capital up to 5 hundred thousand Taka).
8. Printing Press.
9. Plastic & rubber goods (excluding PVC).
10. Restaurant.
11. Cartoon/box manufacturing/printing packaging.
12. Cinema Hall.
13. Dry-cleaning.
14. Production of artificial leather goods (capital up to 5 hundred thousand Taka).
15. Sports goods.
16. Production of salt (capital up to 10 hundred thousand Taka).
17. Agricultural machinery and equipment.
18. Industrial machinery and equipment.
19. Production of gold ornaments.
20. Pin, U Pin.
21. Frames of spectacles.
22. Comb.
23. Production of utensils and souvenirs of brass and bronze.
24. Factory for production of biscuit and bread (capital up to 5 hundred thousand Taka).

25. Factory for production of chocolate and lozenge. (capital up to 5 hundred thousand Taka).
26. Manufacturing of wooden water vessels.

(b) Types of industries under Orange – B category :

1. PVC items.
2. Artificial fiber (raw material).
3. Glass factory.
4. Life saving drug (applicable to formulation only).
5. Edible oil.
6. Tar.
7. Jute mill.
8. Hotel, multi-storied commercial & apartment building.
9. Casting.
10. Aluminum products.
11. Glue (excluding animal glue).
12. Bricks/tiles.
13. Lime.
14. Plastic products.
15. Processing and bottling of drinking water and carbonated drinks.
16. Galvanizing.
17. Perfumes, cosmetics.
18. Flour (large).
19. Carbon rod.
20. Stone grinding, cutting, polishing.
21. Processing fish, meat, food.
22. Printing and writing ink.
23. Animal feed.
24. Ice-cream.

25. Clinic and pathological lab.
26. Utensils made of clay and china clay/sanitary wares (ceramics).
27. Processing of prawns & shrimps.
28. Water purification plant.
29. Metal utensils/spoons etc.
30. Sodium silicate.
31. Matches.
32. Starch and glucose.
33. Animal feed.
34. Automatic rice mill.
35. Assembling of motor vehicles.
36. Manufacturing of wooden vessel.
37. Photography (activities related to production of films for movie and x-ray).
38. Tea processing.
39. Production of powder milk/condensed milk/dairy.
40. Re-rolling.
41. Wood treatment.
42. Soap.
43. Repairing of refrigerators.
44. Repairing of metal vessel.
45. Engineering works (up to 10 hundred thousand Taka capital.)
46. Spinning mill.
47. Electric cable.
48. Cold storage.
49. Tire re-treading.
50. Motor vehicles repairing works (up to 10 hundred thousand Taka capital).
51. Cattle farm: above 10 (ten) numbers in urban area, and above 25 (twenty five) numbers in rural area.
52. Poultry: Number of birds above 250 (two hundred fifty) in urban area and above 1000 (one thousand) in rural area.

53. Grinding/husking wheat, rice, turmeric, chilly, pulses – machine above 20 Horse Power.
54. Production of shoes and leather goods, above 5(five) hundred thousand Taka capital.
55. Furniture of wood/iron, aluminum, etc., above 5(five) hundred thousand Taka capital.
56. Production of artificial leather goods, above 5(five) hundred thousand Taka capital.
57. Salt production, above 10(ten) hundred thousand Taka capital.
58. Biscuit and bread factory, above 5 (five) hundred thousand Taka capital.
59. Factory for production of chocolate and lozenge, above 5(five) hundred thousand Taka capital.
60. Garments and sweater production.
61. Fabric washing.
62. Power loom.
63. Construction, re-construction and extension of road (feeder road, local road).
64. Construction, re-construction and extension of bridge (length below 100 meters).
65. Public toilet.
66. Ship-breaking.
67. G.I. Wire.
68. Assembling batteries.
69. Dairy and food.

(a) Types of industries under Red category :

1. Tannery.
2. Formaldehyde.
3. Urea fertilizer.
4. T.S.P. Fertilizer.
5. Chemical dyes, polish, varnish, enamel.

6. Power plant.
7. All mining projects (coal, limestone, hard rock, natural gas, mineral oil, etc.)
8. Cement.
9. Fuel oil refinery.
10. Artificial rubber.
11. Paper and pulp.
12. Sugar.
13. Distillery.
14. Fabric dying and chemical processing.
15. Caustic soda, potash.
16. Other alkalis.
17. Production of iron and steel.
18. Raw materials of medicines and basic drugs.
19. Electroplating.
20. Photo films, photo papers and photo chemicals.
21. Various products made from petroleum and coal.
22. Explosives.
23. Acids and their salts (organic or inorganic).
24. Nitrogen compounds (Cyanide, Cyanamid etc.).
25. Production of plastic raw materials (PVC, PP/Iron, Polyesterin etc.)
26. Asbestos.
27. Fiberglass.
28. Pesticides, fungicides and herbicides.
29. Phosphorus and its compounds/derivatives.
30. Chlorine, fluorine, bromine, iodine and their compounds/derivatives.
31. Industry (excluding nitrogen, oxygen and carbon dioxide).
32. Waste incinerator.
33. Other chemicals.
34. Ordnance.

35. Nuclear power.
36. Wine.
37. Non-metallic chemicals not listed elsewhere.
38. Non-metals not listed elsewhere.
39. Industrial estate.
40. Basic industrial chemicals.
41. Non-iron basic metals.
42. Detergent.
43. Land-filling by industrial, household and commercial wastes.
44. Sewage treatment plant.
45. Life saving drugs.
46. Animal glue.
47. Rodenticide.
48. Refractories.
49. Industrial gas (Oxygen, Nitrogen & Carbon-dioxide).
50. Battery.
51. Hospital.
52. Ship manufacturing.
53. Tobacco (processing/cigarette/Biri-making).
54. Metallic boat manufacturing.
55. Wooden boat manufacturing.
56. Refrigerator/air-conditioner/air-cooler manufacturing.
57. Tyre and tube.
58. Board mills.
59. Carpets.
60. Engineering works: capital above 10 (ten) hundred thousand Taka.
61. Repairing of motor vehicles: capital above 10 (ten) hundred thousand Taka.
62. Water treatment plant.
63. Sewerage pipe line laying/relaying/extension.
64. Water, power and gas distribution line laying/relaying/extension.

65. Exploration/extraction/distribution of mineral resources.

66. Construction/reconstruction/expansion of flood control embankment, polder, dike, etc.

67. Construction/reconstruction/expansion of road (regional, national & international).

68. Construction/reconstruction/expansion of bridge (length 100 meter and above).

69. Murate of Potash (manufacturing).

Appendix – B

LIST OF INDUSTRIES

JHENAIDAH DISTRICT

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
1	ORANGE-A	JANATA WELDING, HORINAKUNDU BAZAR, JHENAIDAH
2	ORANGE-A	AKLIMA RICE MILL, SHOILOKUPA, JHENAIDAH
3	ORANGE-B	MODERN PHARMACEUTICALS LTD.MODERNPARA, JHENAIDAH
4	ORANGE-B	M/S BAHAR BRICKS, MOHESHPUR, JHENAIDAH.
5	ORANGE-B	CONCORD AGRICULTURE IND. JHENAIDAH
6	ORANGE-A	ALAM RICE MILL, SHAILOKUPA, JHENAIDAH
7	ORANGE-A	RAKIB WELLDING, KUSHBARIA BAZAR, JHENAIDAH.
8	ORANGE-B	M/S BOND BRICKS, MOHESHPUR, JHENAIDAH.
9	ORANGE-A	KANGALI RICE MILL, HARINAKUNDU, JHENAIDAH.
10	ORANGE-B	CONCORD AGRICULTURE IND. JHENAIDAH
11	ORANGE-B	M/S EUSUF BRICKS, MOHESHPUR, JHENAIDAH.
12	ORANGE-A	J SHAMIMA RICE MILL, SOILKUPA, JHENAIDAH.
13	ORANGE-A	M/S BOSDHON BRICKS, DAKATIA, JHENAIDAH.
14	ORANGE-B	SANANDA AGROCHEMICHALS IND. JHENAIDAH.
15	ORANGE-B	M/S RIPA BRICKS, KALIGANG, JHENAIDAH.
16	ORANGE-A	JANATA WELDING, JHENAIDAH.
17	ORANGE-A	AKLIMA RICE MILL, JHENAIDAH.
18	ORANGE-A	RANI WELDING, JHENAIDAH.
19	ORANGE-A	ISMAIL RICE MILL, JHENAIDAH.
20	ORANGE-B	M/S FIVE STAR BRICKS, JHENAIDAH.
21	ORANGE-A	NUPUR STEEL HOUSE, JHENAIDAH.
22	ORANGE-A	VHAI VHAI WELLDING, JHENAIDAH.

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
23	ORANGE-A	RAKIB WELDING, JHENAIDAH.
24	ORANGE-A	KADALI RICE MILL, JHENAIDAH.
25	ORANGE-A	J SHAMIMA RICE MILL, JHENAIDAH.
26	ORANGE-A	ALAM RICE MILL, JHENAIDAH.
27	ORANGE-B	SANONDHA AGROCHEMICALS IND.JENAIDAH
28	ORANGE-B	M/S RIPA BRICKS, KALIGONG,JENAIDAH
29	ORANGE-A	M/S BANDHON BRICKS, JHENAIDAH.
30	ORANGE-B	MODERN PHARMACEUTICALS LTD.MODERNPARA, JHENAIDAH
31	ORANGE-B	M/S FIVE STAR BRICKS, JHENAIDAH.
32	ORANGE-A	ANISUR RAHAMAN RICE MILL, JHENAIDAH.
33	ORANGE-A	IQBAL RICE MILL, JHENAIDAH.

KUSHTIA DISTRICT

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
1	ORANGE-A	NEW JONI WELDING , BOIDHONATHPUR,JAUDIA, KUSHTIA
2	ORANGE-A	NOMAN RICE MILL,JAUDIA, KUSHTIA
3	ORANGE-A	AULIA RICE MILL, TALBARIA, MIRPUR, KUSHTIA
4	ORANGE-A	M/S SHAHIDA RICE MILL, SATIAN, MIRPUR, KUSHTIA
5	ORANGE-B	JIM TRADERS(RICE MILL),KATDAHCHOR, MIRPUR, KUSHTIA
6	ORANGE-A	SWADAGOR WORKSHOP, VOLLOBPUR, PORADAH, KUSHTIA
7	ORANGE-A	M/S RASHID WELDING ,SAWASTIPUR, KUSHTIA
8	ORANGE-B	NASIR BD IND. LTD. DAULATPUR, KUSHTIA
9	ORANGE-B	NASIR TOBACO IND. LTD. DAULATPUR, KUSHTIA
10	ORANGE-A	GOLAM RASUL WELLDING, AZAL, KHOKSA, KUSHTIA.
11	ORANGE-A	RAZZAK WELLDING WORKSHOP, PORADAHA, KUSHTIA.

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
12	ORANGE-A	HAQ RICE MILL, JUGIA, MADARSAHA, KUSHTIA.
13	ORANGE-A	BADSHA WELLDING HOUSE, SHANTIDANGA, E.B. KUSHTIA.
14	ORANGE-A	HAMIDUR WORKSHOP, KUMARKHALI, KUSHTIA
15	ORANGE-A	S. S. GARU MOTATAZAKARAN PROKALPO, KUSHTIA.
16	ORANGE-A	TAMZIM CHAIR CALL, MIRPUR, KUSHTIA.
17	ORANGE-A	SAKI RICE MILL, BAHALBARIA, MIRPUR, KUSHTIA.
18	ORANGE-A	M/S SAJIB ENTERPRISE, MIRPUR, KUSHTIA.
19	ORANGE-A	M/S SHANTA RICE MILL, ALAMPUR, KUSHTIA.
20	ORANGE-A	SWARNA RICE MILL, PORADAHA, KUSHTIA.
21	ORANGE-A	SIRAJ WELLDING WORKSHOP, KUSHTIA.
22	ORANGE-A	GRAM SARKAR RICE MILL, PORADAHA, KUSHTIA.
23	ORANGE-B	NASIR TOBACO IND. LTD. DAULATPUR, KUSHTIA
24	ORANGE-A	VHAI VHAI RICE MILL, KUSHTIA.
25	ORANGE-B	M/S A B BRICKS, KUSHTIA.
26	ORANGE-B	M/S AZAD BRICKS, KUSHTIA.
27	ORANGE-A	M/S ABDUS SAMAD SWARNA RICE MILL, KUSHTIA.
28	ORANGE-A	M/S A M BRICKS, KUSHTIA.
29	ORANGE-B	M/S JUST BRICKS, KUSHTIA.
30	ORANGE-B	M/S M A BRICKS, KUSHTIA.
31	ORANGE-B	M/S A N C BRICKS, KUSHTIA.
32	ORANGE-A	M/S ABDUS SAMAD SWARNA RICE MILL, KUSHTIA.
33	ORANGE-B	M/S RATAN BRICKS, KUSHTIA.
34	ORANGE-A	KUSHTIA PALASTIC, KUSHTIA.
35	ORANGE-B	M/S HAQ BRICKS, KUSHTIA.

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
36	ORANGE-A	BALAKA RICE MILL, KUSHTIA.
37	ORANGE-A	STAR RICE MILL, KUSHTIA.
38	ORANGE-A	NAZMA RICE MILL, KUSHTIA.
39	ORANGE-A	KASEM WELLDING, KUSHTIA.
40	ORANGE-A	DRIVER WORKSHOP, KUSHTIA.
41	ORANGE-A	BAGDAD WELLDING WORKSHOP, KUSHTIA.
42	ORANGE-A	BAZLU & BROTHERS WELLDING, KUSHTIA.
43	ORANGE-A	LUTFAR CYCLE WELLDING, KUSHTIA.
44	ORANGE-A	MA BABAR DOA RICE MILL, KUSHTIA.
45	ORANGE-A	AUAL RICE MILL, KUSHTIA.
46	ORANGE-A	MINI RICE MILL, KUSHTIA.
47	ORANGE-A	JANI RONI WORKSHOP, KUSHTIA.
48	ORANGE-A	RASHID WELDING, KUSHTIA.
49	ORANGE-A	SAODAGAR RICE MILL, KUSHTIA.
50	ORANGE-A	ABDUL MATIN BISWAS DHANKAL, KUSHTIA
51	ORANGE-A	MURGIR FIRM MD. AMINUL HAQ, KUSHTIA.
52	ORANGE-A	M/S NOMAN RICE MILL, KUSHTIA.
53	ORANGE-A	SAHIDA RICE MILL, KUSHTIA.
54	ORANGE-A	JEM TRADERS RICE MILL, KUSHTIA.
55	ORANGE-A	HAMIDUL RICE MELL, KUSHTIA.
56	ORANGE-A	GOLAM RASUL WELDING, KUSHTIA.
57	ORANGE-A	RAJJAK WELDING, KUSHTIA
58	ORANGE-A	TANJUM CHAULCALL, KUSHTIA.
59	ORANGE-A	SS GARU MOTATAZAKARON PROKALPO, KUSHTIA.
60	ORANGE-A	SHAKI RICE MILL, KUSHTIA.

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
61	ORANGE-A	BADSHA WELDING, KUSHTIA.
62	ORANGE-A	SWARNA RICE MILL, KUSHTIA.
63	ORANGE-A	SIRAJ WELDING, KUSHTIA.
64	ORANGE-A	VHAI VHAI MONDAL RICE MILL, KUSHTIA.
65	ORANGE-A	GRAM SARKAR RICE MILL, KUSHTIA.

KHULNA DISTRICT

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
1	ORANGE-A	RAZIB IRON FOUNDARY, BATIAGHATA, KHULNA
2	ORANGE-B	MS. ROYAL BRICKS MANUFACTURE, RUPSHA, KHULNA
3	ORANGE-B	S. B. AGROFERTILIZER,IND. LTD. FULTALA, KHULNA
4	ORANGE-B	CHINA SEA-FOOD PROCESSING CO. LTD. KHULNA
5	ORANGE-A	S. B. AGROFERTILIZER,IND. LTD. FULTALA, KHULNA
6	ORANGE-A	GOSH LAKRI MILL, PAIKGASHA, KHULNA
7	ORANGE-B	M/S CHORKA APC POLLS LTD. SIROMONI,KHULNA
8	ORANGE-A	VAI VAI WORKSHOP, BOYRA, KHULNA
9	ORANGE-B	KHULNA SURGICAL & MEDICAL HOSPITAL(PVT) LTD. A-20/21 MOZID SAWRONI, SONADANGA, KHULNA
10	ORANGE-B	MODERN SEA FOOD IND. LTD. EAST RUPSHA, KHULNA
11	ORANGE-A	VP RICE MILL, BOYRA, KHULNA
12	ORANGE-B	NATIONAL SEA FOOD PVT. LTD. KHULNA
13	ORANGE-B	ARGANIC SHIMPI EXPORT LTD. 15 HAZI MOHSHIN ROAD, KHULNA
14	ORANGE-B	ORIENTAL FISH PROCESSING & CO: LTD. KHANJAHAN ALI ROAD, KHULNA
15	ORANGE-B	ASIAN SEA FOOD LTD. LABANCHARA, KHULNA

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
16	ORANGE-B	SATKHIRA FOODS LTD. TANK ROAD , KHULNA
17	ORANGE-B	M/S JESSORE JUTE PRODUCTS LTD. DAULATPUR, KHULNA
18	ORANGE-B	JAMENE SEA FOODS LTD. KHAN-A-SABUR ROAD, KHULNA
19	ORANGE-B	JALALABAD FROJEN FOODS LTD. KHULNA
20	ORANGE-B	JAHANABAD SEA FOODS LTD. KHULNA
21	ORANGE-B	FRESH FOODS LTD. ELYPUR, RUPSHA, KHULNA
22	ORANGE-B	SEA FRESH LTD. ELYPUR , RUPSHA, KHULNA
23	ORANGE-B	SEN MARTIN SEA FOODS LTD.ELYPUR, RUPSHA, KHULNA
24	ORANGE-B	ATLAS SEA FOODS LTD. RUPSHA APPROCH ROAD,KHULNA
25	ORANGE-B	ACCOA RESOURCES LTD. SIROMONY, KHULNA
26	ORANGE-B	DELTA FISH LTD.33 KDA AVANUE, KHULNA
27	ORANGE-B	SHOUDRAN FOODS LTD. KHAN-A-SABUR ROAD, KHULNA
28	ORANGE-B	LAKHAPUR FISH PROCESSING CO. LTD. RUPSHA, KHULNA
29	ORANGE-B	STAR SEA FOOD IND. LTD. KHULNA
30	ORANGE-B	QUALITY SIMPS EXPORT PVT. LTD.KHULNA
31	ORANGE-B	CHALNA MERIN PVT LTD.KHULNA
32	ORANGE-B	GAZIPUR SEA FOODS PVT LTD.KHULNA
33	ORANGE-B	RUPALI SEA FOODS LTD. 106 HAZI MAHOSHIN ROAD, KHULNA.
34	ORANGE-A	REXONA RICE MILL, ANDULIA, DUMURIA, KHULNA.
35	ORANGE-B	M/S ROYAL BRICKS MANU: RUPSA, KHULNA.
36	ORANGE-B	M/S ROYAL BRICKS MANU: RUPSA, KHULNA.
37	ORANGE-A	FACE FOODS LTD. RUPSA, KHULNA.
38	ORANGE-B	SEA FACE LTD. RUPSA, KHULNA.

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
39	ORANGE-A	TANVIR RICE MILL, KHULNA.
40	ORANGE-B	SATOTA AUTO RICE MILL, KHULNA.
41	ORANGE-B	EKOTA AUTO RICE MILL, KHULNA.
42	ORANGE-B	RAPID PRINTING & PACKAGE, KHULNA.
43	ORANGE-B	SOBI FISH PROCESSING IND LTD. KHULNA.
44	ORANGE-B	EVEREST METAL & BETTERY CO. BISIC, SHIROMONI, KHULNA.
45	ORANGE-B	DOULATPUR BEKARI, KHULNA.
46	ORANGE-A	M/S GAZI & BABAR CHEMICHAL IND. KHULNA.
47	ORANGE-B	R. B. M. BRICKS, KHULNA.
48	ORANGE-A	M/S SOUMIK DEAYRI FARM, KHULNA.
49	ORANGE-B	OHAB JUTE MILL, KHULNA.
50	ORANGE-B	M/S NEW AZAD BRICKS, KHULNA.
51	ORANGE-A	M/S STAR RICE MILL, KHULNA.
52	ORANGE-A	NATURAL FIBERS, KHULNA.
53	ORANGE-A	GHOSH LAKRI MILL , KHULNA
54	ORANGE-B	PUROBI SALT IND. LTD. KHULNA.
55	ORANGE-B	SUNDARBAN VAQUAM SALT IND. KHULNA.
56	ORANGE-B	SUNDARBAN SALT IND. KHULNA.
57	ORANGE-B	TISTA SALT IND. LTD. KHULNA.
58	ORANGE-B	TITAS SALT IND. KHULNA.
59	ORANGE-B	RAMNA SALT IND. KHULNA.
60	ORANGE-B	RAZAPUR SALT IND. LTD.KHULNA.
61	ORANGE-B	MA SALT IND. KHULNA.
62	ORANGE-A	RAJIB IROM FOUNDARY, KHULNA.

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
63	ORANGE-A	DOULATPUR BEKARI, KHULNA.
64	ORANGE-A	TANVIR RICE MILL, KHULNA.
65	ORANGE-B	MOFA FISH PROCESSING PVT. LTD. JESSORE
66	ORANGE-B	ASIAN SEA FOOD LTD. LABANCHARA, KHULNA
67	ORANGE-B	NASIR TOBACO IND. LTD. DAULATPUR, KUSHTIA
68	ORANGE-B	SATKHIRA FOODS LTD. TANK ROAD, KHULNA
69	ORANGE-B	M/S JESSORE JUTE PRODUCTS LTD. DAULATPUR, KHULNA
70	ORANGE-B	JEMINI SEA FOOD LTD. KHAN-A-SOBUR ROAD, KHULNA
71	ORANGE-B	JALALABAD FROJEN FOODS LTD. KHULNA
72	ORANGE-B	JAHANABAD SEA FOODS LTD. KHULNA
73	ORANGE-B	FRESH FOODS LTD. ELYPUR, RUPSHA, KHULNA
74	ORANGE-B	SENT MARTIN SEA FOODS LTD. ELYPUR, RUPSHA, KHULNA
75	ORANGE-B	ATLAS SEA FOODS LTD. RUPSHA APPROCH ROAD,KHULNA
76	ORANGE-B	AQUA RESOURSES LTD. SHIROMONI, KHULNA
77	ORANGE-B	DELTA FISH LTD.33 KDA AVANUE, KHULNA
78	ORANGE-B	SOUTHERN FOODS LTD.KHAN-A-SOBUR ROAD, KHULNA
79	ORANGE-B	LAKHAPUR FISH PROCESSING CO. LTD. RUPSHA, KHULNA
80	ORANGE-A	STAR SEA FOOD IND. LTD. KHULNA
81	ORANGE-B	CHINA SEA-FOOD PROCESSING CO. LTD. KHULNA
82	ORANGE-B	KHULNA SURGICAL & MEDICAL HOSPITAL(PVT) LTD. A-20/21 MOZID SAWRONI, SONADANGA, KHULNA
83	ORANGE-B	MODERN SEA FOOD IND. LTD. EAST RUPSHA, KHULNA
84	ORANGE-B	NATIONAL SEA FOOD IND. LTD.15 HAZI MOHASIN ROAD, KHULNA
85	ORANGE-B	ORGANIC SHIMPI EXPORT LTD.15 HAZI MOHASIN ROAD, KHULNA
86	ORANGE-B	ORIENTAL FISH PROCESSING & CO: LTD.48 KHANJAHAN ALI ROAD, KHULNA

SATKHIRA DISTRICT

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
1	ORANGE-B	MS. RAHMAN BRICKS, KALAROA, SATKHIRA
2	ORANGE-A	ABID WELDING, ASHASUNI, SATKHIRA
3	ORANGE-B	LIPI FISH FEED MILL, ASHASUNI, SATKHIRA
4	ORANGE-A	AL-AMIN ICE PLANT, KALIGONG,SATKHIRA
5	ORANGE-A	KALIPOD RICE MILL,PATKELGHATA, SATKHIRA
6	ORANGE-B	RAYHAN CYCLE STORE ,KALAROHA, SATKHIRA
7	ORANGE-B	M/S RUFIDHA FISH MILL, KALAROHA , SATKHIRA
8	ORANGE-A	MAA-SOROSSOTI RICE MILL,ASASUNI,SATKHIRA
9	ORANGE-A	HOJIRHAT DAAN SATAI MILL,ASASUNI,SATKHIRA
10	ORANGE-A	LIPI ICE FACTORY, BANGDAHA, SATKHIRA
11	ORANGE-A	PRODIP RICE MILL, ASHASUNI, SATKHIRA
12	ORANGE-A	NAHID WORKSHOP, SHYMNAGAR, SATKHIRA.
13	ORANGE-B	M/S POWER DISTRIBUTION, BINERPOTA, SATKHIRA.
14	ORANGE-A	VHAI VHAI BAROFCALL, ASHAMUNI, SATKHIRA.
15	ORANGE-A	ABIR WELLDING, BANGDAHA, SATKHIRA.
16	ORANGE-A	M/S POWER DISTRIBUTION, BINERPOTA, SATKHIRA.
17	ORANGE-A	M/S SARKAR RICE MILL, JHAUDANGA, SATKHIRA.
18	ORANGE-A	M/S MONOAR RICE MILL, CHUPRIA, SATKHIRA.
19	ORANGE-A	CHOWDHURI AGRO ENERGY COMPLEX.
20	ORANGE-B	GONESH & SONS WORKSHOP, TALA, SATKHIRA.
21	ORANGE-A	SAZZAT WORKSHOP. ASHASHUNI, SATKHIRA.
22	ORANGE-B	KADAKATI RICE MILL, ASHASHUNI, SATKHIRA.

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
23	ORANGE-A	NAZMUL WORKSHOP, SATKHIRA.
24	ORANGE-B	M/S RUPSA BRICKS, SATKHIRA.
25	ORANGE-B	M/S M R BRICKS, SATKHIRA.
26	ORANGE-B	M/S MOYNA BRICKS, SATKHIRA.
27	ORANGE-B	M/S K B BRICKS, SATKHIRA.
28	ORANGE-B	M/S ASHA BRICKS, SATKHIRA.
29	ORANGE-B	M/S SEKA BRICKS, SATKHIRA.
30	ORANGE-B	M/S NAT BRICKS, SATKHIRA.
31	ORANGE-B	M/S MP BRICKS, SATHIRA.
32	ORANGE-B	M/S JAMAN BRICKS, SATKHIRA.
33	ORANGE-B	M/S RANI BRICKS, SATKHIRA.
34	ORANGE-B	M/S M B BRICKS, SATKHIRA.
35	ORANGE-B	M/S S K BRICKS, SATKHIRA.
36	ORANGE-B	M/S A B B BRICKS, SATKHIRA.
37	ORANGE-B	M/S KAZIRHAT BRICKS, SATKHIRA.
38	ORANGE-B	M/S S S BRICKS, SATKHIRA.
39	ORANGE-B	M/S SONALI BRICKS, SATKHIRA.
40	ORANGE-B	M/S SANI BRICKS, SATKHIRA.
41	ORANGE-B	M/S SARDAR BRICKS, SATKHIRA.
42	ORANGE-B	M/S RANI BRICKS, SATKHIRA.
43	ORANGE-B	M/S JOINT BRICKS, SATKHIRA.
44	ORANGE-A	M/S MADINA RICE MILL, SATKHIRA.
45	ORANGE-B	M/S R B WS BRICKS, SATKHIRA.
46	ORANGE-A	MINI RICE MILL, SATKHIRA.

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
47	ORANGE-B	M/S KEYA BRICKS, SATKHIRA.
48	ORANGE-A	BABU WELLDING, SATKHIRA.
49	ORANGE-A	M/S SARDAR RICE MILL, SATKHIRA.
50	ORANGE-B	M/S SB BRICKS, SATKHIRA.
51	ORANGE-A	RAZAUL HOSSAIN RICE MILL, SATKHIRA.
52	ORANGE-A	M/S MILON WORKSHOP, SATKHIRA.
53	ORANGE-A	SEKH RIZBI AHMED & AZIZUL WORKSHOP, SATKHIRA.
54	ORANGE-A	M/S KHAN WORKSHOP, SATKHIRA.
55	ORANGE-A	VHAI VHAI RICE MILL, SATKHIRA.
56	ORANGE-A	ABID WELLDING, SATKHIRA.
57	ORANGE-A	M/S AYSHA RICE MILL, PATKELGHATA, SATKHIRA.
58	ORANGE-A	JAKIR HOSSAIN LED WELDING, SATKHIRA.
59	ORANGE-A	BABU WELDING, SATKHIRA.
60	ORANGE-A	SARDAR RICE MELL, SATKHIRA
61	ORANGE-A	HAZARHAT DHAN SATHY , SATKHIRA
62	ORANGE-A	PRODIP RICE MILL, SATKHIRA
63	ORANGE-A	MA SAROSWATI RICE MILL, SATKHIRA
64	ORANGE-A	RAKIB RICE MILL , SATKHIRA
65	ORANGE-A	NUR ISLAM RICE MILL, SATKHIRA.
66	ORANGE-A	GANESH RICE MILL, SATKHIRA
67	ORANGE-A	NAHID WORKSHOP, SATKHIRA.
68	ORANGE-A	RAYHAN CYCLE STORE, SATKHIRA
69	ORANGE-A	GONESH & SONS WORKSHOP, SATKHIRA.
70	ORANGE-A	SAZZAD WORKSHOP, SATKHIRA.

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
71	ORANGE-A	SRI CHITARANJAN RICE MILL, SATKHIRA.
72	ORANGE-A	MONOAR RICE MILL, SATKHIRA.
73	ORANGE-A	SARDAR RICE MILL, SATKHIRA.
74	ORANGE-A	SEN MINI RICE MILL, SATKHIRA.

JOSSORE DISTRICT

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
1	ORANGE-A	SUMON RICE MILLS, KHAMARPARA, SHARMA, JESSORE
2	ORANGE-A	M/S J. HAQ RICE MILL, KHAJURA SADOR, JESSORE
3	ORANGE-B	MOFA FISH PROCESSING PVT. LTD. JESSORE
4	ORANGE-A	SCHAIN COCONUT OIL MILL, KASUBPUR, JESSORE
5	ORANGE-B	NILOY CIMENT KLINGCARISATION, IND. LTD. BASUNDIA, JESSORE
6	ORANGE-A	RASHID RICE MILL, CHOUGASA, JESSORE
7	ORANGE-B	MS.SONALY BRICKS MANUFACTURE,MONYRAMPUR,JESSORE
8	ORANGE-A	M/S MASUD RICE MILL KHADINCHA, CHOUGASA, JESSORE
9	ORANGE-A	NAHAR RICE MILL, BADEKHANPUR, CHOUGASA, JESSORE
10	ORANGE-B	M/S HIROK BRICKS, MAHAKAL, AVOYNAGAR, JESSORE.
11	ORANGE-A	MD. AMTAR ALI RICE MILL, KAGMARI, JIKORGASA, JESSORE.
12	ORANGE-B	SEBA SURGIKAL CLINIC, KESHOBPUR, JESSORE.
13	ORANGE-A	M/S AYSHI FISH FEED. GOGO, SARSA, JESSORE.
14	ORANGE-B	SABUJ FISH FEED, ESBAKARA, MANIRAMPUR, JESSORE.
15	ORANGE-A	FOUR BROTHERS WELDING WORKSHOP, CHURAMONKATHI BAZAR, JESSORE.

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
16	ORANGE-B	M/S BALIADANGA BRICKS FIELD, BALIADANGA, FATAHPUR. JESSORE.
17	ORANGE-A	NITU RICE MILL, RAZAPUR, JESSORE.
18	ORANGE-B	NITAL CIMENT IND. LTD. AVOYNAGAR, JESSORE.
19	ORANGE-A	NITAL CIMENT IND. LTD. BASUNDIA, JESSORE.
20	ORANGE-A	AYSHA WORKSHOP, JHIKARGASA, JESSORE.
21	ORANGE-A	NORESH WORKSHOP, JHIKARGASA, JESSORE.
22	ORANGE-B	A. TALUKDER PIPE IND. RAZARHAT, JESSORE.
23	ORANGE-B	DOCTORS CLINIC, NOAPARA, AVAYNAGAR, JESSORE.
24	ORANGE-A	SHARIFUL WELLDING, BAKRABAZAR, JHIKARGASA, JESSORE.
25	ORANGE-A	LATIF RICE MILL, JHIKARGASA, JESSORE.
26	ORANGE-B	M/S SAHIDUL BRICKS, CHURAMONKATHI, JESSORE.
27	ORANGE-A	HANNAN RICE MILL, JHIKARGASA, JESSORE.
28	ORANGE-A	BISWAS DAIL O CHAUL MILLS, JHIKARGASA, JESSORE.
29	ORANGE-B	ANANDA FISH MILL, JHIKARGASA, JESSORE.
30	ORANGE-B	NOAPARA JUTE MILLS LTD. NAOPARA, JESSORE.
31	ORANGE-A	M/S BRISTI ENTERPRIZE, SHARSHA, JESSORE.
32	ORANGE-A	BISWAS DAIL O CHAUL MILLS, JHIKARGASA, JESSORE.
33	ORANGE-B	ANANDA FISH MILL, JHIKARGASA, JESSORE.
34	ORANGE-B	NOAPARA JUTE MILLS LTD. NAOPARA, JESSORE.
35	ORANGE-A	M/S BRISTI ENTERPRIZE, SHARSHA, JESSORE.
36	ORANGE-A	ABUL & FISH FEED, JHIKARGASA, JESSORE.
37	ORANGE-A	M/S SUJON RICE MILL, CHOUGASA, JESSORE.
38	ORANGE-B	TALUKDAR PIPE IND. RAZARHAT, JESSORE.
39	ORANGE-B	TALUKDAR LIGHT CASTING, RAZARHAT, JESSORE.

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
40	ORANGE-A	M/S ISLAM SHAH BRICKS, BGHAPARA, JESSORE.
41	ORANGE-B	KADAR WELLDING, CHOUGASA, JESSORE.
42	ORANGE-B	M/S KEYA BRICKS, MONIRAMPUR, JESSORE.
43	ORANGE-B	SIKDER BRICKS, BAGHARPARA, JESSORE.
44	ORANGE-B	NAOAPARA SISU PVT. HOSPITAL, AVOYNAGAR, JESSORE.
45	ORANGE-B	NOAPARA SISU HOSPITAL, JESSORE.
46	ORANGE-A	MAMA VAGNAY RICE MILL, CHATAL, JESSORE.
47	ORANGE-B	M/S M R BRICKS, JESSORE.
48	ORANGE-B	MEGHDUT AGRO CHEMECHAL IND(DOSTASAR) LTD. JESSORE.
49	ORANGE-B	MOGHDUT AGRO CHEMICHEL IND.(N.P.K.S)LTD. JESSORE.
50	ORANGE-B	M/S RANI BRICKS, JESSORE.
51	ORANGE-A	FOUR BROTHERS WELDING WORKSHOP, JESSORE.
52	ORANGE-A	NAORESH WORKSHOP, JESSORE.
53	ORANGE-A	HANAN RICE MILL, JESSORE.
54	ORANGE-A	LATIF RICE MILL, JESSORE.
55	ORANGE-A	MITU RICE MILL, JESSORE.
56	ORANGE-A	SACHIN COCONUT OILMILL, JESSORE.
57	ORANGE-A	SHARIFUL WELDING, JESSORE.
58	ORANGE-A	NAHAR RICE MILL, JESSORE
59	ORANGE-A	J. HAQ RICE MILL, JESSORE
60	ORANGE-A	AMTHAR ALI RICE MILL, JESSORE
61	ORANGE-A	MASUD RICE MILL , JESSORE
62	ORANGE-A	SUMON RICE MILLS, JESSORE
63	ORANGE-A	AISHA WORKSHOP, JESSORE

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRIES
64	ORANGE-A	REXONA RICE MILL, JESSORE
65	ORANGE-A	SHERAJUL RICE MILL, JESSORE
66	ORANGE-A	BRISTI ENTERPRIZE, JESSORE.
67	ORANGE-A	SUJON RICE MILL, JESSORE.
68	ORANGE-A	SHAMSUR RICE MILL, JESSORE.
69	ORANGE-A	RASHAD RICE MELL, JESSORE
70	ORANGE-B	G Q BALLPEN IND. JESSORE.
71	ORANGE-B	GRAFFER FOOD PRODUCTS, JESSORE.
72	ORANGE-A	M/S HIRAK BRICKS, JESSORE.
73	ORANGE-A	M/S SAHIDUL BRICKS, JESSORE.
74	ORANGE-B	NORTH SOUTH SPEANING MILLS, JESSORE.

BAGERHAT DISTRICT

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRY
1	ORANGE-A	CHOWDHURI AGRO ENARGY COMPLEX, BAGERHAT.
2	ORANGE-A	OHID SHAK RICE MELL, BAGHARHAT
3	ORANGE-A	ABID TRADERS RICE MILL, BAGERHAT.
4	ORANGE-A	ANSAR RICE MILL, DAYPARA BAZAR, BAGERHAT
5	ORANGE-A	COCONUT FIBER MILL IND., C&B BAZAR, BAGERHAT
6	ORANGE-B	KHAN SAW MILL, CHULKATHY, BAGERHAT
7	ORANGE-B	M/S GAZI AUTO COCONUT OIL MILLS, RAMPAL, BAGERHAT
8	ORANGE-A	S.M.BRISTY TRADERS,CHITOLMARY,BAGERHAT
9	ORANGE-A	MS. KHAKI RICE MILL, MOLLARHAT, BAGERHAT
10	ORANGE-A	ZAHID SHEIK RICE MILL, CHITOLMARI, BAGERHAT
11	ORANGE-B	BAGERHAT SEA FOODS IND. LTD. BAGERHAT

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRY
12	ORANGE-B	SAMPA ICE & CO. STORS LTD.BAGERHAT
13	ORANGE-B	RUPSA FIDS & ALAID INDUSTRIES LTD. BAGERHAT
14	ORANGE-B	MONGLA CEMENT FACTORY,MONGLA.BAGERHAT
15	ORANGE-A	M/S NASIM PASA WHITE STAR FIBERS, BAGERHAT.
16	ORANGE-B	DUBAI BANGLADESH CEMENT LTD. MONGLA, BAGERHAT
17	ORANGE-B	M/S WHITE STAR FIBERS, BAGERHAT.
18	ORANGE-A	VHAI VHAI ASH MILL, BAGERHAT.
19	ORANGE-A	ABID TRADERS RICE MILL, BAGERHAT.
20	ORANGE-A	KADIL WORKSHOP, BAGERHAT.

MAGURA DISTRICT

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRY
1	ORANGE-B	M/S MAMUN BRICKS, SHOTOKHALI, SHALIKHA, MAGURA
2	ORANGE-B	M/S SONALE BRICKS , THADUA, MAGURA
3	ORANGE-B	M/S ARAB BRICKS, MOHAMADPUR,MAGURA
4	ORANGE-B	M/S H.S.A. EATVATA,SREPUR, MAGURA
5	ORANGE-B	M/S NISHAT BRICKS, MOHAMADPUR, MAGURA
6	ORANGE-B	M/S RAJU BRICKS, MOHAMADPUR ,MAGURA
7	ORANGE-B	M/S BASUNDHARA BRICKS , SACHANI, RAUTADA, MAGURA.
8	ORANGE-A	M/S LITION BRICKS, MOHAMMADPUR, MAGURA.
9	ORANGE-B	M/S M B H BRICKS, 18 KHADA, MAGURA.
10	ORANGE-A	G. SARDER WORKSHOP, SHALIKHA, MAGURA.
11	ORANGE-B	M/S R C BRICKS, MAGURA.

MEHERPUR DISTRICT

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRY
1	ORANGE-B	SANO LAB, GENERAL HOSPITAL ROAD, MEHERPUR.
2	ORANGE-B	DR. RAMESH CLINIC LAB AID DIOGNOSTIC CENTER, MEHERPUR.1
3	ORANGE-B	M/S H. B. BRICKS, MEHERPUR.
4	ORANGE-B	THE RUBAL NURSING HOME, MEHERPUR.
5	ORANGE-A	NOMAN WELLDING, MEHERPUR.

NARAIL DISTRICT

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRY
1	ORANGE-A	SUBRATA BISAWS WELDING, MALIAT BAZAR, NARAIL
2	ORANGE-B	M/S RUPA BRICKS, AUDIA, NARAIL.
3	ORANGE-A	M/S B. B. I. BRICKS, LOHAGORA, NARAIL.
4	ORANGE-A	SUBRATA BISWAS WELDING, NARAIL.

CHUADANGA. DISTRICT

SL .NO.	CATEGORY BY DoE	NAME & LOCATION OF INDUSTRY
1	ORANGE-A	BISHAWS RICE MILL DAMUDHUDA , CHUADANGA
2	ORANGE-B	M. M. E. BRICKS, CHUADANGA.
3	ORANGE-B	M/S R.M BRICKS , BULTIA, CHUADANGA
4	ORANGE-A	KALIMUDDIN RICE MILL, CHUADANGA.

LIST OF INDUSTRIES (Without Category)

SL .NO.	TYPE	NAME & LOCATION OF INDUSTRY
1	LUBRICANT OIL	MOHAKAL INTERNATIONAL, ZEHALA BAZAR, AMALDANGA CHUADANGA
2	RAW MATERIAL OF TOURCH CELL	KHORSHED METAL INDUSTRIES LTD, C: 23-29, BSCIC INDUSTRIAL ESTATE, BSCIC SHIROMONEE, KHULNA
3	WOOD PROCESSING	NORDICK WOODS LTD, MIREERDANGA, DOULOTPUR KHULNA
4	PLASTIC WASHING	TAHMINA ENTERPRIZE, B-58, BSCIC INDUSTRIAL ESTATE, BSCIC SHIROMONEE, KHULNA
5	JUTE MAT	JASSORE JUTE PRODUCT, 562/3, KHAN E SHOBUR ROAD, RELI GATE DOULOTPUR KHULNA
6	SCREW GAUGE MANUFACTURING	M/S GLORIE ENGINEERING LTD. PLOT # 07, KDA, SHIROMONEE, KHULNA
7	CEMENT	ZEMKON CEMENT LTD, GILATOLA SHIROMONEE, KHULNA
8	MOBILE PROCESSING	M/S ATLIDE INDUSTRIES LTD, BSCIC INDUSTRIAL ESTATE, BSCIC SHIROMONEE, KHULNA
9	ELECTRICITY GENERATION	AGREEKO INTERNETIONAL PROJECT LTD, GOALPARA, KHULNA.
10	SHIPPING	M/S KHULNA DACKYARD, RAHIM NAGAR, RUPSHA KHULNA
11	FERTILIZER	MEFGHDUT AGRO CHEMICALS INDUSTRIES, HOUSING SHILPA ELAKA, UPOSHOHOR JOSSORE.
12	CEMENT	NAWAPARA CEMENT, NAWAPARA, OVOYNAGAR, JOSSORE.
13	CEMENT	NITOL CEMENT, PREMBAAG, BASHUNDIA, OVOYNAGAR JOSSORE.
14	FERTILIZER	SOUTHBENGAL FERTILIZER, MOHAKAL OVOYNAGAR, JOSSORE
15	FERTILIZER	AGRO BALANCED FERTILIZER, BAGHARPARA JOSSORE
16	CEMENT	NITOL CEMENTINDUSTRIE, BASHUNDIA JOSSORE.
17	CARGO	SHAHJAHAN TRADERS, MOHAKAL, OVOYNAGAR, JOSSORE.

SL .NO.	TYPE	NAME & LOCATION OF INDUSTRY
18	FERTILIZER	S S CHEMICAL, POTENGALI SHADAR, JOSSORE.
19	FERTILIZER	NILIMA AGRO CHEMICALS.
20	REFINARY	MAMUN & BROTHERS, PULER HAT, CHACHRA , JOSSORE.
21	MATINARIES	ENAYET ENGINEERING & FOUNDRY, BSCIC, JOSSORE
22	MATINARIES	RIPON ENGINEERING WOEKSHOP, RAMNOGOR RAJARHAT JOSSORE
23	FERTILIZER	FAIZA AGRO CHEMICALS, SOLEMANPUR, COURT CHANDPUR, JHINAIDAH
24	FERTILIZER	SAYDATIA BAKIBILLAH INDUSTRIES, BISHOYKHALEE, MOHARAJPUR, JHINAIDAH
25	FERTILIZER	FUTURE VISION, A-55, BSCIC INDUSTRIAL ESTATE, JHINAIDAH
26	FERTILIZER	JHINUK MINI FERTILIZER INDUSTRIES
27	FERTILIZER	PISCO AGRO CHEMICAL INDUSTRIES, BSCIC INDUSTRIAL ESTATE, JHINAIDAH
28	FERTILIZER	MILENNIUM FERTILIZER, BSCIC INDUSTRIAL ESTATE, JHINAIDAH
29	FERTILIZER	VAI VAI FERTILIZER, BSCIC INDUSTRIAL ESTATE, JHINAIDAH
30	FERTILIZER	SAYDATIA BAKIBILLAH INDUSTRIES, KORAPARA, PAGLAKANAI, JHINAIDAH
31	FERTILIZER	PRAPTI FERTILIZER INDUSTRIES, HAMDAH JHINAIDAH.
32	FERTILIZER	CONCORD AGRICULTURAL INDUSTRIES, KHUDRAPARA, VATIYAR GATEE, JHINAIDAH.
33	SUGAR MILL	KERU & COMPANY (BANGLADESH) LIMITED, DARSHONA, CHUADANGA.
34	LUBRICANT OIL	PETRO M CHEMICAL INDUSTRIES, DOULOTDIAR, MADRASHAPARA, CHUADANGA
35	RAW MATERIAL OF TOURCH CELL	AVEREST BATERRY, BSCIC INDUSTRIAL ESTATE, KHULNA

SL .NO.	TYPE	NAME & LOCATION OF INDUSTRY
36	RAW MATERIAL OF TOURCH CELL	ABDULLAH BATERRY, BSCIC INDUSTRIAL ESTATE, KHULNA
37	RAW MATERIAL OF TOURCH CELL	FARID BATERRY, BSCIC INDUSTRIAL ESTATE, KHULNA
38	CEMENT	A R CEMENT INDUSTRIES, OVOYNAGAR, JOSSORE
39	CEMENT KLINKER	NILOY CEMENT KLINKER, BASHUNDIA JOSSORE
40	TANNERY	S A F TANNERY, NAWAPARA, JOSSORE
41	FERTILIZER	NASIR AGRO CHEMICALS, BSCIC INDUSTRIAL ESTATE, JHINAIDAH
42	FERTILIZER	TAJ AGRO CHEMICALS, POBHATI SHARAK, JHINAIDAH
43	FERTILIZER	SHANONDA AGRO CHEMICALS INDUSTRIES, VATIAR GATEE, JHINAIDAH.