Floodplain wetlands are critical components of river ecosystems. Amongst other things, these features of the landscape play a vital role in filtering and trapping sediment, nutrients and pesticides from upstream and overland flow. The Wetlands in India support subsistence and livelihood to thousands of people through fishing, collecting edible plants, agriculture, water transport, irrigation and commercial fisheries, besides rich biodiversity. However a significant change in their status has been apparent, of late, due to various natural and anthropogenic reasons. Under this changed scenario the whole range of ecological functions in floodplain wetlands have gone disarray, adversely affecting biodiversity, fish and fisheries and livelihood of thousands of poor people. According to WHO about 80% of the diseases of human being are caused by water. Since it is directly or indirectly related with human health, it is necessary to bring awareness among the present and future generation about the consequences of water pollution and its impact on wetland and its ecosystem. There was no earlier work done to analyze the quality of water and soil of the Rupahi beel of Nagaon district, Assam and so present work “Hydro-geochemical study of floodplain wetland: A case study with Rupahi beel (Borghat), Nagaon, Assam” is undertaken with specific view to strengthen the environment database of the wetland (beel) so that concerted strategies can be adopted at the planning level to keep the contamination of water and soil at the minimum level.

The thesis describes the work done on the water and soil quality analysis of Rupahi beel of Nagaon district, Assam. The work is done over a period of three years in order that a comparative study could be made about the water and soil quality of Rupahi beel. The thesis consist of five chapters under the broad headings of

1. Introduction
2. About the study area
3. Materials and methods
4. Result and discussion
5. Conclusions
CHAPTER-1: Introduction

The first chapter (Introduction) starts with a general description of Floodplain Wetland and the importance of various floodplain wetlands as well as resources of India and Assam. This chapter also clearly demonstrates the ecological variables of floodplain wetland and its impact on beel fisheries and reviews existing literature and data in support of the same. The socioeconomic level of fisherman is also discussed. The various sources that degrade the quality of surface water are highlighted and relevant literatures are reviewed. The water quality and problems created by pollution are described with reviewed relevant literatures. The negative impacts on water quality due to excessive use, misuse and contamination which may harm aquatic life are also highlighted with reference to various case studies. The factors having impact on water quality are discussed.

This chapter gives a description of the desirable range of water of the beel for aquatic life as far standard laid down by various agencies. Metal absorption capacity of water hyacinth (Macrophyte ) and its good and bad impact on the gross environment of the beel are discussed with reviewing various literature. The concentration levels of metals in four commercial fishes found in the beel and the probable threats to human health through consumption of these fishes were discussed by reviewing relevant literature.

The soil of the wetland and its role in maintaining the quality of the water as well as aquatic animals were discussed.

CHAPTER-2: About the study area

This chapter gives the brief introduction of the study area, Rupahi beel, Nagaon (Assam) with respect to the environmental situation. The physiographic of the area, the geology, the climatic and other factors, population, health situation, transportation and all other relevant statistics were provided in this chapter. This chapter is devoted to a listing of the objectives of the work undertaken.
CHAPTER-3: Materials and Methods

This chapter gives the details of the experimental methodology followed in this work. It includes the collection of samples, storage and preservations of the samples, sampling sources, selection of sampling seasons and water and soil quality parameters. Forty sampling stations distributed over the Rupahi beel. Each set of water and soil samples were taken from the same source.

After careful study of the climatic and other physiographic conditions of the study area, it was decided to collect water samples once in each of the four seasons (Monsoon, Post-Monsoon, Winter and Pre-Monsoon) and soil samples once in two seasons (Monsoon and Winter) over a period from July-2009 to March-2012 as shown below:

(i)  Pre-monsoon Season (February-April)
(ii) Monsoon Season (May-July)
(iii) Post-monsoon (August-October)
(iv) Winter Season (November-January)

The periods for analysis of water and soil samples of the beel are from July-2009 to March-2012 and from July-2009 to December-2011 respectively are as shown in the table-1 and table-2 below:

**Table-1 Sampling Season and Period (for water sample)**

<table>
<thead>
<tr>
<th>Season Code</th>
<th>Season</th>
<th>Period (Month/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Monsoon</td>
<td>July/2009</td>
</tr>
<tr>
<td>B1</td>
<td>Post-monsoon</td>
<td>September/2009</td>
</tr>
<tr>
<td>C1</td>
<td>Winter</td>
<td>December/2009</td>
</tr>
<tr>
<td>D1</td>
<td>Pre-monsoon</td>
<td>March/2010</td>
</tr>
<tr>
<td>A2</td>
<td>Monsoon</td>
<td>July/2010</td>
</tr>
<tr>
<td>B2</td>
<td>Post-monsoon</td>
<td>September/2010</td>
</tr>
<tr>
<td>C2</td>
<td>Winter</td>
<td>December/2010</td>
</tr>
<tr>
<td>D2</td>
<td>Pre-monsoon</td>
<td>March/2011</td>
</tr>
<tr>
<td>A3</td>
<td>Monsoon</td>
<td>July/2011</td>
</tr>
<tr>
<td>B3</td>
<td>Post-monsoon</td>
<td>September/2011</td>
</tr>
<tr>
<td>C3</td>
<td>Winter</td>
<td>December/2011</td>
</tr>
<tr>
<td>D3</td>
<td>Pre-monsoon</td>
<td>March/2012</td>
</tr>
</tbody>
</table>
Table 2: Sampling Season and Period (for soil sample)

<table>
<thead>
<tr>
<th>Season Code</th>
<th>Season</th>
<th>Period (Month/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>Monsoon</td>
<td>July/2009</td>
</tr>
<tr>
<td>Y1</td>
<td>Winter</td>
<td>December/2009</td>
</tr>
<tr>
<td>X2</td>
<td>Monsoon</td>
<td>July/2010</td>
</tr>
<tr>
<td>Y2</td>
<td>Winter</td>
<td>December/2010</td>
</tr>
<tr>
<td>X3</td>
<td>Monsoon</td>
<td>July/2011</td>
</tr>
<tr>
<td>Y3</td>
<td>Winter</td>
<td>December/2011</td>
</tr>
</tbody>
</table>

This chapter then describes the methodology adopted for estimating each of the parameters selected. The parameters for water samples are Temperature, pH, Conductance, Hardness, Dissolved Organic Matter, Dissolved Oxygen (DO), Free Carbon dioxide, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), major anions (bicarbonate, chloride, nitrate, sulphate, phosphate, sulfide), major cations (sodium, potassium, ammonium, calcium, magnesium), heavy metals: Iron, Manganese, Cobalt, Copper, Zinc, Chromium, Nickel, Cadmium. The selected soil quality analysis parameters are soil texture, pH, Bulk Density (BD), Conductance, Total nitrogen content, chloride sodium, potassium and trace metals: Manganese, Cobalt, Zinc, Iron, Copper, nickel Chromium and Cadmium.

Again, Trace metals Copper, Nickel and Zinc in roots and leaves of water hyacinth as well as metals Iron, Copper, Chromium, Cadmium and Zinc in muscle tissues of four commercial fish species were analyzed.

The statistical analysis for the data obtained from samples was done by using SPSS 17 software.

CHAPTER-4: Result and discussion

This chapter (result and discussion) is the main part of the thesis giving the results of the present work and their discussion. In this chapter an assessment of water and soil quality parameters along with metal absorption capacity of water hyacinth and four commercial fishes have been discussed in detail. The discussion follows presentation of the results, indicating parameter-wise ranges of values from various types of sources,
the adverse health effects caused by them, and assessment of these parameters with reference to the guideline values prescribed by WHO and similar agencies. All the data have been presented in tabular forms. The tables of the data include season wise values, season wise average, minimum, maximum and standard deviation. The seasonal variations of each experimental data were shown diagrammatically. The statistical analysis like correlation coefficient, ion balance study for the various data are calculated and discussed.

For water parameters:

**Temperature:** The highest temperature (33°C) was recorded during post-monsoon season and lowest temperature (19°C) was recorded during winter season. The variation is due to surface temperature caused by hot and cold season. The temperature is suitable for aquatic life of beel.

**pH:** The pH value of the beel water are within the permissible limit. The pH value was found to be neutral to slightly acidic. The overall examination of the beel water showed that pH of the study area is within the safe limit for aquatic animals (6.5-8.5).

**Conductance:** The conductance value was found to be higher during winter season and lower during monsoon season. The highest value (242.3 µs/cm) was recorded from water sample collected from W2 (near Railway Bridge) during winter season and lowest value (85.0 µs/cm) from W8 (near Markaz Majid) collected during monsoon season. However, the values obtained in all seasons are much lower than the WHO guideline Value (1500 µs/cm). The higher value of conductance during winter may be due to reduced water level which concentrates the ionic matter. The opposite is true for monsoon season due to large dilution.

**Total Hardness:** The total hardness values were found to be higher during winter season and lower during monsoon season. The highest value (173.0 mg/L) was recorded from water sample W5 (near RCC bridge) collected during winter and lowest value (108.0 mg/L) from sampling point W25 (near Tiniali) collected during monsoon season. However, the overall values are lower than the WHO’s guideline value (250
mg/L). As there is no rainfall in winter season, the hardness causing Ca and Mg accumulates in higher amount. However, water level goes up during monsoon due to rainfall and hence hardness causing Ca and Mg gets diluted.

**DO:** The DO value of the study area is higher in pre-monsoon season and lower in winter season. However, the DO content in different seasons is not much different. Highest value (9.46 mg/L) from W11 and W31 are found during pre-monsoon and lower value (7.07 mg/L) from W9 is from winter season. The average value lies between 7.07 to 9.46 mg/L against the requirement for 5 mg/L (WHO limit) for sustaining aquatic life.

**Free Carbon dioxide:** Free Carbon dioxide values are found to be slightly higher during winter than the other seasons. The variations in different locations may be due to high and low populations of primary producers (phytoplankton and aquatic macrophyte). The average value fluctuates between 11.23 to 18.99 mg/L which is slightly higher than WHO guideline value (10 mg/L) for fish culture. However, DO range being high the carbon dioxide value cannot cause stress to aquatic life.

**BOD:** The average BOD value during monsoon season is slightly low as compared to the other seasons. The value fluctuates between 3.25 to 4.34 mg/L. The BOD levels greater than 10 mg/L are considered highly polluted. But the study area having lower value than 10 mg/L is less polluted and has less amount of degradable organic matter.

**COD:** The COD in all the samples are higher than BOD, indicating considerable presence of chemically oxidizing matters, most of which are non-biodegradable. The average value (75.58 mg/L) of all seasons have almost similar range.

**Bicarbonate:** The bicarbonate range during winter season is higher and lower during monsoon season. The values range between 51.37 and 69.12 mg/L. This value is significant for regulating the pH of water of the beel though much less than standard limit (1000 mg/L). The bicarbonate value indicates that the water of the beel is not harmful in the study area.
Chloride: The distributions of chloride in all the four seasons are almost same and the range is 7.24 to 10.36 mg/L. The concentration of chloride is much less than the WHO permissible limit for drinking (250 mg/L) and irrigation (600 mg/L) purpose.

Nitrate: The average range of nitrate concentration in the beel is 0.05 to 43.34 mg/L which is more than WHO permissible limit (20 mg/L). The higher concentration of nitrate in the beel may be due to human and/or animal waste contamination. The values are comparatively higher during monsoon season than the other seasons and the reason may be input from the runoff by rain water during monsoon season and use of nitrogenous fertilizers in the catchment area. As the concentration exceeded, it is necessary for investigation to determine the source of nitrate effluent.

Sulphate: The range of sulphate content in the beel is 11.74 to 14.29 mg/L. The average concentration is found to be almost similar in all the seasons and is less than the WHO permissible limit (150 mg/L). Therefore, the beel is not harmful with respect to sulphate.

Phosphate: The mean phosphate content in the beel water range from BDL (below detectable level) to 0.29 mg/L. Considering all season value, the concentration of phosphate is slightly higher than the WHO guideline value (0.1 mg/L). So the water of the beel is not fit for drinking. However, it is not harmful for aquatic animal and irrigation purposes.

Sulfide: The sulfide in water samples from many locations in different seasons are found to be below detectable level (BDL). Therefore, it is not a matter of concern as compared to WHO guideline limit (0.3 mg/L).

Ammonium-Nitrogen: The average ammonium concentration in water samples of the beel range from BDL to 0.05 mg/L. These values are lower than the WHO guideline (0.1 mg/L). Hence the beel is not harmful for fish and other aquatic animals.
Sodium: The concentrations of Na in all samples were below the WHO guideline value (200 mg/L). Therefore, the water of the beel is not harmful as far sodium is concern.

Potassium: The average potassium concentration range from 2.04 to 9.62 mg/L which is below the WHO maximum limit (12 mg/L). Therefore, water of the beel is safe for drinking and fish production.

Calcium: All the water samples in all seasons have average Ca concentrations below WHO maximum limit (100 mg/L). Hence the beel is not harmful for aquatic animals, irrigation and even for drinking.

Magnesium: The average magnesium concentration in four seasons range from 10.84 to 16.85 mg/L which is less than the WHO permissible limit (150 mg/L). Magnesium is not toxic to human and aquatic animal in the concentration obtained.

Manganese: The mean Mn concentration in winter season is found to be higher and lower during monsoon season. It ranged from 0.10 to 0.90 mg/L and is higher than the WHO permissible limit (0.5 mg/L). This may inter human body through food chain and may be harmful. However, for irrigation purpose the water of the beel is safe.

Cobalt: The Co content of water of the beel ranged from 0.08 to 0.41mg/L, which is lower than WHO guideline value. The beel water is safe as far Co is concern.

Zinc: The average concentrations of Zn in different seasons are from 1.17 to 4.54 mg/L. About 50% of sampling point contains mean Zn concentration higher than WHO permissible limit (3 mg/L). However, for aquatic life the value is less than WHO limit (15 mg/L). Hence the water of the beel need attention as there is risk of health.

Iron: Most of the water samples in the study area have iron concentration higher than WHO permissible limit (0.3 mg/L). Though the water of the beel is not suitable for drinking, it is suitable for pisciculture as well as other aquatic life.
**Copper:** The water samples of the study area are free from copper pollution as the concentrations are within the WHO maximum limit (2 mg/L).

**Nickel:** The average nickel concentration in all the water samples ranged from BDL to 0.147 mg/L. Most of the water samples have Ni concentration higher than WHO permissible limit (0.02 mg/L). The probable source of Ni may be due to entry of runoff, garbage dumping etc. Hence the water of the beel is not safe for drinking.

**Cadmium:** Most of the water samples have Cd concentration higher than the WHO guideline (0.01 mg/L). There may be chances of biomagnifications in fishes and may enter human body through food chain.

**Metals in Water hyacinth:** The average concentrations of three metals viz. Cu, Ni and Zn were found to be 12.42, 16.34 and 174.23 mg/L respectively. The Zn absorption ability were found to be maximum than the other two (Cu, Ni) and the concentrations of metals are higher than the concentrations in water.

**Metals in Fish samples:** The average concentrations of metals such as Fe, Cu, Cr, Cd and Zn in four commercial fish samples viz. Channa punctatus (CP), Catla catla (CC), Silver carp (SC) and Labeo rohita (LR) are as shown in the table below:

<table>
<thead>
<tr>
<th>Fish sample</th>
<th>Fe (ppm)</th>
<th>Cu (ppm)</th>
<th>Cr (ppm)</th>
<th>Cd (ppm)</th>
<th>Zn (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>1.64</td>
<td>0.46</td>
<td>0.04</td>
<td>0.02</td>
<td>5.65</td>
</tr>
<tr>
<td>CC</td>
<td>1.26</td>
<td>0.11</td>
<td>0.08</td>
<td>0.86</td>
<td>0.74</td>
</tr>
<tr>
<td>SC</td>
<td>1.31</td>
<td>0.10</td>
<td>0.08</td>
<td>0.85</td>
<td>0.64</td>
</tr>
<tr>
<td>LR</td>
<td>1.43</td>
<td>0.09</td>
<td>0.04</td>
<td>0.08</td>
<td>0.83</td>
</tr>
<tr>
<td>WHO 1984</td>
<td>100.0</td>
<td>20.0</td>
<td>1.0</td>
<td>0.5</td>
<td>5.0</td>
</tr>
</tbody>
</table>

The concentration of metal Cd in Catla catla and silver carp and Zn in Channa punctatus are found to be higher than WHO permissible limits for water. Therefore, these metals may contaminate to human body through food chain. Thus the sources of these metals that has inter into fish samples need to be determined.
For Soil Samples:

Soil: The soil sample of the study area has 56.59 to 80.02 % sand, 0.04 to 4.36 % silt and 9.15 to 20.54% clay. Hence the study area is predominantly sandy with moderate percentage of clay.

pH: The pH of the soil samples in different sampling point of the study area are 6.22 to 7.42. Hence the soil is neutral in totality and in not harmful to aquatic plants.

Bulk Density: The average BD of the soil of the beel ranged from 0.88 to 1.18 g/cm$^3$. These values signify compactness of the soil.

Conductance: The conductance of soil samples were from 0.013 to 0.047 µS/cm.

Total Organic Carbon: The percentage organic carbon present in the soil of the beel ranged from 3.22 to 35.47 %.

Chloride: The average chloride concentration in soil samples varied from 71.06 to 177.34 mg/kg.

Sodium: The mean sodium content in the soil samples of the study area ganged from 2.12 to 5.24 mg/kg.

Potassium: The average potassium concentration in the soil samples of the beel in different point ranged from 2.06 to 10.28 mg/kg.

Manganese: The average Mn concentration in the soil samples of the beel in different point ranged from 0.54 to 2.99 mg/kg.

Cobalt: The average Co concentration in the soil samples of the beel in different point ranged from 0.59 to 1.23 mg/kg.
**Zinc:** The average Zn concentration in the soil samples of the beel in different point ranged from 4.37 to 6.42 mg/kg.

**Iron:** The average Fe concentration in the soil samples of the beel in different point ranged from 96.52 to 118.65 mg/kg.

**Copper:** The average Cu concentration in the soil samples of the beel in different point ranged from 0.30 to 5.05 mg/kg. The Cu concentrations during monsoon were found to be higher than winter season.

**Nickel:** The average Ni concentration in the soil samples of the beel in different point ranged from 1.88 to 5.94 mg/kg. The concentration of mean Ni during winter was higher than monsoon.

**Chromium:** The average Cr concentration in the soil samples of the beel in different point ranged from 0.87 to 2.21 mg/kg. The concentration in both season are almost same.

**Cadmium:** The average Cd concentration in the soil samples of the beel in different point ranged from 0.038 to 0.136 mg/kg.

**Correlation Co-efficient of the data for water samples:**

During the correlation study of the water samples, it was found that positive correlation of EC (electrical conductivity) exist with Na, K, Ca, Mg, Co, Zn, Fe, Cu, Ni, Cd, Hardness, COD, NO$_3^-$, SO$_4^{2-}$. The significant positive correlation at 0.01 levels was found between pH and Cl, pH and NO$_3^-$, COD and Ni, Mn and SO$_4^{2-}$, Fe and K, Ni and K, Fe and Zn, Ni and Cu. The significant positive correlation at 0.05 levels was found between pH and Na, Conductance and Hardness, Na and Hardness, DO and Free CO$_2$, K and COD, Mn and NO$_3^-$, Cu and Na, Ni and Fe. The positive correlation of K with Ca, Mg, Mn, Co, Zn, Fe, Ni and Cd indicated that these cations originated from the same source.
Correlation Co-efficient of the data for soil samples:

The correlation coefficient study of the soil samples showed that the positive correlation of Conductance exist between Cl, K, Mn, Co, Zn, Cu, Cr, Ni and Cd. The positive significant correlation at 0.01 levels was observed between Cd and K, Zn and Co. Again the positive significant correlation at 0.05 levels was observed between Ni and Cl, Na with Fe and Cr, Cr with K, Zn, Co with Zn.

Chapter-5: Conclusions

This chapter of the thesis summaries the conclusions that can be drawn from the results obtained on the general status of quality of water and soil of the Rupahi beel. Here suggestions are also given to take some protective measure for better management of the beel. In order to reduce the contamination of study area (Rupahi beel), the point sources should be properly treated. The farmers should be encouraged to use bio-fertilizers and bio-pesticides to their agricultural fields to avoid the water and soil contamination which will improve the quality of the study area. The scope and need for further study in this field were mentioned at the end of this chapter.

The thesis concludes with a list of publications and books consulted during the preparation of this volume.