ASSESSING SOIL QUALITY AND YIELD PERFORMANCE OF RICE UNDER CONVENTIONAL AND NON-CONVENTIONAL IRRIGATION WATERS IN WESTERN FRINGE OF KHULNA CITY, BANGLADESH

Bachelor of Science in Environmental Science

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INTRODUCTION

1.1 Background and Justification of the Study

Irrigated agriculture currently consumes 70% of the world's developed freshwater and produces 40% of the food supply (Gleick, 2000); however, irrigated agriculture is facing a problem of water shortage, especially in arid and semi-arid regions. This problem is more extreme in developing countries because they use over 80% of their fresh water for irrigation. In Asia, much of the water scarcity is induced by overdrawing groundwater for agriculture, industry and domestic use, which leads to falling water tables. Bangladesh is an agrarian country where 84% of its population live in rural areas and are engaged in a wide range of agricultural activities accounting for 62% of the countries' labour force (BBS, 2004). The country has 8.3Mha (million hectare) of cultivable land of which 7.0Mha are potential area for irrigation. However, only 4.48Mha is covered by irrigation systems and 2.52Mha remains out of irrigation due to shortage of water (BBS, 2004).

Pereira *et al*. (2002) reviewed different options for the development of irrigation, such as more efficient use of water or use of alternative sources of water, and suggested using treated wastewater when freshwater is scarce. Pescod (1992) described the controlled use of urban wastewater as a contributor to water conservation and food production. A wider recognition is now being given to wastewater as an important resource in many countries. Irrigation with wastewater has become a common practice in peri-urban areas. At the advent of increased scarcity of freshwater in Bangladesh, low quality water warranted attention for further development of irrigation by coping with water shortage. The major sources of low quality water in the country include arsenic-polluted water, urban and industrial wastewater, and saline water. The densely populated cities in the country receive, on priority, almost all the water they need and 70% of which returns as waste. According to van Rooijen et al. (2005), the rapidly growing cities along with improved water supplies can easily double the wastewater flow in few years' time due to mounting use of water and also its control disposal. The Economic and Social Commission for Asia and the Pacific (ESCAP, 2000) reported an annual production of 725Mm3 of wastewater from the urban areas of Bangladesh. So, it is plausible and convincing that the use of this water for irrigation can be integrated in a holistic approach for the management of water quantity and quality. Well-planned utilization of wastewater in agriculture will increase food production by more irrigation coverage and improve the livelihood of farmers at the proximity of wastewater sources.

A few numbers of studies were conducted to assess soil quality and yield performance of rice under conventional and non-conventional irrigation waters in agricultural sector of Bangladesh. But in the south west coastal region of Bangladesh there was not conducted any significant study. By considering the coastal region as a major portion of Bangladesh this study is very much essential.

The main area of this study is Khulna, the headquarters of Khulna division, is the third largest city in Bangladesh and the second largest in the coastal zone. It is located in the south-west of the country and on the banks of two tidal rivers i.e. the Rupsha and the Bhairob (Figure 2.1). Dwellers of the KCC area, usually, consume water for domestic purpose, commercial and industrial purposes, and public sector. The coverage is only 30% of households with piped water supply. The rest is self-managed and many of the people face water crisis. Considering other demands as 10% of the consumer demand and leakage through the network as 20% of water supply, it was estimated that the water supply requirement was 165 liter per capita per day (lcd) (IWM, 2007). As such, the water supply requirement was found to be 242 million liters per day (MLD) for 1.47 million people in 2007. IWM (2007) also assumed that the prevailing population growth would continue and the population of Khulna would be around 2.9 million by the year 2030, which would make the water requirement 478 MLD. Groundwater is the main source of water supply in KCC area. Total 56 production wells operated by Khulna Water Supply and Sewerage Authority (KWASA) and about 12,000 hand tube-wells (deep and shallow tube-wells) operated by private owners have combined production of around 125 MLD. However, the actual total production is about 90 MLD considering low production efficiency, malfunctioning of wells, etc. The critical situations with water supply becomes more critical each day, regarding that the demands for quality water are constantly increasing and the available water of satisfactory quality is shorter in supply, because of its uneven distribution in terms of space and time, and because of the intensive pollution. Drainage system in Khulna City is not well-developed. The wastewater effluents, generated in KCC area, flow through the numerous concrete and earthen drains which finally dispose of to the nearby water bodies, i.e. the Mayur River, Rupsha River, etc.

Farmers of the western fringe of Khulna city has been using conventional water (surface water and groundwater) as irrigation water for rice cultivation during the dry season (November-May). The Mayur River is one of the most important freshwater sources for irrigation and domestic uses. However, about 18 big and small canals and drains drain out the effluents from KCC area to the said river which is flowing just western fringe of the city. This triggered the reduction in fish population, deteriorated the water quality, increased the prevalence of disease, etc. The wastewater is now polluting the river water as the treatment facilities are not yet established in Khulna. As the quality of wastewater is not satisfactory, problems like pollution of surrounding rivers and the streams, deterioration of the environment, and health sanitation have become alarming.

During the last few dry seasons, there has been growing concern about the water crisis in terms of quantity and quality. The river usually store insufficient water for irrigation during the *rabi* season. In addition, water is not in usable form as the river has become a dumping ground of wastewater generated in KCC area (Das, 2011). However, cultivators has been using this polluted river water for irrigation which gradually degraded the soil quality and reduced the growth and yield performance of rice as revealed from the farmers perception. Moreover, there has already been an increasing interest among farmers in reuse of non-conventional water (wastewater) in agriculture over the last few dry seasons due to the increased demand for fresh water. They increasingly practice the use of mostly untreated urban wastewater in agriculture particularly in rice production during the dry season. Untreated urban wastewater is generally considered unacceptable for direct use because of potential health risks. However, in many parts of the world, poor farmers in peri-urban areas use untreated wastewater (Hoek *et al*., 2002). Wastewater is used extensively for irrigation in certain countries e.g. 67% of total effluent of Israel, 25% in India and 24% in South Africa (Blumenthal *et al.*, 2000). This practice is likely to continue in the foreseeable future due to the high investment cost associated with the installation of treatment facilities.

1.2 Objectives of the Study

In order to systematically identify the growth and yield performance of rice conventional (Groundwater and surface water) and non-conventional (wastewater) waters, this study was undertaken in peri-urban setting in Khulna City during dry season (November-May). The specific objectives are:

(i) To assess the quality status of conventional and non-conventional waters and the quality of soil irrigated with these sources of waters.

(ii) To examine the growth and yield performances of rice (BRRI dhan28) under conventional and non-conventional irrigation waters.

1.3 Review of Literature

Liqa *et al*. (2008) conducted a study is that a cross country analysis of 53 cities in the developing world, contributes to an understanding of the factors that drive wastewater use. The 53 cities represent a range of settings in arid and humid areas, in rich and poor countries, and coastal as well as inland cities to provide a picture of wastewater use globally. It relates the wastewater collection and disposal practices to the increasing impact of poor water quality on agriculture. In four out of every five cities surveyed wastewater is used in urban and peri-urban agriculture even if areas cultivated in each of the cities may sometimes be small. Across 53 cities it was conclude that just for these cities alone, approximately 0.4 million hectares (Mha) are cultivated with wastewater by a farmer of 1.1 million with about 4.5 million households. Compiling information from various sources, the total number of farmers irrigating worldwide with treated, partially treated and untreated wastewater is estimated at 200 million; farming on at least 20 Mha. These figures include areas where irrigation water is heavily polluted. Though the actual physical areas under cultivation may be small, some vegetables are grown up to 10 times a year on the same plot. Data from a detailed city study in Accra showed that about 200,000 urban dwellers benefit everyday from vegetables grown on just 100 ha of land. Strict irrigation water quality guidelines can hardly be imposed where traditional irrigation water sources are polluted, and thousands of farmers depend on it, unless alternative sources of water are provided.

Khan *et al*. (2012) carried out a research on the impact of domestic/municipal wastewater (mww) of Dera Ismail Khan, Pakistan was assessed through its effects on biomass, physiology and yield of canola (*Brassica napus* L.). The pot experiments were conducted in a completely randomized design with three replications in net house during winter season 2006-07 and 2007-08 at Gomal University, Dera Ismail Khan, Pakistan. Treatments included were T_0 (tube well/tap water), T_1 (20% mww), T_2 (40% mww), T_3 (80% mww) and T_4 (100% mww/raw-form municipal wastewater). The quality and chemical composition of wastewater was deviating from international (Anon., 1985) as well as NEQS (2005) standard. Analysis of wastewater showed that biochemical oxygen demand (BOD), chemical oxygen demand (COD), sodium adsorption ratio (SAR) and total suspended solids (TSS) were above the permissible limit of irrigation. In pods per plant, the reduction was 61.55% by recording 110 pods per plant with T_4 (100% mww) as compared to control T_0 (286.1 pods per plant). Similarly pod length (reduced by 59.72%), seeds per pod (reduced by 42.53%), Seeds per plant (reduced by 82%), seed weight per plant (reduced by 88%), 100-seed weight (reduced by 19.54%) and straw yield (reduced by 54.23%) were significantly reduced by applying 100% wastewater. The most affected yield contributing traits were seeds per plant and seed weight per plant with 82% and 88% reduction, respectively due to T_4 (100% mww). On average, the decrease was 60% in the first stage and a further decrement of 4.83% was observed when they obtained seeds were re-sown in 2007-08.

Tabari *et al*. (2012) conducted a study is that the effects of municipal sewage irrigation on the soil and black locust (*Robinia pseudoacacia* L.) tree were studied. For this purpose, two artificial black locust stands under irrigation of municipal sewage and well water were selected in south of Tehran, Iran. Data were collected using technique of systematic random sampling with 4 replicates in each stand. It was found that the growth of black locust tree, as indicated by diameter at breast height, total height, crown length, average crown diameter, basal area and volume, in sewage irrigation stand was much higher than that of well water irrigation stand ($P < 0.01$). Plant analysis indicated that concentrations of leaf nutrients (N, P, K, Ca, Mg, Na, Fe, Mn, Cu and Zn) were greater in sewage-irrigated trees, without toxicity to the minerals of tree leaf, than those of well water irrigated trees, and positively correlated with their respective value in soil. Ni, Cr and Pb were not detected in leaf samples. Application of sewage resulted in a 1.5-fold increase in the concentrations of soil nutrients, Ni, Cr and Pb.

Among these minerals only Pb and Ni in some soil samples exceeded the toxicity limit. The increase in pH, electrical conductivity (EC) and organic carbon of soil was also observed in sewage irrigation. Results confirm that besides the use as irrigation water, municipal sewages are also a potential source of plant nutrients.

Mojid *et al.* (2012) conducted a study to assess the interaction effects of five irrigation water qualities formed with municipal wastewater and two inorganic fertilizer levels on the growth and yield of wheat were explored in three consecutive growing seasons during 2007–2010. The experiment was set in a split-plot design with two factors and three replications. The five irrigation treatments – I_1: freshwater (groundwater extracted by tube-well) as control, I_2–I_4: diluted wastewater (having wastewater fraction of 0.25, 0.50 and 0.75, respectively) and I_5: raw/undiluted wastewater – were allocated to the main plots, and the two fertilizer levels – F_0: no fertilizer and F_1: recommended standard dose – were allocated to the sub-plots. The wastewater contained nitrogen (N), phosphorus (P) and potassium (K) at concentrations of 17.5, 3.7 and 10.3 mg L−1, respectively, which correspondingly contributed 4.8–19.1, 3.8–15.1 and 5.4–21.7% of the recommended N, P and K. Wastewater exerted a significant (= 0.05) positive impact on most growth and yield variables and grain and biomass yields of wheat irrespective of the applied fertilizer dose. The highest values of the crop variables and yields were generally obtained in I4F1 (irrigation water containing 75% wastewater under the fertilized condition) and I5F0 (irrigation by raw wastewater under the non-fertilized condition). On average, over three years, the treatments that received 50–100% wastewater in irrigation (I_3F_1–I_5F_1) provided statistically identical results. Although wastewater always promoted leaf growth, its effectiveness in improving the leaf area index (LAI) decreased with its elevated quantity in irrigation. Raw wastewater promoted the highest leaf growth at 65 days after sowing (DAS) and provided the maximum LAI under both fertility treatments.

Khai *et al.* (2008) carried out a research to determine the effects of using wastewater as nutrient source on soil chemical properties in peri-urban agricultural systems. This study investigated the effects of using domestic wastewater in field experiments on Fluvisols soils in peri−urban areas of Hanoi and Nam Dinh cities in Vietnam. They compared long-term (30−50 years) wastewater irrigated rice dominated farming systems. Using wastewater for irrigation significantly affected pH, electrical conductivity (EC), exchangeable K and Na and reverse *aqua regia* digestible. There were no significant effects of wastewater irrigation on the NH_4NO_3extractable fraction of cadmium (Cd) and other trace metals, but the EDTA extractable fraction of Cu, Pb and Zn was significantly increased.

Kiran D *et al.* (2012) carried out a research on impact of Domestic Wastewater Irrigation on Soil Properties and Crop Yield in India. They found that application of domestic water increased the yield of crops compared to irrigation with ground water; it also increases total N, P, K and organic carbon content of soil. In field irrigation with domestic wastewater, the pH of soil extract was found to be slightly decreased. The organic carbon of soil irrigated with domestic wastewater was increased. This indicates that domestic wastewater irrigation helps to improve in fertility status of soil after harvest of *Rabi* crops. The crops yield irrigated with ground water along with fertilizer was found to be better as compared to application of wastewater without a recommended dose of fertilizer. The test weight of crops like wheat, gram, Palak was significantly maximum as recorded by domestic wastewater over the ground water irrigation. The crop yield of grain and straw was significantly influenced due to irrigation of crops through different sources the significantly higher grain and straw yield was recorded due to application of domestic wastewater over ground water irrigation. Findings indicate that, the use of domestic wastewater with physical treatment could increase water resources for irrigation may prove to be beneficial for agricultural production.

Begum *et al.* (2011) carried out a research at Mouchack textile industrial area of Gazipur in Bangladesh for two consecutive years (1999-2000) to study the effects of use of industrial waste water on the yield, nutrient content, and uptake of Boro rice. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The six treatments in this study were: T_1: uncontaminated field + fresh water, T_2: uncontaminated field + mixed water, T_3: uncontaminated field + contaminated water for non-contaminated field, and T_4: effluent contaminated field + fresh water, T_5: effluent contaminated field + mixed water, T_6: effluent contaminated field + contaminated water for contaminated field. Among the six treatments, uncontaminated field + fresh water (T_1) showed the best positive effect on rice. The N, P. K, and S contents and uptake were higher in T_1, but Zn, Mn, Fe, Cu, and Pb were higher in T_6 treatment. The treatment T_1, gave the highest grain yield (5.23 t/ha in 1999 and 5.40 t/ha in 2000), followed by mixed water (4.19 t/ha in 1999 and 4.24 t/ha in

2000) in both the growing seasons. Fresh and polluted water had significant effect on straw yield of *boro* rice in both fresh and polluted soils. In fresh soil, the highest straw yield (5.42 t/ha in 1999 and 5.57 t/ha in 2000) was recorded from fresh water as irrigation followed by mixed water (4.34 t/ha in 1999 and 4.40 t/ha in 2000). The lowest straw yield (3.02 t/ha in 1999 and 3.13 t/ha in 2000) was recorded with polluted irrigation water. Similarly in polluted soil, highest straw yield (2.59 t/ha in 1999 and 2.68 t/ha in 2000) was found from fresh water as irrigation followed by mixed water (2.01 t/ha in 1999 and 2.07 t/ha in 2000). The polluted water recorded the lowest straw yield (1.36 t/ha in 1999 and 1.40 t/ha in 2000). Results clearly indicate that textile industrial waste water was detrimental to rice growth and always gave the poor straw yield of *boro* rice even in the fresh soil. Fresh and textile waste water had significant effect on grain yield of *boro* rice in both fresh and polluted soils.

Mojid *et al.* (2010) carried out a research in twelve peri-urban and two sugar mill areas of Bangladesh. Information was collected on the use of urban wastewater. In all cases, untreated sewage water was used without primary treatment. The domestic polluted water originated from household kitchen, cloth wash, bathroom shower, and other municipal sources (e.g., supermarkets, restaurants, offices). Moreover it was often diluted by urban storm-water drainage. Major quality parameters of the wastewater were determined. The boron, iron, sodium, nitrogen, phosphate and zinc content along with the electrical conductivity and pH of the wastewater, with few exceptions, were lower than their safe limits for irrigation. The manganese content always exceeded the recommended threshold limit. Most farmers irrigated rice (Oryza sativa L.), and, in few locations, potato (Solanum tuberosum L.), wheat (Triticum aestium L.) and vegetables (e.g., tomato; Lycopersicon esculentum L.) with wastewater. At one peri-urban area, farmers stopped irrigating with wastewater after having (free) access to freshwater. The farmers at another area were very concerned of its negative impact on human and soil health. The peri-urban farmers articulated mixed experiences on the quantity of crop yields obtained under irrigation with wastewater; the majority of them reported getting increased yield. The peri-urban farmers at Rajshahi and Mymensingh claimed getting significantly ($p < 0.05$) higher yield of rice, wheat, potato and maize grown under irrigation with wastewater than the yield of these crops grown under irrigation with freshwater. Because of inappropriate fertilizer application some farmers at Mymensingh obtained reduced yield of rice; excessive vegetative growth caused lodging and reduced yield. The farmers did not recognize any problem with the quality of yield produced with wastewater except that only a few farmers at Mymensingh made non-specific complaints of low quality of rice. The quality aspect of the yield produced under irrigation with wastewater reported herein was, however, not conclusive since crop samples were not analyzed.

Qadir *et al., (2010)* he conducted his study that the volume of wastewater generated by domestic, industrial and commercial sources has increased with population, urbanization, improved living conditions, and economic development. The productive use of wastewater has also increased, as millions of small-scale farmers in urban and peri-urban areas of developing countries depend on wastewater or wastewater polluted water sources to irrigate high-value edible crops for urban markets, often as they have no alternative sources of irrigation water. Undesirable constituents in wastewater can harm human health and the environment. Hence, wastewater irrigation is an issue of concern to public agencies responsible for maintaining public health and environmental quality. For diverse reasons, many developing countries are still unable to implement comprehensive wastewater treatment programs. Therefore in the near term, risk management and interim solutions are needed to prevent adverse impacts from wastewater irrigation. A combination of source control, and farm-level and post-harvest measures can be used to protect farm workers and consumers. The WHO guidelines revised in 2006 for wastewater use suggest measures beyond the traditional recommendations of producing only industrial or non-edible crops, as in many situations it is impossible to enforce a change in the current cash crop pattern, or provide alternative vegetable supply to urban markets.

1.4 Organization of the Thesis

This report contains four chapters which are structured as follow:

Chapter One

This chapter describes the brief discussion on the study comprising of the background and the present status of the problem, objectives, rationale of the study. The present extent of conventional and non-conventional irrigation water in both local and global scale was appraised. Moreover, assessment of soil quality and yield performance of rice under conventional and- non conventional irrigation water was reviewed from the available secondary sources.

Chapter Two

In this chapter, the description of the study area along with location and extent, climatic and agricultural pattern were provided. Then selection of water, wastewater and soil sampling spots, collection of water, wastewater, and irrigated Soil and plant matter have been provided with schedule of sampling in materials and method section. The laboratory analysis techniques of water, soil, paddy leaf, and rice grain were discussed in brief. The evaluation criteria of water, wastewater, soil, plant matter and other data appraisal methods were also discussed.

Chapter Three

This chapter describes the findings of the study and relevant discussion. At first, the physico-chemical characteristics of the irrigation water were identified by various methods. The quality of the irrigation water has been evaluated by comparing with the standards and using different diagrams. In addition, nutrient status of soil, paddy leaf and rice grain were also estimated and presented. The impact of conventional and non-conventional irrigation water on growth and yield parameters of rice were detected.

Chapter Four

It contains ultimate findings of the study including soil growth and yield performance of rice and suitability of conventional and non-conventional irrigation water in a brief.

CHAPTER TWO

MATERIALS AND METHODS

2.1 Introduction

In this chapter, the description of the study area along with location and extent, climatic and agricultural pattern were provided. Thenselection of water,wastewater and soil sampling Spots,collection of water, wastewater, and irrigated Soil and plant matter have been provided with schedule of sampling in materials and method section. The laboratory analysis techniques of water, soil, paddy leaf, and rice grain were discussed in brief. The evaluation criteria of water, waste water, soil, plant matter and other data appraisal methods were also discussed.

2.2 Description of the Study Area

This chapter describes the historical background and general information such as location, physical and biological characteristics, population, socio-economic and environmental condition of the study area, Khulna City Corporation.

2.2.1 Historical background of the study area

Khulna is the third largest city in Bangladesh. It is located on the banks of the Rupsa and Bhairab rivers in Khulna District. It is the divisional headquarters of Khulna Division and a major industrial and commercial center. It has a seaport named Mongla on its outskirts, 38 km from Khulna City. The population of the city, under the jurisdiction of the City Corporation, was 1,000,000 in 2010 estimation. The wider Statistical Metropolitan Area had at the same time an estimated population of 1,435,422.

2.2.2 General information of the study area

Location and extent: Bangladesh is located in Southeast Asia. Khulna is one of the greater districts in Bangladesh, which is located in south west of Bangladesh.This study is now undertaking in western fringe of Khulna City which lies between 22°47´16´´ to 22°52´ north latitude and 89°31´36´´ to 89°34´35´´ east longitude (Figure 2.1).

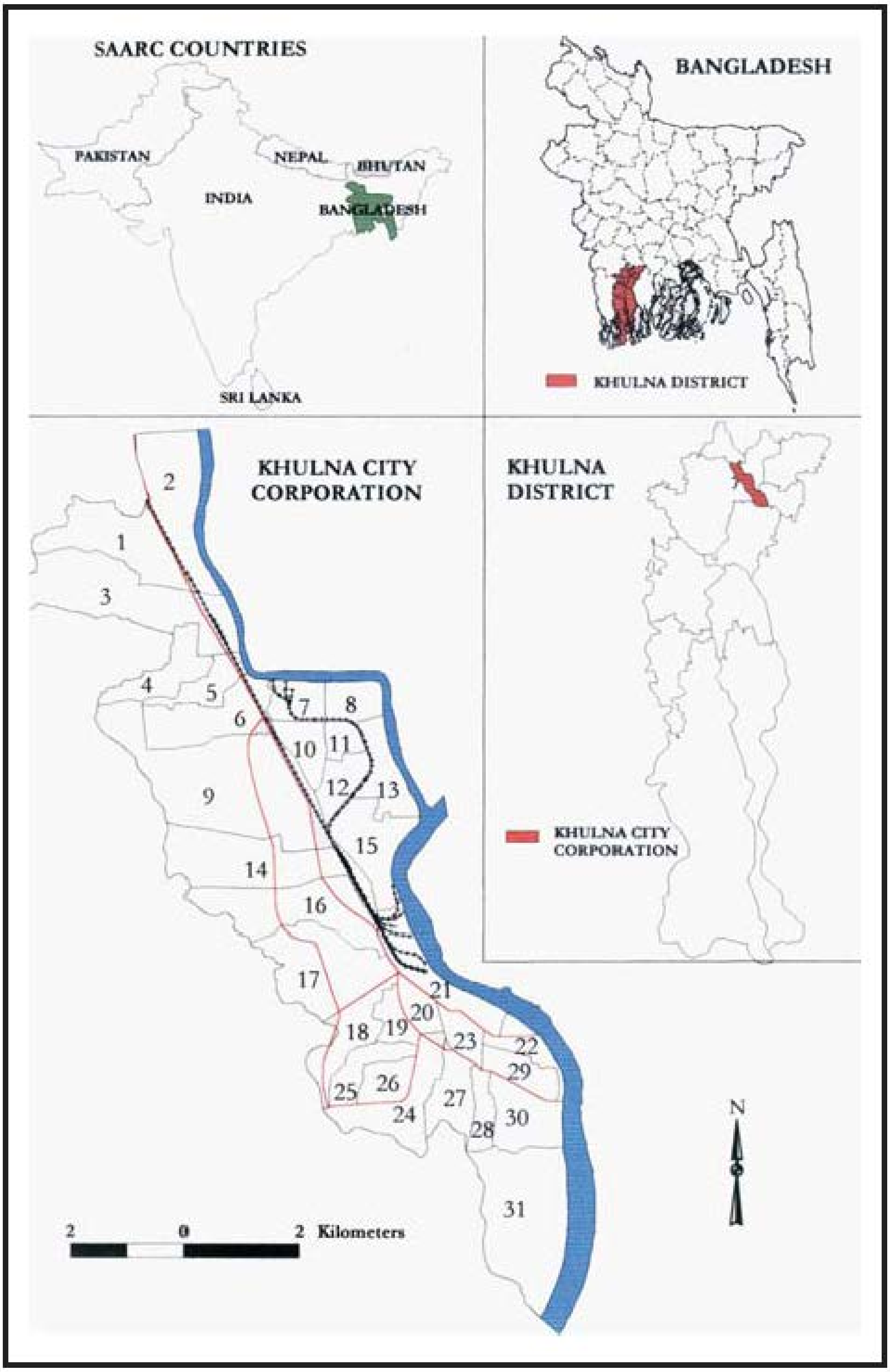

Figure 2.1: Khulna City Corporation (KCC) area (Source: KCC, 2010)

2.2.3 Physical and biological characteristics

Land formation: Natural environment has a profound impact on a town in shaping its physical setting and its pattern of growth. Khulna City Corporation town is located in the southwest region of the country, which has been developed and influenced by the process of siltation from a network of rivers. Because of its location in a moribund delta and tidal environment, the town has specific characteristics on land, soil, climate, hydrology and rainfall.The land of Khulna City Corporation region can be broadly characterized by the Ganges-tidal floodplain having lower relief and being criss-crossed by innumerable tidal rivers and channels. It is nearly flat and the surface is poorly drained.

The land surface of Khulna City Corporation town area is not perfectly level and is characterized by six major geomorphic units. These are natural levees, floodplains, old meander complex, bar, tidal marsh and back swamps. Natural levees are well developed along the Bhairab Rupsha banks and are occupied mainly by the present built-up area of the town. The low-lying areas extend mainly towards fringe areas of the town characterized by swampy areas, currently used for agricultural purposes that are poorly drained and persistent water logging problems.

Soil type: Khulna City Corporation district is formed entirely by the deltaic action of the Ganges which brought mud and lime stone from the Himalayas. The soil is to a great extent uniform in character and varies only greater or smaller admixture of sand, silt and clay. Naturally, the percentage of sand is greater along the riverside and smaller in those areas where deltaic action has ceased. The town fringes particularly are the marsh areas.The study area has black-brown peat soil (BBS, 2003).

River system: The Khulna City Corporation town has been growing in a linear shape following the Bhairab-Rupsha course. The Bhairab, originating from the Kobadak, flows southward. At present the main town is situated on the southwest bank of the Bhairab course. It is also the main natural drainage for the town.

Climatic pattern

Temperature: Remarkable changes in temperature can be found with the changes of seasons in Khulna City Corporation town. April is the hottest month showing a monthly average maximum temperature of up to 36°C. However, Khulna City Corporation town shows a mild summer than of inland areas, particularly northwestern district, where summer temperature sometimes exceeds 37°C. In June, there is sharp fall in temperature due to the outbreaks of monsoon. The cool dry winter season begins in November, and January is the coldest month with an average minimum is about15°C.The humidity rises more than 88% during monsoon.

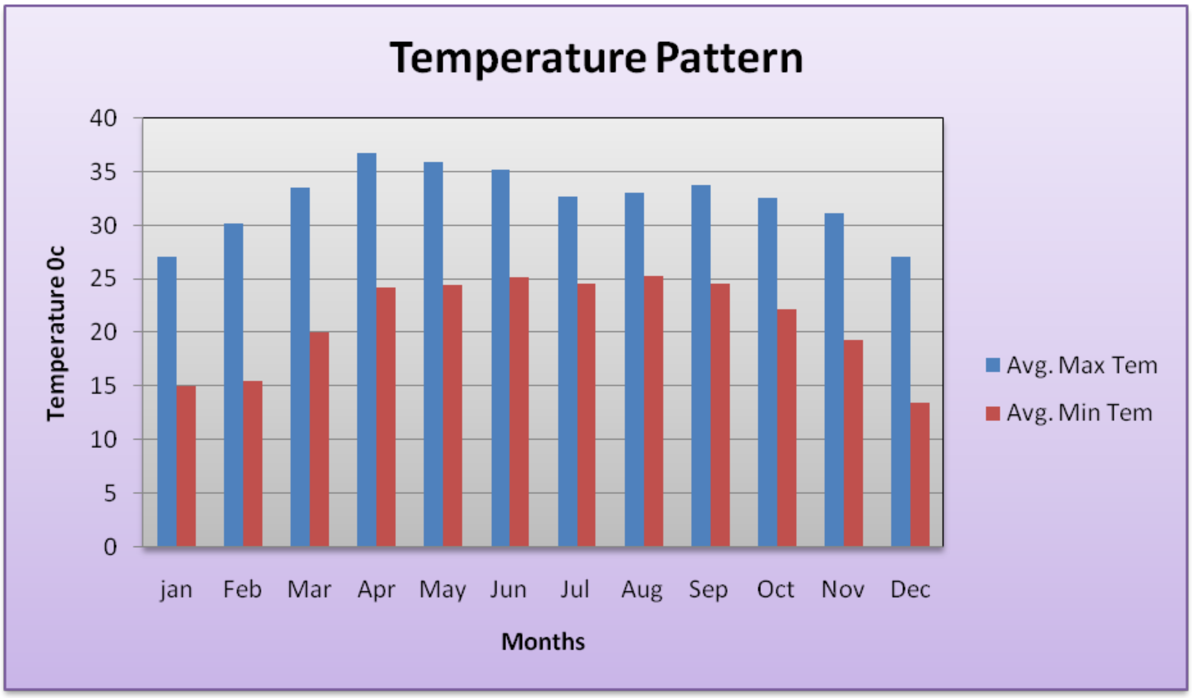

Figure 2.2: Monthly average maximum and minimum temperature pattern

Rainfall: The average rainfall of this town is about 1800mm. The main source of rainfall is the southwestern monsoon. Nearly 85 per cent of total rainfall occurs during June-October. During March-May some rainfall also occurs due to Nor'wester effect. Winter is the dry with little or nearly no rainfall. However, during the months of December and January little or no rainfall is recorded (Meteorological Dept. Khulna City Corporation, 2009).

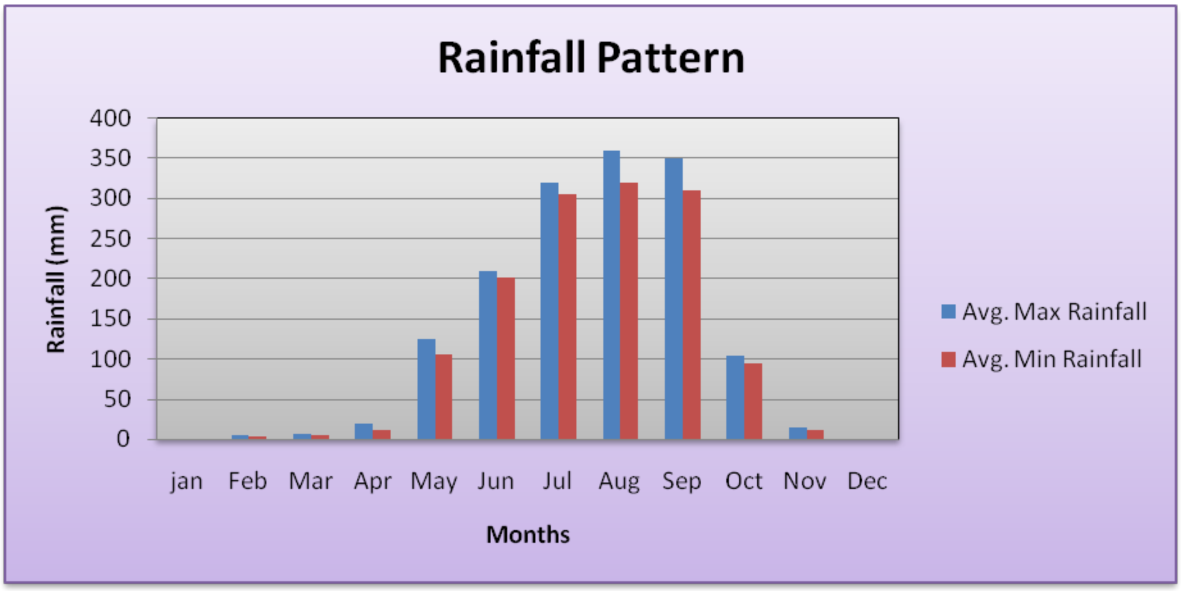

Figure 2.3: Monthly average maximum and minimum rainfall pattern (2009)

Wind: Due to monsoonal variation of the climate, there are variations in wind direction in Khulna City Corporation town. The southwesterly monsoon starts from about the middle of March and recedes about the end of September. The monsoon winds blow from the south with sustain force from March to October, The wind blows from the north and northeast in January. February is a calm month with foggy weather in the morningparticularly.

2.2.4 Demographic features of Khulna City Corporation

Khulna City Corporation is one of the densely populated municipalities of Bangladesh.According to BBS 2001 the total population of the town was 177155 andMunicipal Office Report, 2010 the total population is 246135. The total population and population growth rate is shown in Table 2.1.

Table 2.1 The total population and population growth rate of Khulna City Corporation.

Year	Total population	Population growth rate (%)
1981	112234	4.20
1991	432128	2.94
2001	877155	2.18
2010	>1000000	1.48

Source: BBS and KCC , 2010.

2.2.5 Economic characteristics

Like the other big cities of Bangladesh, notably Dhaka and Chittagong, Khulna is undergoing a major transformation, due to its immensely growing population and its status as Bangladesh's third largest city. Because of its strategic location of only 45 km from the port of Mongla, Khulna is considered as being a port city like Chittagong. Khulna is also known as the city of shrimps, because 75% of all shrimps exported from Bangladesh are cultivated in the Khulna zone.Khulna has some heavy and medium type industries like Khulna Hardboard Mills, Bangladesh Oxygen Company, Khulna Oxygen Company, Platinum Jubilee Jute Mills, Star Jute Mills, and Dada Match Factoryetc.The means of livelihood of the peri-urban community peoples are mainly agriculture, service, business, day labour, etc.

2.2.6 Land utilization

Farmers communities produce varieties of crops namely local and high yielding variety (HYV) rice, wheat, vegetables, spices, pulse and others during different crop growing seasons i.e. *Kharif* and *Rabi* (BBS, 2000).

Kharif crops are grown in the spring or summer season and harvested in late summer or in early winter. The season is conveniently divided into Kharif I and Kharif II. Kharif I, often called *Pre-kharif*, actually starts from the last week of March and ends in May. The Kharif season is characterized by high temperature, rainfall and humidity (WFP, 2009). The principal crops grown in the area beside Moyur River during this season are Aus and Aman rice. The rabi season is when crops are dependent on stored soil moisture for the majority of their growing period. Delays in harvesting the Aman crops or an early end to the kharif period can reduce the residual soil moisture and limit the opportunities for rabi cropping. *Rabi* season begins at the end of the humid period when the Southeast monsoon begins to stop in November and extends up to the end of March. The season is characterized by dry sunny weather, warm at the beginning and end, but cool in December-February. The average length of the *rabi* growing period ranged from 100-120 days in the study area (WFP, 2009). Major r*abi* crops grown in the country include boro rice, oilseeds, pulses, winter vegetables, viz. cabbage, brinjal, tomato, radish, spinach, country bean, and garden pea.

2.3 Materials and Methods

2.3.1 Selection of water and wastewater sampling spots

Before samplings of wastewater, 3 sampling spots on the trunk drains that are located near the Abu Naser Specialized Hospital (Figure 2.4). For collection of river water, total 3 sampling spots on the Mayur River, were selected near Rayer Mahal Sluice gate. For collection of fresh water, 3 sampling spots were also selected on the local canal near Lata Bridge.

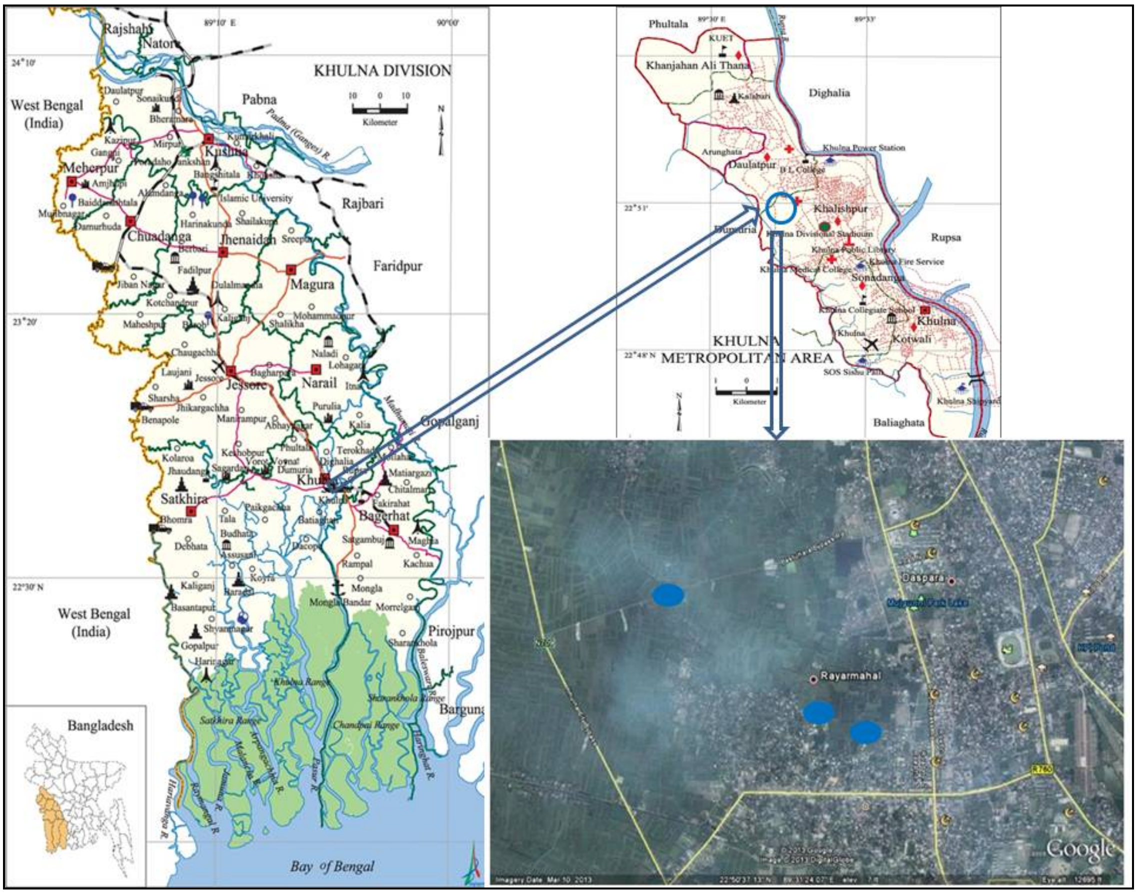

Figure 2.4: Locations of sampling spots

2.3.2 Selection of soil sampling spots

Before sampling of soil, experimental plots were selected on the basis of three distinct sources of irrigation waters namely (a) along pollution affected reach of the Mayur River (polluted site), (b) along the pollution free upstream reach of the Local canal (control site), and (c) along the trunk drain on the drainage system of the KCC area (wastewater site). The characteristics of irrigated soil in all through the sites are similar in nature. Agronomic parameters were also similar which was found from the table which is given below:

Total 3 plots as replications for each site were selected for cultivating rice as well as collection of soil samples. The same size and shape of experimental plots would be maintained as much as possible. Table 2.3 shows the owners, locations and coordinates of the rice plots in the peri-urban setting of the KCC area. And the same characteristics of irrigated soils for all the three settings.

Table 2.3: Owners, location and coordinates of the rice plots

Location	Coding	Longitude	Longitude	Farmers Name
Abu Naser Hostipal (Wastewater Site)	T_1S_1	22°51´04´´	89°31´39´´	Mr. Zahed
	T_1S_2	22°51´03´´	89°31´39´´	Mr. Mosarraf
	T_1S_3	22°51´02´´	89°31´39´´	,,
Boyra (Polluted Site)	T_2S_1	22°50´43´´	89°30´52´´	Mr. Tuzomber
	T_2S_2	22°50´43´´	89°30´53´´	,,
	T_2S_3	22°50´37´´	89°30´49´´	Mrs. Sufia Begum
Lota Bridge (Control Site)	T_3S_1	22°51´46´´	89°30´02´´	Mr. Swapon Tarafder
	T_3S_2	22°51´47´´	89°30´01´´	,,
	T_3S_3	22°51´48´´	89°30´00´´	,,

BRRI dhan28 was selected and transplanted in each site as it is usually cultivated by more than 90% farmers in the study area as revealed from the community perception. Fresh and clean seeds for each site were collected from district agricultural office, Bangladesh Agricultural Development Corporation (BADC) and supplied to the farmers for growing seedlings at seed-bed or nursery-bed.

2.3.3 Collection of water, soil and plant matters

Irrigation waters and irrigated soils were collected from pre-selected sampling spots during three broad schedules: (i) before ploughing the rice plots; (ii) at the vegetative (40 Days After Transplantation (DAT)), reproductive (80 DAT) and ripening (120 DAT) stages; and (iii) after harvesting the paddy (Appendix-C). However, plant matters (leaf and grains) are being collected only during rice growing season mainly during vegetative, reproductive and ripening stages for observing the nutrient uptake under different sources of irrigation waters. Samplings of irrigation waters, wastewater, irrigated soil and plant matters were carried out following standard guidelines provided by different respective bodies in home and abroad (UNEP/WHO, 1996; Petersen, 2002; BARC, 2005). The break-up of sample collection schedules are arranged in Table 3.

Table 2.4: Schedule for sample collection

Sl. No.	Season	Phase	Break-up	Time specification	Comment
1.	After *Kharif* season	Before ploughing	Before 1st flooding	-	RW, WW, CW, IS
2.	Rice growing season (avg. 120 days)	Vegetative stage (40 DAT)	Vegetative stage	35 DAT	RW, WW, CW, IS, PM (leaf)
		Reproductive stage (80 DAT)	Reproductive stage	-	RW, WW, CW, IS, PM (leaf)
		Ripening stage (120 DAT)	Ripening stage	-	RW, WW, CW, PM (leaf)
3.	Before *Kharif* season	After harvesting paddy	Before starting rain	-	RW, WW, CW, IS, PM (grain)

Note: RW = river water; WW = wastewater; CW= control water IS = irrigated soil; PM = plant matter

2.3.4 Sampling procedures

2.3.4.1 Water and wastewater

Water and soil samples were collected following standard guidelines (UNEP/WHO, 1996; BARC, 2005; APHA, 2006). For sampling, firstly seventy bottles were collected and washed well with household water 6 or 7 times and then, by entering 1-2 ml 95-98% industrial sulfuric acid with water (to remove foreign chemicals) into each bottles. The bottles were then sealed well and preserved for one night. After that, each bottle was properly washed with shaking by water again 6 or 7 times and then preserved in room temperature. Before sampling, the bottle was rinsed with sample water 3 or 4 times and sank entirely (at least 2 feet) so that the sample could represent the total characteristics of the canal water (UNEP/WHO, 1996; APHA, 2006).

For analysis of dissolved oxygen (DO), water samples were collected without letting the samples remaining in contact with air or be agitated. Water samples were collected in narrow-mouth glass-stoppered BOD bottles of 300 mL capacity with tapered and pointed ground-glass stoppers and flared mouths. Entraining or dissolving atmospheric oxygen was avoided. The bottles were overflowed two or three times its volume and stopper were replaced so that no air bubbles are entrained (APHA, 2006).All water samples were collected from the mid stream of the river and at least below 15 cm from the surface water level to avoid the photo effects, and then securely sealed with proper leveling (sample number and location).The pH, EC, TDS, DO, and Temperature were tested at the field spots during collection of samples.

2.3.4.2 Irrigated soil

Every possible precaution was taken to obtain a representative soil sample. Firstly, poly-packs were collected; each of 1.5 kg capacity. By using a spade, soil was collected from 9 spots of a field and kept on a polythene sheet, which was mixed for the exact representation of the field. Two layer poly-packs were used to protect it from damaging during the transportation, and labeling of sample (with sample ID, date and location) was done with a permanent marker. Soil sample was dried in room temperature for getting the exact result without exposing to direct sunlight (BARC, 2005). Sample was dried in room temperature for getting the exact result without exposing to direct sunlight (BARC, 2005).

2.3.4.3 Paddy leaf sampling procedure

Zipped poly-packs were used for collecting paddy leaf. As third leaf of rice represents the greatest range of nutrient level and contains relatively more conductive tissues; so it was collected from the field (Bhargava and Raghupathi, 1999; Petersen, 2002). For the collection of paddy leaves, hand gloves were used for avoiding the contamination and proper leveling (with sample ID, date and location) was done. Then, samples were preserved in an ice-box, in which temperature was lowered by using ice-cubes. It was then preserved in refrigerator because at low temperature reduces the physiological activity to minimum and checks the spoilage of sample due to high temperature and high humidity.Thenthe fresh tissue was washed with wetted cloth. The extra moisture was wiped out, the sample was then cut into small pieces and placed in an oven for drying at 65^0 to 70^0 C temperature for 24 to 48 hours (till complete drying) with careful protection from fumes which could lead to contamination. Leaf samples were grinded with a rolling mill. Then, the samples were preserved in plastic container for nutrient uptake analysis (Petersen, 2002).

2.3.4.4 Rice grain sampling procedure

Fresh dried seeds were collected from farmers' households. For the determination of nutrient uptake, dried grain samples were de-husked and preserved in poly-packs.

2.3.4.5 Plant agronomic data sampling procedure

All agronomic parameters of ricelike plant height, root length, panicle length, tillers/plant, Grains/Panicle were collected during ripening stage and grain yield were collected from fields and farmer's households at post harvesting stage.

2.3.5 Analysis of Water, Soil and Plant Matters

Parameters of conventional and non-conventional waters, irrigated soil and plant matters were selected on the basis of agricultural significance, soil nutrient requirement for rice production, and the effects of some inorganic elements in irrigation waters on soil fertility, nutrient uptake in plant matters and rice yield.

For assessing the quality status of river water and wastewater, hydrogen ion concentration (pH), electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD_5), chemical oxygen demand (COD), chloride (Cl^-), sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium absorption ratio (SAR), potassium (K^+), bicarbonate (HCO_3^-), sulfate (SO_4^{2-}), nitrate (NO_3^-), phosphate (PO_4^{3-}), some trace elements, etc. were selected. Among these, pH, EC/TDS and DO are usually measured on spots by using portable pH meter, EC/TDS meter and digital oxygen meter, respectively. The remaining parameters are being analyzed in laboratory following standard methods and techniques (APHA, 1992; Ramesh and Anbu, 1996; Metcalf and Eddy, 1996). Table 2.4 shows the selected parameters for irrigated water and respective recommended methods with reference.Table 2.5 shows the selected parameters for irrigated soil and respective recommended methods with reference. Paddy leaf and grain samples would be analyzed in the laboratory by following the methods in Table 2.6. Quality parameters of river water, wastewater, irrigated soil and plant matter are being analyzed using laboratory facilities of Environmental Science Dsicipline, Forestry and Wood Technology Discipline, Soil Science Discipline, etc. of Khulna University.

Table 2.5: The methods/instruments, book references and units that were used to measure the parameters

Temperature	℃	PoratbleMultimeter. HACH Portable case far pH, pH/ISEConductivity &DO Meter.	
pH			
TDS	ppm		
EC	µs/cm		
DO	ppm	Titrimetric method	Standard Method(APHA,AWWA&WEF} $_1$*1995*
BOD_5	ppm	Titrimetric method	
COD	ppm	Portable Spectrophotometer,DR/2400,HACH	
Sodium (N^+)	ppm	Flame photometric method (Flame photometer- models PEP 7 and PEP 7/C)	Ramesh and Anbu, 1996
Potassium (K^+)	ppm	Flame Atomic Absorption Spectrophotometer (AAS) AA 240,VARIAN, Australia.	Greenberg, et al., 1992
Calcium (Ca^{2+})	ppm	EDTA, Titrimetric method	Standard method (APHA,AWWA&WEF) ,1995
Magnessium($Mg^{2+)}$	ppm	EDTA, Titrimetric method	
Phosphate ($P0_4^{3-}$)	ppm	Portable Spectrophotometer,DR/2400,HACH	
Chloride(Cl^-)	ppm	Ion Electrode Method (Cole-parmer R 27502-12,-13)	
Bicarbonate(HCO_3^-)	ppm	Potentiometric method.	Ramesh and Anbu, 1996
Sulphate (SO_4^{2-})	ppm	Turbidimetricmethod(Thermospectronic,UV-visibleSpectrophotometers,Helios 9499230 45&11)	
Nitrate (NO_3^-)	ppm	Ultraviolet spectrophotometric Screening method.	Greenberg, et al., 1992

Table 2.6: Parameters and methods of analysis for irrigated soil

Parameters	**Unit**	**Methods/ Instruments**	**Reference**
P^H	--	HANNA instrument, P^H 211 (Microprocessor P^H meter)	Jackson (1973)
EC	(µs/cm)	Electrode Method, Microprocessor conductivity TDS meter, Model No: HI-9635	Petersen (2002)
CEC	cmol/kg	Flame emission spectroscopic method (Flame photometer, model no: PEP 7)	Petersen (2002)
Phosphorus (P)	%	Molybdophosphoric blue color metod in sulfuric acid system (Spectrophotometer, Model: UVG-102010)	Petersen (2002)
Potassium ($K^{+)}$	%	Flame emission spectroscopic method (Flame photometer, model no: PEP 7)	Petersen (2002)

Sulfer (S)	%	Turbidimetric method (Spectrophotometer, Model: UVG-102010)	Black, 1965
Ca++	%	Titrimetric method	Hesse (2002)
Mg++	%	Titrimetric method	Hesse (2002)
Na^+	%	Flame emission spectroscopic method (Flame photometer, model no: PEP 7)	Petersen (2002)

Table 2.7: Parameters and methods of analysis for paddy leaf and rice grain

Parameters	**Unit**	**Methods/ Instruments**	**References**
Total Phosphorus (P)	%	Spectrophotometric method (Model: HITACHI, U-2910)	Allen et al., 1974.
Potassium (K+)	%	Flame emission spectroscopic method (Flame photometer, model no: PEP 7)	Allen et al., 1974.
Sodium (Na)	%	Flame emission spectroscopic method (Flame photometer, model no: PEP 7)	Allen et al., 1974.
Ca++	%	Titrimetric method	Hesse (2002)
Mg++	%	Titrimetric method	Hesse (2002)
Sulfer (S)	%	Turbidimetric method (Spectrophotometer, Model: UVG-102010)	Black, 1965

2.3.5.1 Water and wastewater

The water quality of the irrigation canal was analyzed in the laboratory according to standard methods and by using sophisticated instruments (APHA, 2006; Ramesh and Anbu, 1996). Physico-chemical parameters were determined by using the following methods/instruments. All chemical parameters were at first calculated into parts per million (ppm) and when needed, it was then converted into milliequivalent per liter (meq/l) by using the conversion factors.

Temperature

Temperature was measured at field as described by APHA (2006) and it was done with a good mercury-filled Celsiusthermometer. The thermometer had the capacity of measuring minimum temperature as 10°C, and maximum was 150°C.The thermometer had a minimal thermalcapacity to permit rapid equilibration. In field, the bulb of thermometer containing mercury was immersed in water and kept for several minutes until the mercury level is fixed, and then the reading was taken.

Dissolved Oxygen (DO)

DO was measured at field as described in APHA (2006) by Mancy and Jaffe (1966). A well calibrated DO meter, Model: LT (Lutron YK22 DO; Country of Origin: Taiwan) was used for measuring DO. The meter was first calibrated exactly to obtain guaranteed precision and accuracy.The probe was immersed inside sampled water with care so that air bubble is not entrapped inside the probe. The probe was kept inside water until a fixed reading was shown on the display. Then the result was recorded on the notebook.

Hydrogen Ion Concentration (pH)

pH is an important parameter for assessing water quality. The pH value was measured electronically on a direct reading Microprocessor pH meter (HANNA instruments, Model no: pH 8424; Country of Origin: United States of America) according to the procedure stated in Ramesh &Anbu (1996).First pH meter was standardized by distilled water and buffer solution.Then 50 ml of sample was taken in clean 100 ml plastic beaker and immersed the pH meter and waited for at least five minutes.Then pH reading was collected from pH meter and written down in the notebook.

Electrical Conductivity (EC) and Total Dissolve Solids (TDS)

EC and TDS were measured in parts per million (ppm) by portable water proof Multi range Conductivity/TDS meter (Model no: H1-9635; Country of Origin: Portugal) as the procedure uttered by Ramesh and Anbu (1996). Firstly conductivity/TDS meter was calibrated. 20 ml sample was taken in 50 ml measuring cylinder and immersed the electrode and waited for at least 10 seconds. Then, EC and TDS readings were collected from this meter and wrote down in the notebook.

Sodium (Na^+)

The flame photometric method (Ramesh and Anbu, 1996) was applied for the determination of Na^+ concentration in ppm. Flame photometer (model: PEP 7 and PEP 7/C; Country of origin: United Kingdom) were used for determining the Na^+ concentration.Na^+ standardswere prepared from 1000 ppm stock sodium solution, which was made by dissolving 0.25419 g sodium chloride (NaCl) in 100 ml distilled water. At first, flame photometer was standardized by standard solutions. Standard solutions were analyzed by flame photometer and the absorbances were recorded and in the same way samples were analyzed. Blank sample absorbance was always zero.

Potassium (K^+)

The flame photometric method (Ramesh and Anbu, 1996) was applied for the determination of K^+ concentration in ppm. Flame photometer (model: PEP 7 and PEP 7/C; Country of origin: United Kingdom) were used for determining the K^+ concentration. K^+ standardswere prepared from 1000 ppm stock solutions, which was made by dissolving 0.1907 g potassium chloride (KCl) in 100 ml distilled water.Flame photometer was first standardized by standard solutions. Standard solutions and samples were analyzed by flame photometer and the absorbances were recorded. Blank sample absorbance was always zero.

Calcium (Ca^{2+}) and Magnesium (Mg^{2+})

Titrimetric method (Ramesh and Anbu, 1996) was applied for determination of Ca^{2+} and Mg^{2+} concentrations in ppm.20 ml sample was taken into a 100 ml clean beaker and diluted it with 25 ml of distilled water and then 2 ml ammonium chloride-ammonia buffer solution and 30-40 mg Eriochrome Black-T indicator was added.It was titrated with the 0.01 M EDTA solution until the color changed from wine red to steel blue.No tinge of reddish hue was remained at the equivalent point. A blank sample (distilled water) was analyzed.For measuring Ca^{2+} content,20 ml sample was taken into a 100 ml biker and diluted with 25 ml of distilled water. Then 2 ml of 1N sodium hydroxide solution and 30-40 mg of murexide indicator was added. It was titrated with 0.01 M EDTA solution until the color changed from red to blue-violet. A blank sample was also analyzed.

Chloride (Cl^-)

Argentometric/ Mohr's Titration Method according to Ramesh and Anbu(1996) was used to measure Cl^-.20 ml of the sample was taken into a 250 ml clean conical flask and 1 ml of potassium chromate indicator solution was added using a pipette. Then, 0.05 N silver nitrate solution was added from a burette drop wise, by swirling the liquid constantly until a red color is formed. The titration was continued, until a faint but distinct change in color occurs which is the end point.

Bicarbonate (HCO_3^-)

Potentiometric method (Ramesh and Anbu, 1996) was applied for the determination of bicarbonate in ppm unit.pH/millivolt meter (HANNA instruments, Model no: p^H 8424; Country of Origin: United States of America) was used. 50 ml water sample was taken into a clean biker. It was titrated against 0.02 N hydrochloric acid (HCl) from the burette till the pH fixed at 4.5. Similarly, the bicarbonate standard solutions were titrated.

Nitrate (NO_3^-)

Spectrophotometric method (APHA, 2006) was applied and thermo-spectronic UV-visible spectrophotometer (Model: Helios, UVG-102010; Country of origin: England) was used for determining NO_3^- concentration.50 ml sample was taken and added 0.1 ml of HCl by the micropipette and mixed it well.The absorbance was measured at 220 nm and 275 nm in a 1 cm cell against reagent blank distilled as reference.

Ortho-Phosphate (PO_4^{3-})

PO_4^{3-} concentration was measured by spectrophotometric method (Ramesh and Anbu, 1996) by using thermo-spectronic UV-visible spectrophotometer (Model: Helios, UVG-102010; Country of origin: England). 0.1433 g anhydrous KH_2PO_4 was dissolved in distilled water and diluted to 100 ml to prepare 1000 ppm stock phosphate solution. In 25 ml sample water, 0.025 ml phenolphthalein indicator and 4 ml combined reagent was added and mixed it thoroughly.After 10 minute, but not more than 30 minute absorbance of samples were measured at 880 nm using reagent blank as reference.

Sulphate (SO_4^{2-})

Sulphate concentration was measured by spectrophotometric method (Ramesh and Anbu, 1996) with a thermo-spectronic UV-visible spectrophotometer (Model: Helios, UVG-102010; Country of origin: England). 0.1479 g of Na_2SO_4 was dissolved in distilled water and diluted to 100 ml to prepare 1000 ppm standard sulphate solution.In 20 ml sample 5 ml conditioning reagent was added and mixed well.The beaker was constantly stirred and continued for 1 minute after addition of barium chloride.The turbidity was measured at 420 nm after stirring for 5 minutes.

2.3.5.2 Irrigated soil

Soil samples were prepared as described by Petersen (2002).The soil samples were placed in a thin layer on a clean piece of paper in the soil preparation room and left until air dried. Visible roots and plant fragments were removed from the soil sample and discarded. The sample were taken in a polythene bag and hit gently with a wooded hammer inside a jutesack. The entire soil samples were passed through a 2 mm stainless steel sieve. It was then stored in a plastic container to avoid moister. The sieve was cleaned properly before sieving the next soil sample.

Soil pH

The most important chemical property of soil is pH that directly or indirectly influences all soil properties. Soil pH was measured by glass electrode method suggested by Jackson (1973) by Microprocessor pH meter (HANNA instruments, Model no: p^H 8424; Country of Origin: United States of America).20 g air dried soil was taken into a 100 ml beaker and 50 ml distilled water (dw) was added (soil: dw = 1: 2.5).

The mixture was stirred for half an hour, left in rest to settle down the soil and the electrode of the pH meter was immerged into the overlying water. Electrode was not allowed to touch the underlying soil. The electrode was washed for several times before use again.pH of soil samples was evaluated by comparing with the Table 3.5.

Soil Electrical Conductivity (EC)

The true soil salinity is the dissolved salt content in soil solution. ECwas measured in μS/cm by portable water proof Multi range Conductivity/TDS meter (Model no: H1-9635; Country of Origin: Portugal) as the procedure described by Petersen (2002).10 g air dried soil was taken into a 100 ml beaker and 50 ml dw was added (soil:dw = 1:5).The mixture was stirred for half an hour and filtered with WN-1 filter paper. The

EC meter electrode was inserted into the aliquate. The EC reading was recorded. EC values of soil samples were compared with the following Table 3.2.

Soil Sodium (Na^+)

Both soil salinity (EC) and pH is related with the presence of Na^+ in soil. The flame photometric method(Petersen, 2002) was applied for the determination of Na^+ concentration by using Flame photometer (Model: Jenway, PEP 7 and PEP 7/C, Country of origin: United Kingdom). 8 g air dried soil was taken into a 250 ml conical flask.40 ml NH_4OAc (1 N, pH-7) was added and the content was shakedfor 30 minutes, and then filtered with WN-1 filter paper.1000ppmstandard Na^+ solution was prepared by dissolving 0.25419 g sodium chloride (NaCl) in 100 ml distilled water. Flame photometer readingwas taken of standard solutions, sample and blank.

Soil Potassium (K^+)

Potassium is present in relatively large quantities in most soils, averaging about 1.9%. Potassium was measured according to Petersen (2002) by usingFlame photometer (Model: Jenway, PEP 7 and PEP 7/C, Country of origin: United Kingdom). 4 g air dried soil was taken into a 250 ml conical flask.40 ml NH_4OAc (1 N, pH-7) was added. The content was shakedfor 30 minutes, and filtered WN-1 filter paper. 1000 ppm Standard K^+ solution was preparedby dissolving 0.19067 gmKCl in distilled water into a 100 ml volumetric flask. Flame photometer reading was taken of standard solutions, sample and blank.To convert K^+ content in ppm to meq/100 gm soil, it was multiplied by 0.1 and divide by equivalent weight of potassium (39.102). After that the analyzed data were compared with Table 3.7 to identify the status of soil Potassium.

Soil Calcium (Ca^{++}) and Magnesium (Mg^{++})

Plant takes up $Ca^{2+}Mg^{2+}$ from soil solution. The quantity of Mg^{2+} taken up by plants is usually less than that of both Ca^{2+} and K^+. Calcium (Ca^{++}) and Magnesium (Mg^{++}) was determined by titrimetric method described in Hesse (2002). For Ca^{2+}determination, 4 g air dried soil was taken into a 250 ml conical flask and 40 ml 1 N NH_4OAc (pH-7) was added (Soil:extractant = 1:10). The mixture was shaked thoroughly for half an hour and then filterd with WN-1 filter paper. In 5 ml aliquot taken in 100 ml beaker, 5.5 ml NaOH (10%) and 0.02 to 0.05 g murexide indicator was added. The mixture appeared pink which confirms the presence of Ca^{++}. It was titrated against 0.01 N EDTA solution until the colour appeared purple.A blank titration was done.

For Magnesium determination 4g air dried soil was taken into a 250 ml conical flask and 40 ml 1 N NH_4OAc (pH-7) was added (Soil:Extractant = 1:10). The mixture was shaked thoroughly for half an hour and then filtered with WN-1 filter paper. In 5 ml aliquot taken in 100 ml beaker, 25 ml dw, 10 ml buffer solution (pH-10), 10 drops potassium ferrocyanide, 10 drops HAH and 5 drops TEA was added in sequence. The contents was mixed thoroughly and left for 15 to 30 minutes to complete the chelation reactions.3 drops EBT solution was added just prior to titration. Appearance of the mixture red indicates the presence of Ca^{++} and Mg^{++} in the solution. It was titrated against 0.01 N EDTA solution until the color appeared blue.A blank titration was run. It was compared with Table 3.7, to find the suitability of the soil for rice production.

Soil Sulfur (S)

Solution plus adsorbed SO_4^{2-} represents the readily available fraction of S utilized by plants. The available sulfer was measured by turbidimetric method (Black, 1965) by using a UV specto-photometer (Model: HITACHI, U-2910; Country of origin: Japan).5 g fresh air dried soil was taken in a 250 ml conical flask and 40 ml 500 ppm P solution was added (Soil : Extractant = 1 : 8). The content was shaken for 30 minutes and filtered by using WN-1 filter paper.1000 ppm Standard S solution was prepared by dissolving 0.5435 g K_2SO_4 into 100 ml volumetric flask.In 10 ml extract which was taken into a 100 ml beaker; 1 ml 6N HCl solution, 3 ml $BaCl_2$-Tween 80 solution was added. Finally the volume was made 25 ml with dwand Spectrophotometer reading (absorbance) was taken at 420 nm wavelength between 10 to 30 minutes. The concentration was compared with Table 3.7.

Soil Available Phosphorus (P)

Phosphorus is absorbed by plants largely as orthophosphate ions ($H_2PO_4^-$ and HPO_4^{2-}), but plant uptake of HPO_4^{2-} is much slower than $H_2PO_4^-$. As soil pH was> 5.5, so Olsen extractant (0.5 N $NaHCO_3$ at pH-8.5) was used for extracting available P (Olsen et al., 1954) using molybdophosphoric blue colour method in sulfuric acid systemdescribed in Petersen (2002). 2 gm air dried soil was taken into a 250 ml conical flask, and 40 ml 0.5 N $NaHCO_3$ solution (extractant) was added. The content was shaked for 30 minutes, thenn filtered with WN-1 filter paper. Charcoal was added to remove yellow coloured fulvic acid molecules, and again filtered. 1000 ppm Standard P solution was prepared by dissolving 0.4394 g KH_2PO_4 into a 100 ml volumetric flask.pH of the sampleswas fixed at 3.0 to 3.05. 10 ml of the sample was taken in a 100 ml beaker and 4 ml colouring reagent was added and mixed thoroughly. Finally the volume was made 25 ml. After 10 minute, spectrophotometer reading was taken at 882 nm. The concentration was compared with Table 3.7.

For evaluating chemical characteristics, soil samples were analyzed in the laboratory for pH, Electrical Conductivity (EC),Organic matter (OM),available Nitrogen (N), available Phosphorous (P), Potassium (K^+), Sulfur (S), Calcium (Ca^+), Magnesium (Mg^+), and Sodium (Na^+).

2.3.5.3 Paddy leaf

2.3.5.3.1 Sample preparation

Plant samples were prepared as described in Petersen (2002). Just prior to weighing for analysis, the grinded samples which were preserved in a plastic container,were re-dried in oven at 65^0 to 70^0 C temperature for about an hour to obtain a constant weight.

2.3.5.3.2 Chemical analysis of paddy leaf and rice grain

Total Phosphorus (P)

Spectrophotometric method was used for the determination of total phosphorus (P) in plant as cited in Allen *et al.*, 1974. At first, 0.1 g of plant sample was digested by using digestion chamber (VelpScientifica; Model: F 30620198; Country of origin: England).1000 ppm stock solution was prepared by dissolving 1.433 gm KH_2PO_4 in 1000 ml distilled water.1 ml of digested was diluted 10 times. Then 1 ml of mixing reagent was added. Finally, the standard and sample reading were taken in UV specto-photometer (Model: HITACHI, U-2910) at 885 nm wavelength to measure Phosphorus (P).

Sodium (Na) and Potassium (K)

Flame Photometry method was used for determination of Na and K as cited in Allen *et al.,* 1974; by using Flame photometer (Model: Jenway, PEP 7 and PEP 7/C, Country of origin: United Kingdom).0.1 g of plant sample was digested in digestion chamber (VelpScientifica; Model: F 30620198; Country of origin: England). 1 ml of digested solution diluted 10 times. Then, the reading in flame photometer for the measurement of Sodium (Na) and Potassium (K) was taken.

Sulfur (S)

Solution plus adsorbed SO_4^{2-} represents the readily available fraction of S utilized by plants. The available sulfer was measured by turbidimetric method (Black, 1965) by using a UV specto-photometer (Model: HITACHI, U-2910; Country of origin: Japan).5 g fresh air dried soil was taken in a 250 ml conical flask and 40 ml 500 ppm P solution was added (Soil : Extractant = 1 : 8). The content was shaken for 30 minutes and filtered by using WN-1 filter paper.1000 ppm Standard S solution was prepared by dissolving 0.5435 g K_2SO_4 into 100 ml volumetric flask.In 10 ml extract which was taken into a 100 ml beaker; 1 ml 6N HCl solution, 3 ml $BaCl_2$-Tween 80 solution was added. Finally the volume was made 25 ml with dwand Spectrophotometer reading (absorbance) was taken at 420 nm wavelength between 10 to 30 minutes. The concentration was compared with Table 3.7.

Calcium (Ca^{2+}) and Magnesium (Mg^{2+})

Titrimetric method (Ramesh and Anbu, 1996) was applied for determination of Ca^{2+} and Mg^{2+} concentrations in ppm.20 ml sample was taken into a 100 ml clean beaker and diluted it with 25 ml of distilled water and then 2 ml ammonium chloride-ammonia buffer solution and 30-40 mg Eriochrome Black-T indicator was added.It was titrated with the 0.01 M EDTA solution until the color changed from wine red to steel blue.No tinge of reddish hue was remained at the equivalent point. A blank sample (distilled water) was analyzed. For measuring Ca^{2+} content,20 ml sample was taken into a 100 ml biker and diluted with 25 ml of distilled water. Then 2 ml of 1N sodium hydroxide solution and 30-40 mg of murexide indicator was added.

2.3.5.3.3 Rice grain

Rice grain was analysed by using the same procedure which was applied in case of paddy leaf analysis. The data were processed and analyzed by using MS Excel of Office 2007 version. All the results of interpretation are presented in tables and graphs using MS Word of Office 2007 and MS Excel of Office 2007.

2.3.6 Survey for agronomic parameters

The surveys data were categorized and analyzed by using MS Excel 2007 were used whereas MS Word 2007 was used for table representation. Rice varieties which are most suitable for cultivating in the study area were screened out by comparing the average yield of eight rice varieties.

CHAPTER THREE

RESULT AND DISCUSSION

3.1 Introduction

The quality of irrigation water and its nutrient content is essential for judging its suitability for irrigation purposes and contribution to plant supply. In this chapter, at first the quality of the irrigation water of irrigation water of has been evaluated by comparing with the standards and using graphs. In addition, nutrient status of soil, paddy leaf and rice grain were also evaluated. The impact of wastewater on soil, paddy leaf, and various growth and yield parameters were detected.

3.2 Hydrochemistry of the Conventional and Non-conventional Irrigation Waters

The major components of natural water are Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, HCO_3^{-}, SO_4^{2-}, SiO_2 and trace elements (Berner and Berner, 1987). Analyzed results of physico-chemical parameters of water samples at different growth stages are presented in Appendix (Table 3.1).

Average temperature of the water throughout the growth stages is within the range of 18.7 to 33.75°C; whereas minimum and maximum level is found to be 18.7 and 33.75°C at “before ploughing stage” and “post harvest stage”, respectively. This might be due to the increasing of temperature of the atmosphere. Average pH level is within the range of 6.52 to 7.86, whereas minimum level is found at “before ploughing stage” and maximum level is at “post harvest stage” in three selective sites. pH found in control site ranged between 6.52 to 6.89 which indicate normal range. In the pH level showed an increasing trend throughout the growth stages. This is happened most probably due to increasing alkaline salt concentration.

The electrical conductivity is the measure of capacity of a substance or solution to carry an electrical current. The conductivity is represented by the reciprocal value of electrical resistance in ohms relative to cubic centimeter of water 25°C. The electrical conductivity is a total parameter for dissolved and dissociated substances. Its value depends on the concentrations and degree of dissociation of the ions as well as the temperature and migration velocity of the ion in the electric field.

EC value in the irrigation waters were found ranged between 503.80 to 2896.00 µs/cm in the control site, 1550.00 to 8636.00 µs/cm in the polluted water site (river water site), 1600.00 to 3215.00 µs/cm in the wastewater site for the respective growing seasons. EC level also showed an increasing trend throughout the growth stages in the three selective sites. It might be happened due to sea water intrusion and decreased water volume. EC value is highest in the river water site it may be due to the electrical charge of cations (positive) and anions (negative). Generally, water with large amount of dissolved ions will show higher conductivity compared to dilute waters (Subramanian, 2000).

In non-conventional water, dissolved solids consists mainly of inorganic salts such as carbonates, bicarbonates, chlorides, phosphate and nitrates of calcium, magnesium, sodium, potassium, iron etc. and small amount of organic matter and dissolved gases. The determination of dissolved solids does not give a clear picture of the kind of pollution. TDS were found ranged between 289.50 to 2009.60 mg/l in the control site, 1152.00 to 6210.80 mg/l in the river water site and 1009.00 to 2411.25 mg/l in the wastewater site for the respective growing seasons. According to agriculture water quality standard (Table 3.7) the recommended TDS for Irrigation for all the options is (0 – 2000) mg/l. So in Control Site BPS, VS, RiS and ReS are Suitable but PHS exceeds the recommended value (Table 3.1) and hence unsuitable. Similarly in Polluted Water Site BPS,VS are Suitable but RiS , ReS and PHS exceeds the recommended value and hence unsuitable. In Wastewater Site BPS, VS, RiS and ReS are Suitable but PHS exceeds the recommended value and hence Unsuitable. TDS also demonstrated increasing trend throughout the growth stages in the three selective sites. TDS value is highest in the river water site rather than that of other two sites because of EC. Total Dissolved Solids of water is interrelated to the electrical conductivity. TDS content of water increases with the increasing of EC.

Dissolved oxygen is one of the most important factors in water quality assessment and reflects the physical and biological processes prevailing in the natural water. The main source of dissolved oxygen is the diffusion from the atmosphere and the photosynthetic evolution. Welch (1952) pointed out that under natural conditions, the running waters typically contain a relatively high concentration of dissolved oxygen tending towards saturation. DO were found ranged between 4.15 to 7.15 mg/l in the control site, 1.57

to 3.70 mg/l in the river water site and 0.65 to 3.20 mg/l in the wastewater site for the respective growing seasons.

However the recommended DO for Irrigation for all the options is 5ppm (Table 3.7). So in control site BPS and VS are unsuitable but RiS, ReS and PHS are Suitable (Table 3.7). In Polluted Water Site BPS, VS, RiS, ReS and PHS all are suitable. Similarly in wastewater site BPS, VS, RiS, ReS and PHS all are Suitable. DO values showed an decreasing trend throughout the growth stages in the three selective sites. Decreased level of DO might be due to the decreased volume of water as well as increased pollution load and temperature. From the table 3.1°C it is observed that the temperature is highest in the control site rather than that of other two sites. Maximum DO is at before ploughin stage 7.15 mg/l with temperature 18.7 in control site where as minimum DO is at post harvest stage 0.65 mg/l with temperature 33.0°C. Thomas (1969) has reported low solubility of oxygen at higher temperature. Which is also in close accordance with the present study, loss of oxygen to the atmosphere and its utilization by faster decomposition of organic matter at higher temperature seems to be the cause for such an observation.

BOD_5 is found ranged between 6.20 to 29.00 mg/l in the control site, 18.00 to 84.00 mg/l in the river water site and 125 to 370 mg/l in the wastewater site for the respective growing seasons. The recommended BOD for Irrigation for all the options is 10 ppm (Table 3.7). In control site BPS and VS are suitable but RiS , ReS and PHS are unsuitable (Table 3.1) . In polluted water Site BPS,VS, RiS , ReS and PHS all are unsuitable . Similarly in wastewater site BPS, VS, RiS , ReS and PHS all are unsuitable (Table 3.1)

COD is found ranged between 9.52 to 44.62 mg/l in the control site, 18.00 to 84.00 mg/l in the river water site and 192.31 to 569.23 mg/l in the wastewater site for the respective growing seasons. TDS also showed increasing trend throughout the growth stages in the three selective sites.

The range of average Sodium (Na^+) of the irrigation water is found ranged between 27.47 to 207.26 mg/l in the control site, 296.66 to 2519.40 mg/l in the river water site and 212.0 to 266.0 mg/l in the wastewater site for the respective growing seasons. However the recommended sodium (Na^+) for Irrigation for all the options is 0 – 40 meq/L (Table 3.7). In control site BPS is suitable but VS, RiS , ReS and PHS all are unsuitable. In polluted water site BPS,VS, RiS , ReS and PHS all are unsuitable. similarly in wastewater site BPS,VS, RiS , ReS and PHS all are unsuitable. Na^{+} also demonstrated increasing trend throughout the growth stages in the three selective sites. Hardness results from the presence of the bivalent metallic cations, of which calcium and magnesium are the most, dominate (Todd, 1980). Ca^{2+} is found ranged between 21.10 to 31.80 mg/l in the control site, 52.00 to 181.56 mg/l in the river water site and 26.23 to 104.20 mg/l in the wastewater site for the respective growing seasons. Recommended Ca^{2+} for Irrigation for all the options is 0 – 20 meq/L (Table 3.7). In control water site BPS,VS, RiS , ReS and PHS all are unsuitable. In polluted water site BPS,VS, RiS , ReS and PHS all are unsuitable. Similarly in wastewater site BPS,VS, RiS , ReS and PHS all are unsuitable. Mg^{2+} is found ranged between 5.42 to 30.02 mg/l in the control site, 23.40 to 80.00 mg/l in the river water site and 26.23 to 72.92 mg/l in the wastewater site for the respective growing seasons. However the Recommended Mg^{2+} for Irrigation for all the options is 0 – 5 meq/L. In Control Water Site BPS, VS, RiS, ReS and PHS all are Unsuitable. In polluted water site BPS, VS, RiS , ReS and PHS all are unsuitable. Similarly in wastewater site BPS,VS, RiS , ReS and PHS all are unsuitable. Ca^{2+} and Mg^{2+} concentration of the water showed an increasing trend throughout the growth stages it might be happened due to sea water intrusion. Generally, Mg level is decreasing with in small amount and this may be due to the increase of sodium level in wastewater as the volume of Mg is replaced by Na.

Chlorides in the form of chloride ions are one of the major inorganic anions present in natural waters. Only the water containing 250 mg/l chloride and above may have a detectable salty taste if the cation is sodium, on the other hand, the typical salty taste may be absent in waters containing as much as 1000 mg/l chlorides, when the predominate cations are calcium and magnesium (APHA, 1976). The range of average Cl^{-} of the irrigation water is found between 227.91 to 2498.6 mg/l in the control site, 167.30 to 254.00 mg/l in the river water site and 2498.6 to 254.00 mg/l in the wastewater site for the respective growing seasons. However the Recommended Cl^{-} for Irrigation for all the options is 0 - 30 meq/L. In Control Water Site BPS is suitable but VS, RiS , ReS and PHS are Unsuitable. In Polluted Water Site BPS,VS, RiS , ReS and PHS all are unsuitable. Similarly in Wastewater site BPS,VS, RiS , ReS and PHS all are unsuitable. Cl^{-} also demonstrated increasing trend throughout the growth stages in the three selective sites. Cl^{-} also showed increasing trend throughout the growth stages in the three selective sites. Cl^- concentration is highest in polluted river water site. This may be due to presence of large amount of organic matter in the water Adoni (1985).

Bicarbonate is one of the most important parameter in water, particularly wastewaters. It is generated in the chemical reactions between soil minerals and water presence of atmospheric CO_2 and hence always present in any water bodies. Bicarbonate also determines how hard is given water for drinking purposes (Subramanian, 2000). The range of average HCO_3^- of the irrigation water is found ranged between 155.99 to 235.22 mg/l in the control site, 290.36 to 554.21 mg/l in the river water site and 158.6 to 385.2 mg/l in the wastewater site for the respective growing seasons. The Recommended HCO_3^- for Irrigation for all the options is 0 - 10 meq/L (Table 3.7). In control water site BPS, VS, RiS and ReS and PHS all are Unsuitable. In polluted water site BPS,VS, RiS , ReS and PHS all are unsuitable. Similarly in wastewater site BPS, VS, RiS and ReS and PHS all are Unsuitable. Cl^- also demonstrated increasing trend throughout the growth stages in the three selective sites. HCO_3^- concentration is heights in polluted river water site it may be due to the presence of excess of free carbon dioxide produced in the process of decomposition.

Sulfate (SO_4^{2-}) is one of the major anions occurring in natural water. Sulfate being a stable, highly oxidized and soluble form of sulfur is the form in which the element is generally present in natural surface and ground water. SO_4^{2-} is found ranged between 7.50 to 117.41 mg/l in the control site, 19.72 to 172.39 mg/l in the river water site and 19.76 to 77.05 mg/l in the wastewater site for the respective growing seasons. The recommended SO_4^{2-} for Irrigation for all the options is 0 - 20 meq/L (Table 3.7). In control water site BPS,VS are suitable but RiS , ReS and PHS all are unsuitable. In polluted Water Site BPS,VS, RiS and ReS and PHS all are unsuitable. Similarly in wastewater site BPS,VS, RiS , ReS and PHS all are unsuitable. SO_4^{2-} also demonstrated increasing trend throughout the growth stages in the three selective sites. HCO_3^- concentration is heights in polluted river water site rather than that of other two sites it is due to infiltration-waters and surface run-off.

Nitrates are widely present in substantial quantities in soil, in most waters and in plants. Nitrate is toxic when present in excessive in water. The productivity of natural waters in terms of algal growth is related to the fertilizing matter that gains entrance to them. Nitrogen in its various forms is a major consideration. Also reduced forms of nitrogen are oxidized in natural water, there by affecting the dissolved oxygen resources. NO_3^- is found ranged between 2.43 to 3.97 mg/l in the control site, 4.93 to 7.97 mg/l in the river water site and 0.5 to 1.8 mg/l in the wastewater site for the respective growing seasons. It showed decreasing patterns throughout the growing stages of the rice cultivation this may be due to the application of urea fertilizer in the agricultural field.

In natural waters, phosphorus occurs principally as inorganic orthophosphate. Phosphorus determination is extremely important in assessing the potential biological productivity of water. PO_4^{2-} is found ranged between 0.08 to 0.08 mg/l in the control site, 5.17 to 8.79 mg/l in the river water site and 1.16 to 3.95 mg/l in the wastewater site for the respective growing seasons. However the Recommended PO_4^{2-} for Irrigation for all the options is 10 ppm. In Control Water Site BPS,VS, RiS and ReS and PHS all are suitable. In Polluted Water Site BPS, VS, RiS and ReS and PHS all are suitable. Similarly in Wastewater site BPS,VS, RiS, ReS and PHS all are suitable. It showed increasing patterns throughout the growing stages of the rice cultivation this may be due to the application of fertilizer.

3.3 Chemical Properties of Irrigated Soil

It is obvious that soil chemical properties are mainly affected by the applied water properties. The level of nutrients in soil is proportionally affected by that in irrigated water and sometimes it may increase due to nutrients accumulation especially in low permeable soil and/or low leaching fraction application. In order to identify the soil status in the wastewater site, Polluted water site (river water site), and fresh water or controlsiteof the study area, pH, EC, cation exchange capacity (CEC), available (P), available (K), available (S), available (Na), available (Mg), and available (Ca) were analyzed in the laboratory, which is provided in the Appendix (Table 3.2).

3.3.1 Variations of soil pH

Significance of pH lies in its influence on availability of soil nutrients, solubility of toxic nutrients elements in soil, physical breakdown of root cells, cation exchange capacity in soils whose colloids (clay/ humus). Soil pH is affected by the duration of wastewater irrigation. Many researches pointed that there is inconsistency in wastewater effect on soil pH (Rusan et al, 2007). pH is observed from Table 3.2 that, at before plowing stage the average range of soil pH in the wastewater site of the three selective plots ($P_1T_1S_1$, $P_1T_1S_2$, and $P_1T_1S_3$) is 7.69, Polluted water site (river water site) ($P_1T_2S_1$, $P_1T_2S_2$, and $P_1T_2S_3$) is 7.52 and fresh water or control site ($P_1T_3S_1$, $P_1T_3S_2$, and $P_1T_3S_3$) is 7.71. It is also measured that in the vegetative stage the average pH in the wastewater site ($P_2T_1S_1$, $P_2T_1S_2$, and $P_2T_1S_3$) is 7.79, river water site ($P_2T_2S_1$, $P_2T_2S_2$, and $P_2T_2S_3$) is 7.45 and fresh water or control site ($P_2T_3S_1$, $P_2T_3S_2$, and $P_2T_3S_3$) is 7.76. At reproductive stage the average pH of soil in the wastewater site ($P_3T_1S_1$, $P_3T_1S_2$, and $P_3T_1S_3$) is 7.77, river water site ($P_3T_2S_1$, $P_3T_2S_2$ and $P_3T_2S_3$) is 7.65 and fresh water or control site ($P_3T_3S_1$, $P_3T_3S_2$ and $P_3T_3S_3$) is 7.72. At post harvest stage the average pH of soil in the wastewater site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 7.47, river water site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 7.48 and fresh water or control site ($P_3T_1S_4$, $P_3T_2S_4$ and $P_3T_3S_4$) is 7.44. Variations of soil pH in four growing seasons in three selective sites are shown in Figure 3.1

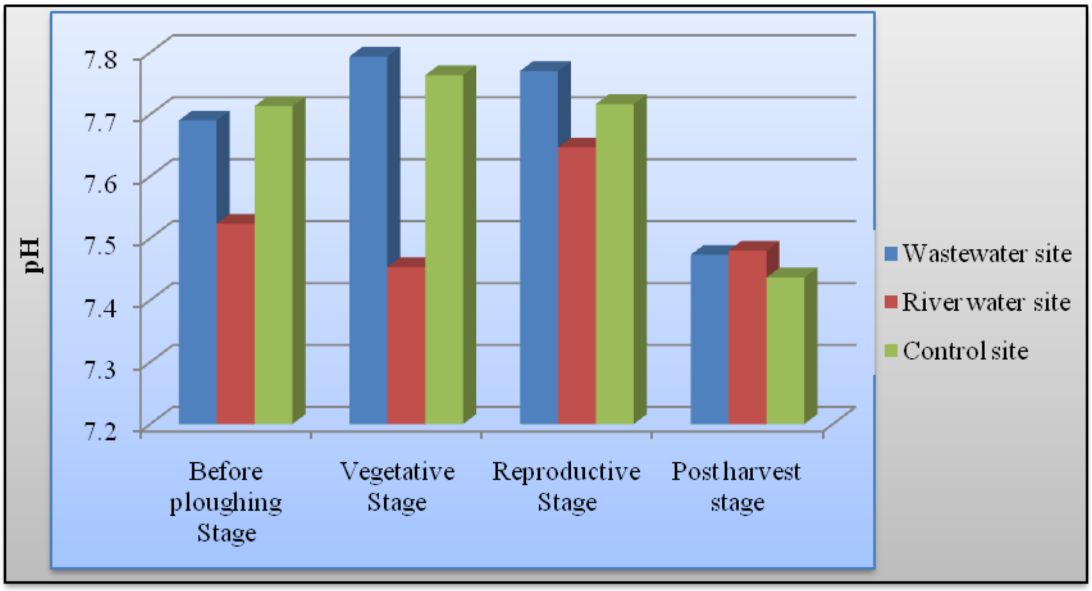

Figure 3.1: Variations of soil pH at various rice growing stages

From the Figure 3.1 it is observed that the pH value of four rice growing stages is neutral. At before ploughing pH is relatively high in control site and low in wastewater site and river water site it may be due to the presence of lime in it. At vegetative stage it is increased in iste water site and control site but decreased in case of river water site it may be organic acids formation. At reproductive stage the change is remains same in case of control sit and wastewater site but river water site it is increased. This result also indicated that long term use of wastewater application result in soil pH decrease for both soil layers (Nada, 2009). At the post harvest stage the value of pH is decreased with respect to other stages of three selective sites this may due to humus increment causing formation of organic acids.

3.3.2 Variations of soil electrical conductivity (EC)

The variable EC is used to monitor soil salinity, due to the particularly of measurement and high correlation with the amount of soluble salts, since it represent the phenomenon of transfer of electric current exerted by charged particles, ionic solutions (cations and anions) and colloids on a force applied to an electric field (Ponnamperuma, 1972). The true soil salinity is the dissolved salts content in the soil solution. Crops are differing in its resistance to salts. Salinity is expected to cause yield reduction of crops for various levels of soil salinity under normal growing conditions. When salt accumulate in soil, the soil solution osmotic pressure increases. EC is observed from Table 3.2 that, at before plowing stage the average range of soil EC in the wastewater site of the three selective plots ($P_1T_1S_1$, $P_1T_1S_2$, and $P_1T_1S_3$) is 2597.843 µs/cm, river water site ($P_1T_2S_1$, $P_1T_2S_2$, and $P_1T_2S_3$) is 3959.735 µs/cm and fresh water or control site ($P_1T_3S_1$, $P_1T_3S_2$, and $P_1T_3S_3$) is 7578.518 µs/cm. It is also measured that in the vegetative stage the average EC in the wastewater site ($P_2T_1S_1$, $P_2T_1S_2$, and $P_2T_1S_3$) is 3789.685 µs/cm, river water site ($P_2T_2S_1$, $P_2T_2S_2$, and $P_2T_2S_3$) is 4829.377 µs/cm and fresh water or control site ($P_2T_3S_1$, $P_2T_3S_2$, and $P_2T_3S_3$) is 3148.268 µs/cm. At Reproductive stage the average EC of soil in the wastewater site ($P_3T_1S_1$, $P_3T_1S_2$, and $P_3T_1S_3$) is 5873.543 µs/cm, river water site ($P_3T_2S_1$, $P_3T_2S_2$, $P_3T_2S_3$) is 4993.46 µs/cm and fresh water or control site ($P_3T_3S_1$, $P_3T_3S_2$ and $P_3T_3S_3$) is 62367.33 µs/cm. At post harvest stage the average EC of soil in the wastewater site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 2667.952 µs/cm, river water site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 1614.835 µs/cm and fresh water or control site ($P_3T_1S_4$, $P_3T_2S_4$ and $P_3T_3S_4$) is 1695.385 µs/cm. EC Variations of soil in four growing seasons in three selective sites are shown in Figure 3.2

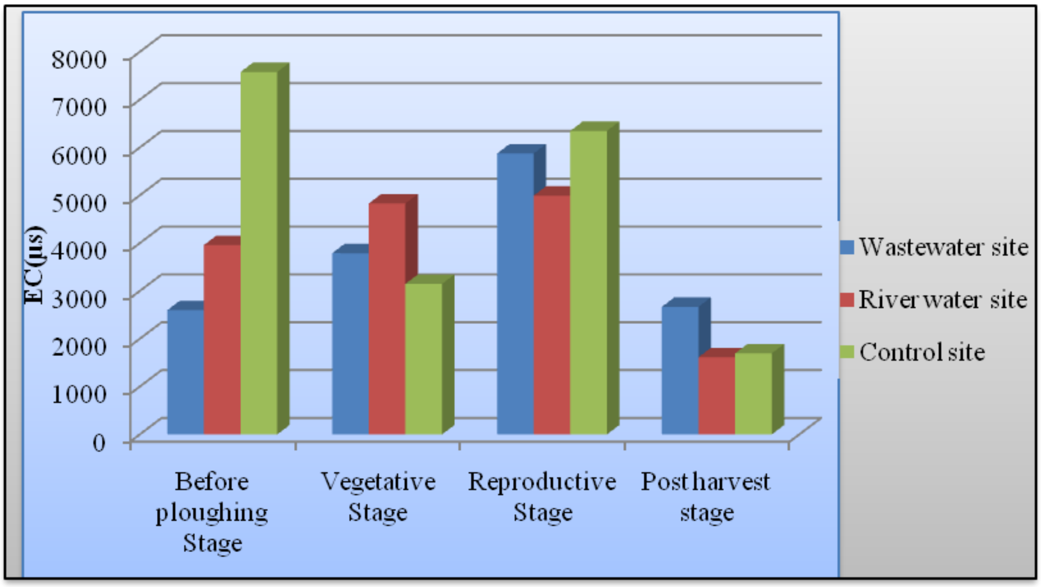

Figure 3.2: Variations of soil electrical conductivity (EC) at various rice growing stages

The EC is maximum at before plowing stage in control site (Figure 3.2) due to the presence of salts. At vegetative stage it is decreased in case of control site and in river water sites it is increased. At reproductive stage it is increased in case of three respective sites it may be due to the fertilizer application. At post harvest stage it is decreased in case of all selective sites, maximum EC is showed in wastewater site it may be high SAR. Generally sodium adsorption ratio (SAR) is higher in domestic wastewater rather than that of and fresh water (Kiran D, 2012)

3.3.3 Variations of soil cation exchange capacity (CEC)

CEC is observed from Table 3.2 that, at before plowing stage the average range of soil CEC in the wastewater site of the three selective plots ($P_1T_1S_1$, $P_1T_1S_2$, and $P_1T_1S_3$) is 38.96623 cmol/kg, river water site ($P_1T_2S_1$, $P_1T_2S_2$, and $P_1T_2S_3$) is 10.4907 cmol/kg and fresh water or control site ($P_1T_3S_1$, $P_1T_3S_2$, and $P_1T_3S_3$) is 14.12493 cmol/kg. It is also measured that in the vegetative stage the average CEC in the wastewater site ($P_2T_1S_1$, $P_2T_1S_2$, and $P_2T_1S_3$) is 14.5983 cmol/kg, river water site ($P_2T_2S_1$, $P_2T_2S_2$, and $P_2T_2S_3$) is 12.80973 cmol/kg and fresh water or control site ($P_2T_3S_1$, $P_2T_3S_2$, and $P_2T_3S_3$) is 17.0799 cmol/kg. At Reproductive stage the average CEC of soil in the wastewater site ($P_3T_1S_1$, $P_3T_1S_2$, and $P_3T_1S_3$) is 22.55807 cmol/kg, river water site ($P_3T_2S_1$, $P_3T_2S_2$ and $P_3T_2S_3$) is 28.84807 cmol/kg and fresh water or control site ($P_3T_3S_1$, $P_3T_3S_2$ and $P_3T_3S_3$) is 22.89753 cmol/kg. At post harvest stage the average CEC of soil in the wastewater site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 25.11063 cmol/kg, river water site

($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 24.03757 cmol/kg and fresh water or control site ($P_3T_1S_4$, $P_3T_2S_4$ and $P_3T_3S_4$) is 22.48915 cmol/kg. CEC variations of soil in four growing seasons in three selective sites are shown in Figure 3.3.

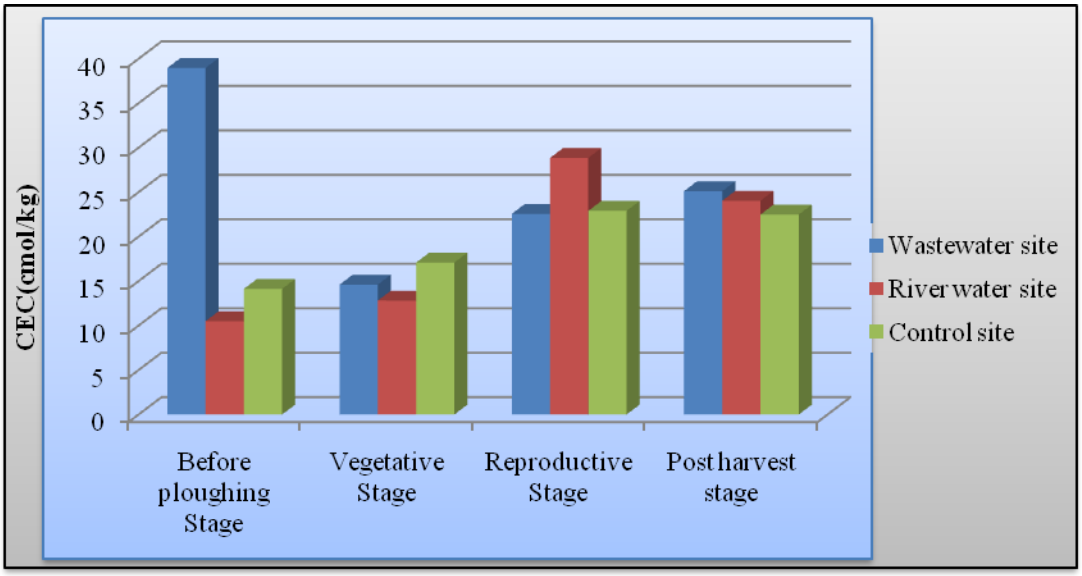

Figure 3.3: Variations of soil cation exchange capacity (CEC) at various rice growing stages

From the Figure 3.3 it is observed that in control site CSE is showed an increasing trend from before plouging stage to other growing stages. This is indicating that soil has a greater capacity to hold cations. But maximum CEC showed in wastewater site at before plowing stage with respect to other two sites. It decreases in the vegetative stage and it also showed a spatial increasing trend among, polluted water and control sites showed same state. These types of Variations showed because soil acidity increases (pH decreases), more H^+ ions are attached to the colloids and push other cations from the colloids and into the soil solution (CEC decreases). Inversely, when soils become more basic (pH increases), the available cations in solution decreases. Because there are fewer H^+ ions to push cations into the soil solution from the colloids (CEC increases).

3.3.4 Variations of soil available phosphorus (P)

Phosphorus does not occur as abundantly in soils as N and K. However, understanding the dynamics of P transformations in soil will provide the basis for sound management of soil and fertilizer P to ensure adequate P availability to plants. Soil pH is the most important among the factors responsible for P fixation reactions. Besides pH, some other soil properties e.g. organic matter content influence P solubility and adsorption reactions, which affect P availability to plants and recovery of fertilizer P by crops (BARC, 2005).P is observed from Table 3.2 that, at before plowing stage the average range of soil P in the wastewater site of the three selective plots ($P_1T_1S_1$, $P_1T_1S_2$, and $P_1T_1S_3$) is 0.01136%, river water site ($P_1T_2S_1$, $P_1T_2S_2$, and $P_1T_2S_3$) is 0.008273% and fresh water or control site ($P_1T_3S_1$, $P_1T_3S_2$, and $P_1T_3S_3$) is 0.002407%. It is also measured that in the vegetative stage the average P in the wastewater site ($P_2T_1S_1$, $P_2T_1S_2$, and $P_2T_1S_3$) is 0.011987%, river water site ($P_2T_2S_1$, $P_2T_2S_2$, and $P_2T_2S_3$) is 0.001167% and fresh water or control site ($P_2T_3S_1$, $P_2T_3S_2$, and $P_2T_3S_3$) is 0.001894%. At reproductive stage the average P of soil in the wastewater site ($P_3T_1S_1$, $P_3T_1S_2$, and $P_3T_1S_3$) is 0.002173%, river water site ($P_3T_2S_1$, $P_3T_2S_2$ and $P_3T_2S_3$) is 0.005767% and fresh water or control site ($P_3T_3S_1$, $P_3T_3S_2$ and $P_3T_3S_3$) is 0.009471%. At post harvest stage the average P of soil in the wastewater site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.011867%, river water site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.00756% and fresh water or control site ($P_3T_1S_4$, $P_3T_2S_4$ and $P_3T_3S_4$) is 0.009173%. The results of available phosphorus are represented graphically in Figure 3.4 of all growth stages in the three selective sites.

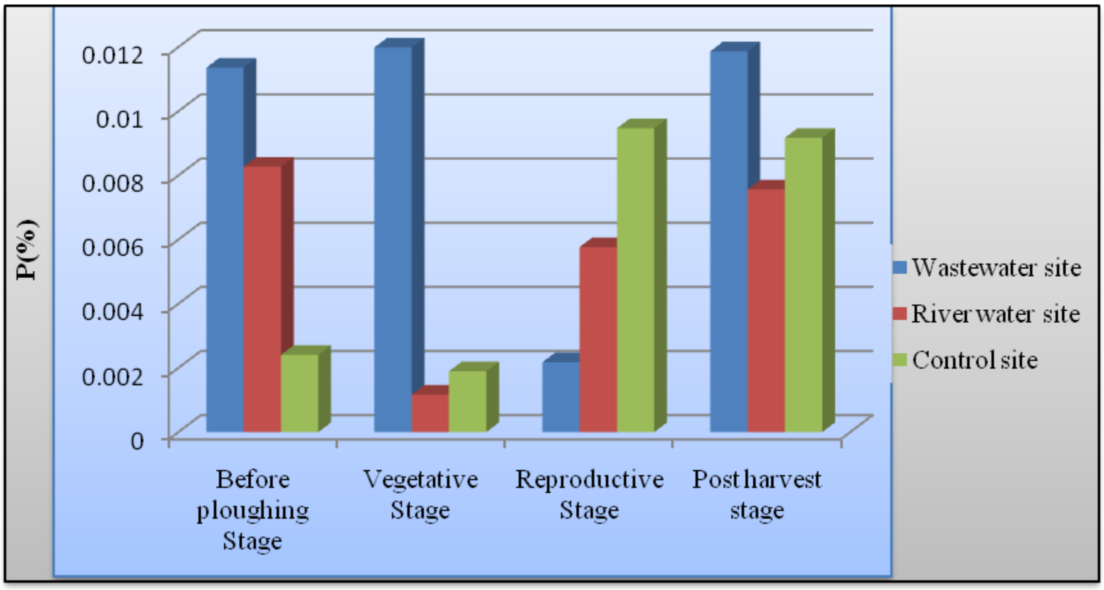

Figure 3.4: Variations of soil phosphorus (P) at various rice growing stages

Soil phosphorus is most available for plant use at pH values of 6 to 7. If pH values exceed 7.3, phosphorus is increasingly made unavailable by fixation in calcium phosphates. From the Figure 3.4 it is observed that P concentration is low in control site and high in the wastewater site of three growing stage except reproductive stage. The maximum value of wastewater is in vegetative stage it may be due to the application of fertilizer and the value is decreased in reproductive stage because P level is being decreased during plant growth time it might be the utilization by paddy and leaching with irrigation water. The P concentration again increased in post harvest stage, it includes sufficient soil moisture and other essential nutrients present in adequate wastewater supply (Nada, 2009).

3.3.5 Variations of soil available potassium (K)

Potassium requirement of rice is high and responses to K fertilizer, particularly in coarse textured, piedmont and terrace soils are well established. Soil K exists in four forms, each differing in its availability to crops. There is a continuous but slow transfer of K from the primary minerals to the exchangeable and slowly available forms (BARC, 2005). K is observed from Table 3.2 that, at before plowing stage the average range of soil K in the wastewater site of the three selective plots ($P_1T_1S_1$, $P_1T_1S_2$, and $P_1T_1S_3$) is 0.027867%, river water site ($P_1T_2S_1$, $P_1T_2S_2$, and $P_1T_2S_3$) is 0.01604% and fresh water or control site ($P_1T_3S_1$, $P_1T_3S_2$, and $P_1T_3S_3$) is 0.019543%. It is also measured that in the vegetative stage the average K in the wastewater site ($P_2T_1S_1$, $P_2T_1S_2$, and $P_2T_1S_3$) is 0.032247%, river water site ($P_2T_2S_1$, $P_2T_2S_2$, and $P_2T_2S_3$) is 0.020417% and fresh water or control site ($P_2T_3S_1$, $P_2T_3S_2$, and $P_2T_3S_3$) is 0.01604%. At Reproductive stage the average K of soil in the wastewater site ($P_3T_1S_1$, $P_3T_1S_2$, and $P_3T_1S_3$) is 0.032243%, river water site ($P_3T_2S_1$, $P_3T_2S_2$ and $P_3T_2S_3$) is 0.008593% and fresh water or control site ($P_3T_3S_1$, $P_3T_3S_2$ and $P_3T_3S_3$) is 0.016913%. At post harvest stage the average K of soil in the wastewater site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.023047%, river water site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.01954% and fresh water or control site ($P_3T_1S_4$, $P_3T_2S_4$ and $P_3T_3S_4$) is 0.019563%. The results of available potassium are represented graphically in Figure 3.5 of all growth stages in the three selective sites.

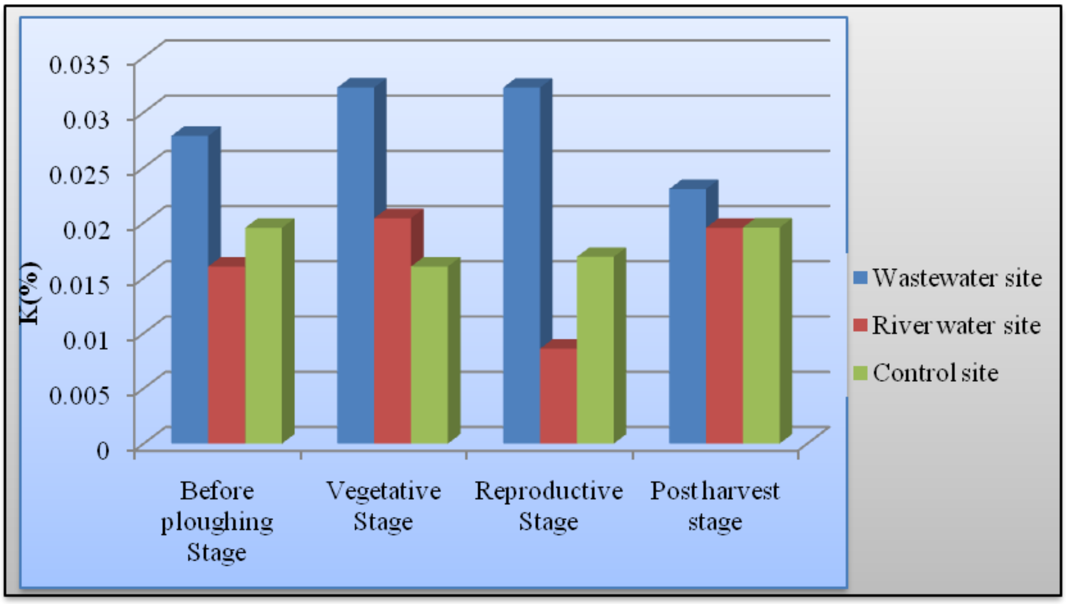

Figure 3.5: Variations of potassium soil (K) at various rice growing stages in three selective sites

From the Figure 3.5 it is observed that available potassium slightly increased in wastewater site rather than that of control site and river water site at before plowing stage and vegetative stage. This is happened due to application of fertilizer. At reproductive stage the values remains same but decreased in case of river water site. This statement matches with Ponnamperuma, after irrigation, oxygen is rapidly consumed and anaerobic microorganisms use oxidized soil compounds as electron acceptors, including nitrate, iron and Mn oxides (Ponnamperuma, 1972). The soil solution composition would therefore change by an increase of Fe^{2+}, Mn^{2+}, and NH^{4+} levels, causing a displacement of other cations to the solution, such as K (De Datta, 1981), increasing the plant availability and leaching losses which are significantly higher when the rice fields are continuously flooded (Santos et al., 2002). In case of post harvest stage this condition may be happened.

3.3.6 Variations of soil sulphur (S)

Reaction of S is similar to that of N, which is dominated by the organic or microbial fraction in the soil. Sulphur application is beneficial for more than one crop grown in sequence. Response to applied S is more in rice than in whet or other upland crops. Anaerobic conditions brought about by submergence significantly reduce S availability in soil. So in rice based cropping systems, transplant rice should receive fertilizer S on a priority basis (BARC, 2005).

S is observed from Table 3.2 that, at before plowing stage the average range of soil S in the wastewater site of the three selective plots ($P_1T_1S_1$, $P_1T_1S_2$, and $P_1T_1S_3$) is 0.038109%, river water site ($P_1T_2S_1$, $P_1T_2S_2$, and $P_1T_2S_3$) is 0.006443% and fresh water or control site ($P_1T_3S_1$, $P_1T_3S_2$, and $P_1T_3S_3$) 0.010088%. It is also measured that in the vegetative stage the average S in the wastewater site ($P_2T_1S_1$, $P_2T_1S_2$, and $P_2T_1S_3$) is 0.031664%, river water site ($P_2T_2S_1$, $P_2T_2S_2$, and $P_2T_2S_3$) is 0.011909% and fresh water or control site ($P_2T_3S_1$, $P_2T_3S_2$, and $P_2T_3S_3$) is 0.005797%. At Reproductive stage the average S of soil in the wastewater site ($P_3T_1S_1$, $P_3T_1S_2$, and $P_3T_1S_3$) is 0.034331%, river water site ($P_3T_2S_1$, $P_3T_2S_2$ and $P_3T_2S_3$) is 0.014045% and fresh water or control site ($P_3T_3S_1$, $P_3T_3S_2$, and $P_3T_3S_3$) is 0.005419%. At post harvest stage the average S of soil in the wastewater site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.030171%, river water site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.011501% and fresh water or control site ($P_3T_1S_4$, $P_3T_2S_4$, and $P_3T_3S_4$) is 0.010168%. Variations of soil S in four growing seasons in three selective sites are shown in Figure 3.6.

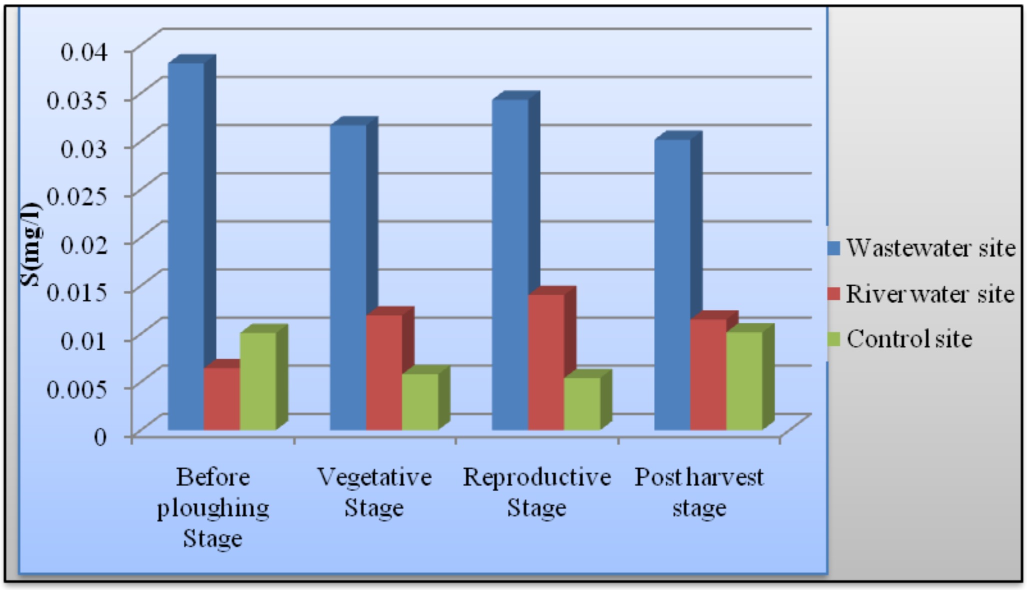

Figure 3.6: Variations of soil sulphur (S) value at various rice growing stages

From the Figure 3.6 it is observed that, in wastewater site is very high compared with other sites this may be due to the nutrient enrichment and control site soil S decreased from before plowing stage to vegetative stage, vegetative stage to reproductive stage and increased again in reproductive stage to post harvest stage. Again in river water site it is increased before plowing stage to vegetative stage, vegetative stage to reproductive stage and decreased from vegetative stage to postharvest stage. It is occurred most probably due to microbial action in soil and uptake by paddy. It might be that the increase of sulfur from reproductive stage is mainly due to the increase SO_4^{2-} in irrigation water.

3.3.7 Variations of soil sodium (Na^+)

Na^+ is observed from Table 3.2 that, at before plowing stage the average range of soil Na^+in the wastewater site of the three selective plots ($P_1T_1S_1$, $P_1T_1S_2$, and $P_1T_1S_3$) is 0.354743%, river water site ($P_1T_2S_1$, $P_1T_2S_2$, and $P_1T_2S_3$) is 0.39159% and fresh water or control site ($P_1T_3S_1$, $P_1T_3S_2$, and $P_1T_3S_3$) is 0.437107%. It is also measured that in the vegetative stage the average Na^+ in the wastewater site ($P_2T_1S_1$, $P_2T_1S_2$, and $P_2T_1S_3$) is 0.47178%, river water site ($P_2T_2S_1$, $P_2T_2S_2$, and $P_2T_2S_3$) is 0.330907% and fresh water or control site ($P_2T_3S_1$, $P_2T_3S_2$, and $P_2T_3S_3$) is 0.32223%. At reproductive stage the average $Na^+$of soil in the wastewater site ($P_3T_1S_1$, $P_3T_1S_2$, and $P_3T_1S_3$) is 0.46528%, river water site ($P_3T_2S_1$, $P_3T_2S_2$, $P_3T_2S_3$) is 0.339577% and fresh water or control site ($P_3T_3S_1$, $P_3T_3S_2$ and $P_3T_3S_3$) is 0.421933%. At post harvest stage the average $Na^+$of soil in the wastewater site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.33307%, river water site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.37425% and fresh water or control site ($P_3T_1S_4$, $P_3T_2S_4$ and $P_3T_3S_4$) is 0.326573%. The results of available sodium are represented graphically in Figure 3.7 of all growth stages in the three selective sites.

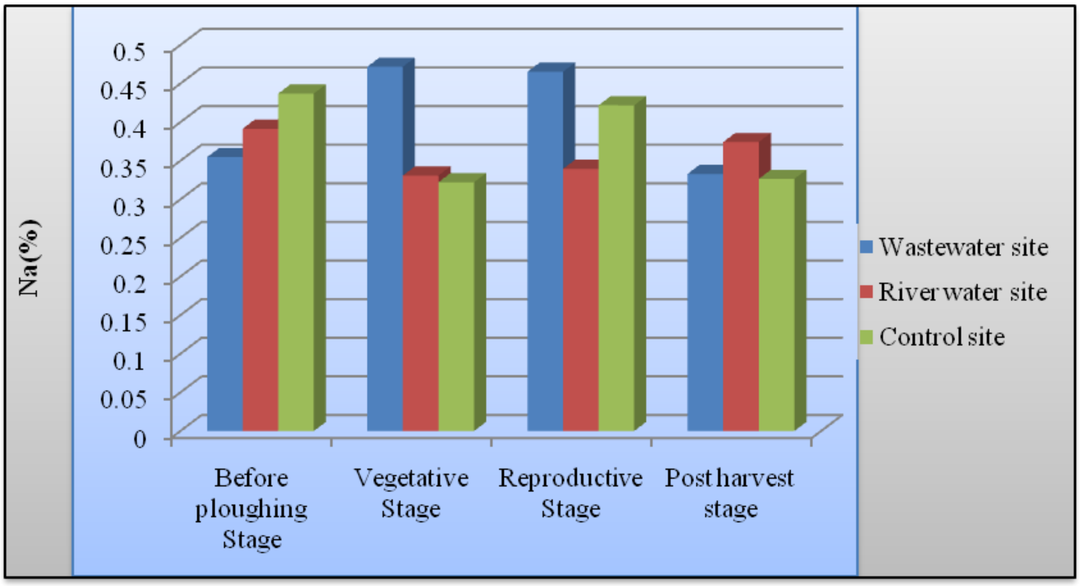

Figure 3.7: Variations of soil sodium (Na^+) at various rice growing stages

From Figure 3.7, it is clear that, soil sodium (Na^+) is decreased at the before plowing stage to vegetative stage in case of polluted and control site, which might be due to the plugging and submergence of soil under water that leached out some sodium from the soil water. At the reproductive stage sodium is increased; because after ploughing gypsum ($C_aS_4.2H_2O$) is applied in the field, which might remove the sodium attached to the clay particles and made it available in soil water. At the post harvest post harvest stage, sodium of some experimental plots is decreased slightly, due to small rainfall in the study area. The Na^+ and Mg^{++} saturation of the exchange complex complex is harmful because they destroy the soil physical properties and offset plant nutrition (Haque, 2006).

3.3.8 Variations of soil magnesium (Mg^{++})

Ca^{++} and Mg^{++} are associated with soil colloidal fractions and have like K^+.Many minerals in soil are negatively charged and can attract or retain cations such as Potassium K^+, Calcium Ca^{++}, Sodium Na^+, and Magnesium Mg^{++}etc. the exchangeable capacity is the reversible process as elements can be held in the soil and not lost through leaching and subsequently released for crop uptake. Mg^{++} is observed from Table 3.2 that, at before plowing stage the average range of soil Mg in the wastewater site of the three selective plots ($P_1T_1S_1$, $P_1T_1S_2$, and $P_1T_1S_3$) is 0.122667%, river water site ($P_1T_2S_1$, $P_1T_2S_2$, and $P_1T_2S_3$) is 0.149333% and fresh water or control site ($P_1T_3S_1$, $P_1T_3S_2$, and $P_1T_3S_3$) is 0.166667%. It is also measured that in the vegetative stage the average Mg^{++} in the wastewater site ($P_2T_1S_1$, $P_2T_1S_2$, and $P_2T_1S_3$) is 0.053333%, river water site ($P_2T_2S_1$, $P_2T_2S_2$, and $P_2T_2S_3$) is 0.14% and fresh water or control site ($P_2T_3S_1$, $P_2T_3S_2$, and $P_2T_3S_3$) is 0.228%. At reproductive stage the average Mg^{++} of soil in the wastewater site ($P_3T_1S_1$, $P_3T_1S_2$, and $P_3T_1S_3$) is 0.177333%, river water site ($P_3T_2S_1$, $P_3T_2S_2$ and $P_3T_2S_3$) is 0.146667% and fresh water or control site ($P_3T_3S_1$, $P_3T_3S_2$ and $P_3T_3S_3$) is 0.166667 %. At post harvest stage the average Mg^{++} of soil in the wastewater site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.114667%, river water site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.144% and fresh water or control site ($P_3T_1S_4$, $P_3T_2S_4$ and $P_3T_3S_4$) is 0.169333%.

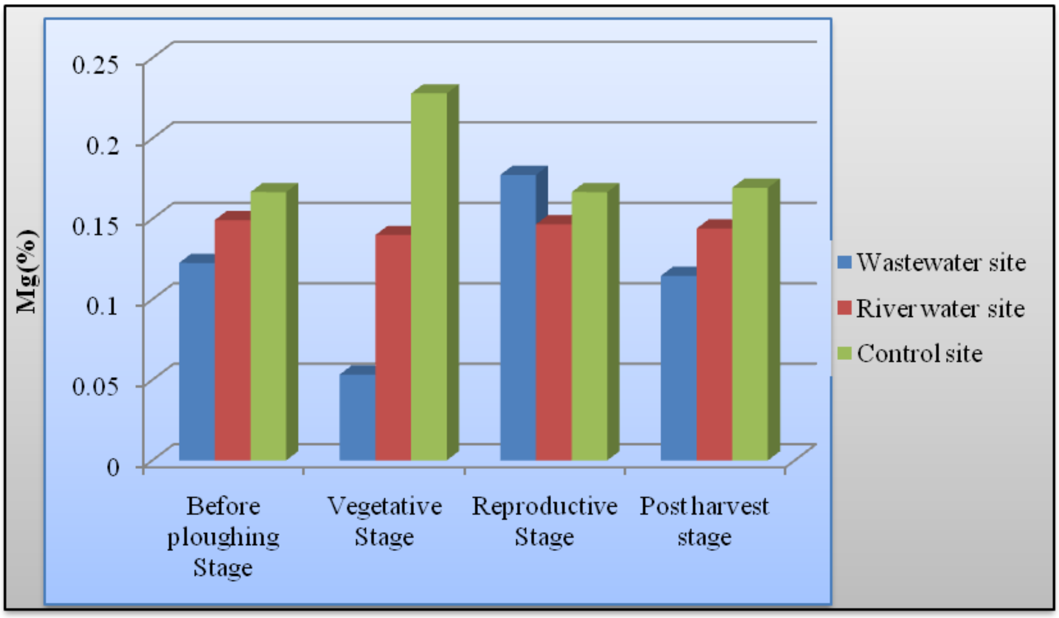

Figure 3.8: Variations of soil magnesium (Mg^{++}) at various rice growing stages

From the Figure 3.8 it is observed that at reproductive stage soil magnesium (Mg^{++}) is increased with compared with other stages in three selective sites except control site, which might be due to the presence of salt. In control site this value is decreased with respect to vegetative stage this may be due to the reduction of exchangeable volume occupied by Mg^{++} as it is replaced by Na cations. It is also known that high concentrations of sodium reduces the uptake of important mineral nutrients, K^{+} and Ca^{++} which further reduces cell growth especially for roots (Nada, 2009). The Na^{+} and Mg^{++} saturation of the exchange complex is harmful because they destroy the soil physical properties and offset plant nutrition. Mg^{++} has synergistic effect of plant uptake of Na^{+} as well as antagonistic effect on the uptake of Ca^{++} and K^{++} (Haque, 2006).

3.3.9 Variations of soil calcium (Ca^{++})

Calcium (Ca^{++}) requirement of plant is greater than Sulfur, Magnesium, and Phosphorus. Ca^{++} is observed from Table 3.2 that, at before plowing stage the average range of soil Ca^{++} in the wastewater site of the three selective plots ($P_1T_1S_1$, $P_1T_1S_2$, and $P_1T_1S_3$) is 0.524%, river water site ($P_1T_2S_1$, $P_1T_2S_2$, and $P_1T_2S_3$) is 0.377333% and fresh water or control site ($P_1T_3S_1$, $P_1T_3S_2$, and $P_1T_3S_3$) 0.4%. It is also measured that in the vegetative stage the average Ca in the wastewater site ($P_2T_1S_1$, $P_2T_1S_2$, and $P_2T_1S_3$) is 0.468%, river water site ($P_2T_2S_1$, $P_2T_2S_2$, and $P_2T_2S_3$) is 0.414667% and fresh water or control site ($P_2T_3S_1$, $P_2T_3S_2$, and $P_2T_3S_3$) is 0.316667%. At reproductive stage the average Ca^{++} of soil in the wastewater site ($P_3T_1S_1$, $P_3T_1S_2$, and $P_3T_1S_3$) is 0.48 %, river water site ($P_3T_2S_1$, $P_3T_2S_2$ and $P_3T_2S_3$) is 0.38 % and fresh water or control site ($P_3T_3S_1$, $P_3T_3S_2$ and $P_3T_3S_3$) is 0.393%. At post harvest stage the average Ca^{++} of soil in the wastewater site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.466667%, river water site ($P_1T_1S_4$, $P_1T_2S_4$, and $P_1T_3S_4$) is 0.436667% and fresh water or control site ($P_3T_1S_4$, $P_3T_2S_4$ and $P_3T_3S_4$) is 0.38 %.

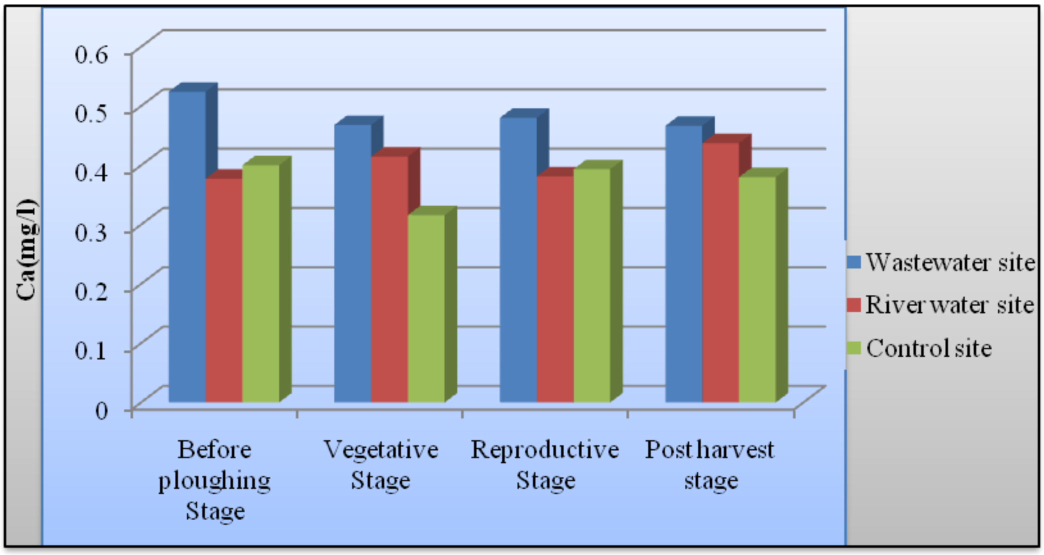

Figure 3.9: Variations of soil calcium (Ca^{++}) at various rice growing stages

From the Figure 3.9 it is observed that soil Ca^{++} concentration is increased at wastewater site and control water site which might be due to increase irrigation water salinity. In control site it decreased before plowing stage to vegetative Stage because of plant uptake leach by plant it also increased in reproductive stage because the presence of fresh water gastropod molluses. It is also known that high concentrations of sodium reduces the uptake of important mineral nutrients, K^+ and Ca^{++} which further reduces cell growth especially for roots (Nada, 2009). The Na^+ and Mg^{++}saturation of the exchange complex is harmful because they destroy the soil physical properties and offset plant nutrition. Mg^{++}has synergistic effect of plant uptake of Na^+ as well as antagonistic effect on the uptake of Ca^{++} and K^{++} (Haque, 2006).

3.4 Chemical Properties of Paddy Leaf

In order to identify the soil status in the three selective site of the study area, available (K), available (P), available (S), available (Ca), available (Mg), available (Na) were analyzed in the laboratory, which is provided in the Appendix (Table 3.3) .

3.4.1 Variations of leaf potassium (K)

Potassium plays an important role in plant such as enzyme activation; osmotic and ionic regulation, and one of the most important elements affecting the N metabolism of the rice plant (Ahmed *et al.*, 1987). K is observed from Table 3.3 that, at Vegetative Stage the average range of leaf K in the wastewater site of the two selective plots ($P_2T_1L_1$ and $P_3T_1L_1$) is 0.089505%, river water site ($P_2T_2L_1$) is 0.09324% and fresh water or control site ($P_1T_3L_1$, $P_2T_3L_1$, and $P_3T_3L_1$) is 0.096147%. It is also measured that in the reproductive stage the average K in the wastewater site ($P_2T_1L_2$, and $P_3T_1L_2$) is 0.11193%, river water site ($P_2T_2L_2$) is 0.11066% and fresh water or control site ($P_1T_3L_2$, $P_2T_3L_2$, and $P_3T_3L_2$) is 0.0954%. At ripening stage the average K of soil in the wastewater site ($P_2T_1L_3$, and $P_3T_1L_3$) is 0.103205%, river water site ($P_2T_2L_3$) is 0.09698% and fresh water or control site ($P_1T_3L_3$, $P_2T_3L_3$, $P_3T_3L_3$) is 0.08701%.

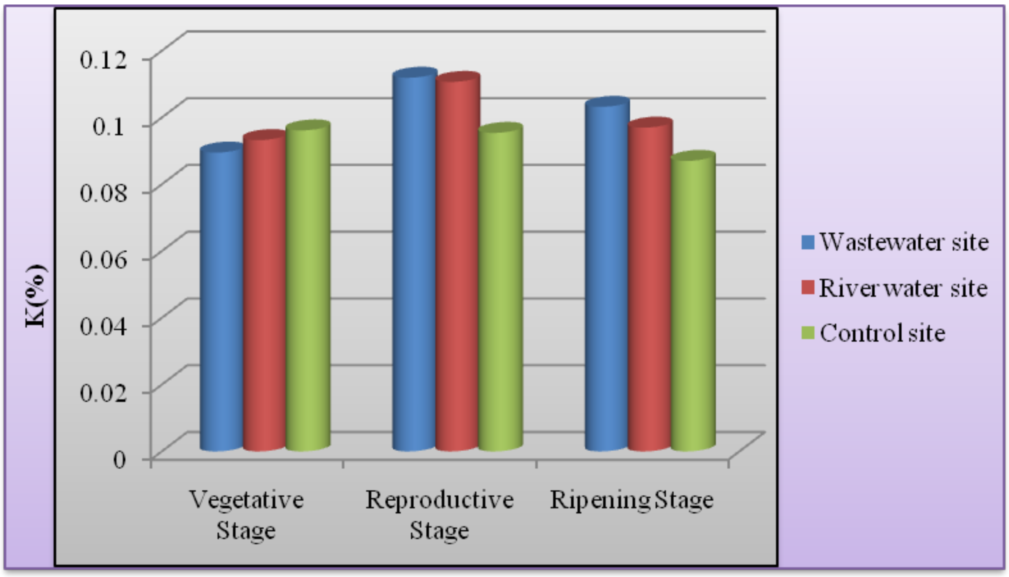

Figure 3.10: Variations of leaf potassium (K) at various rice growing stages

Leaf potassium is found highest in the reproductive growth stage, relatively less in the ripening stage, and lowest in Vegetative state. In case of control site K concentration is high in vegetative stage and relatively less in other two stages. The findings matches with the statement that the peak of K uptake by rice takes place from the panicle differentiation, i.e., about 35 to 40 days after the beginning of flooding in early-maturing cultivars, and drops dramatically after full flowering (Lopes *et al.*, 1994). Zelenesksy (2000) also reported that that the increase in slot concentration causes a decrease in N, P, and K content in rice. The concentration of K^+ is less in the saline soil compared to that of non-saline soil for the same variety. The diminution of K^+ at plasma membrane, inhibition of Na^+ on K^+ transport process in xylem tissues and/or Na^+ induced K^+ efflux from the roots (Amirjiani, 2010). High Na^+ accumulation in rice roots have been reported to result in an enhance membrane damage, electrolyte leakage and oxidative damage (Mandhania *et al.,* 2006).

3.4.2 Variations of leaf phosphorus (P)

Phosphorus is the constituent of nucleic acids and phospholipids; which involve in energy transfer (BRAC, 2005). P is observed from Table 3.3 that, at vegetative stage the average range of leaf P in the wastewater site of the two selective plots ($P_2T_1L_1$ and $P_3T_1L_1$) is 0.0559%, river water site ($P_2T_2L_1$) is 0.06588% and fresh water or control site ($P_1T_3L_1$, $P_2T_3L_1$, and $P_3T_3L_1$) is 0.01365333%. It is also measured that in the reproductive stage the average P in the wastewater site ($P_2T_1L_2$, and $P_3T_1L_2$) is 0.04481%, river water site ($P_2T_2L_2$) is 0.04448% and fresh water or control site ($P_1T_3L_2$, $P_2T_3L_2$, and $P_3T_3L_2$) is 0.03463333%. At ripening stage the average P of soil in the wastewater site ($P_2T_1L_3$, and $P_3T_1L_3$) is 0.01492%, river water site ($P_2T_2L_3$) is 7.05 % and fresh water or control site ($P_1T_3L_3$, $P_2T_3L_3$, $P_3T_3L_3$) is 0.04464667%.

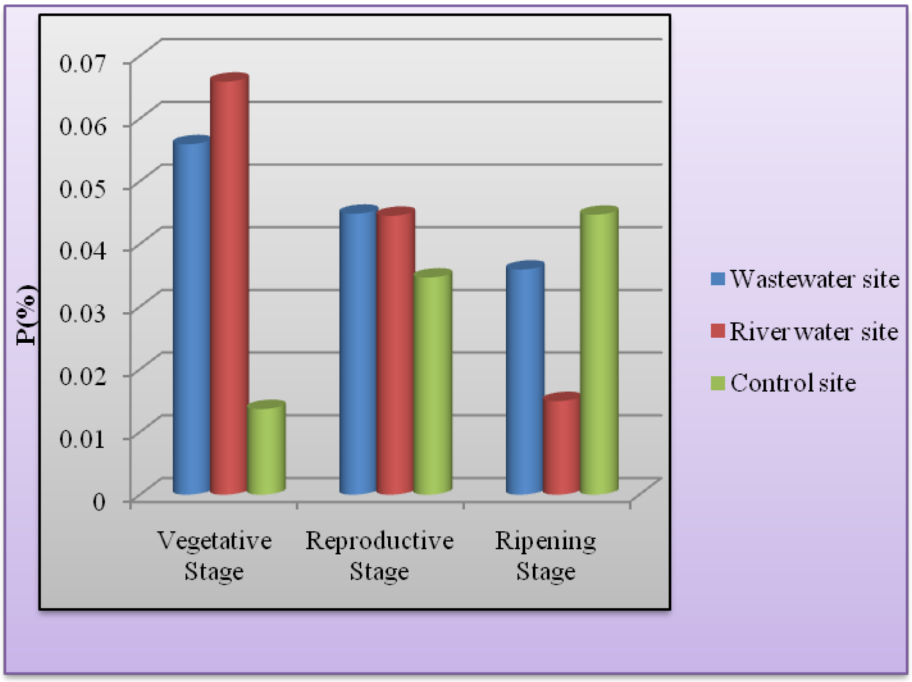

Figure 3.11: Variations of leaf phosphorus (P) at various rice growing stages

From the Figure 3.11 it is observed that leaf P is minimum in control site and maximum at the vegetative growth stage in river water site, relatively low in wastewater site. Leaf P is moderate in reproductive stage and ripening stage for both wastewater and river water site. But in case of control water site it is increased.

3.4.3 Variations of leaf sulphur (S)

sulphur is observed from Table 3.3 that, at vegetative stage the average range of leaf S in the wastewater site of the two selective plots ($P_2T_1L_1$ and $P_3T_1L_1$) is 0.04024%, river water site ($P_2T_2L_1$) is 0.04176% and fresh water or control site ($P_1T_3L_1$, $P_2T_3L_1$, and $P_3T_3L_1$) is 0.03488%. It is also measured that in the reproductive stage the average S in the wastewater site ($P_2T_1L_2$, and $P_3T_1L_2$) is 0.02776%, river water site ($P_2T_2L_2$) is 0.02688% and fresh water or control site ($P_1T_3L_2$, $P_2T_3L_2$, and $P_3T_3L_2$) is 0.02666667%. At ripening stage the average S of soil in the wastewater site ($P_2T_1L_3$, and $P_3T_1L_3$) is 0.0192%, river water site ($P_2T_2L_3$) is 0.0216% and fresh water or control site ($P_1T_3L_3$, $P_2T_3L_3$ and $P_3T_3L_3$) is 0.0216 %.

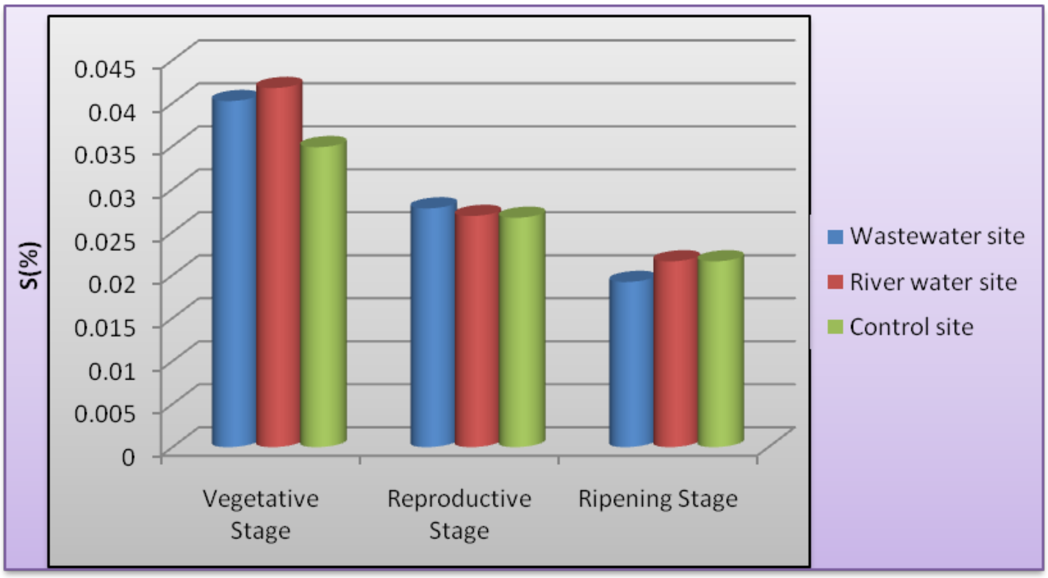

Figure 3.12: Variations of leaf sulphur (S) at various rice growing stages

Leaf sulfur is found to be highest in the vegetative stage, relatively less in the reproductive growth stage, and lowest at the ripening stage of the three selective sites. It happened because during the ripening, about 70% of the S absorbed by the straw will be translocated to the grain. This findings matches with the statement of Yoshida (1981) that, in general, the nitrogen, phosphorus, and sulfur contents in the vegetative stage are generally high at early growth stages and decline toward maturity.

3.4.4 Variations of leaf calcium (Ca^{2+})

Calcium is observed from Table 3.3 that, at vegetative stage the average range of leaf Ca^{2+}in the wastewater site of the two selective plots ($P_2T_1L_1$ and $P_3T_1L_1$) is 0.056%, river water site ($P_2T_2L_1$) is 0.056% and fresh water or control site ($P_1T_3L_1$, $P_2T_3L_1$ and $P_3T_3L_1$) is 0.0893%. It is also measured that in the reproductive stage the average Ca^{2+} in the wastewater site ($P_2T_1L_2$, and $P_3T_1L_2$) is 0.068%, river water site($P_2T_2L_2$) is 0.048% and fresh water or control site ($P_1T_3L_2$, $P_2T_3L_2$, and $P_3T_3L_2$) is 0.070667%. At ripening stage the average Ca of soil in the wastewater site ($P_2T_1L_3$, and $P_3T_1L_3$) is 0.07%, river water site ($P_2T_2L_3$) is 0.056% and fresh water or control site ($P_1T_3L_3$, $P_2T_3L_3$ and $P_3T_3L_3$) is 0.08%.

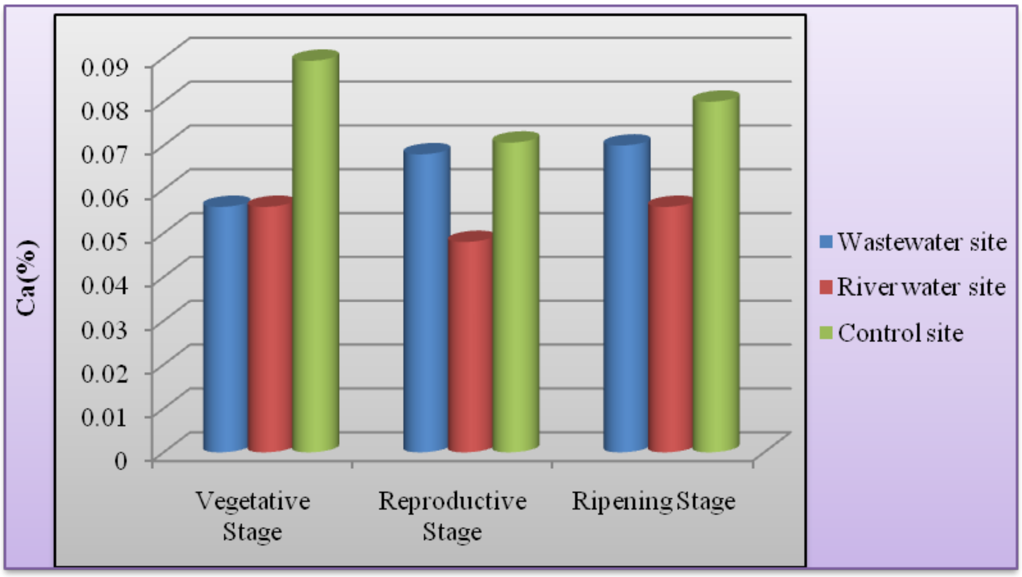

Figure 3.13: Variations of leaf calcium (Ca^{2+}) at various rice growing stages

Ca^{2+} is observed from Figure 3.13 that, in control site Ca^{2+} showed highest concentration at the respective growing seasons, in the wastewater site Ca^{2+} concentration is increased vegetative stage to reproductive and ripening stage. Wastewater and river water site remains varied from the range 0.4 to 0.0.9 (Table 3.3). These variations in the cell Ca^{2+} homeostasis is suggested as a primary response to salinity stress as perceived by the root cells (Rengel, 1992).

3.4.5 Variations of leaf magnesium (Mg^{2+})

Mg is observed from Table 3.3 that, at vegetative stage the average range of leaf Mg^{2+} in the wastewater site of the two selective plots ($P_2T_1L_1$ and $P_3T_1L_1$) is 0.016%, river water site ($P_2T_2L_1$) is 0.028% and fresh water or control site ($P_1T_3L_1$, $P_2T_3L_1$, and $P_3T_3L_1$) is 0.026667%. It is also measured that in the reproductive stage the average Mg in the wastewater site ($P_2T_1L_2$, and $P_3T_1L_2$) is 0.036%, river water site ($P_2T_2L_2$) is 0.024% and fresh water or control site ($P_1T_3L_2$, $P_2T_3L_2$, and $P_3T_3L_2$) is 0.016%. At ripening stage the average Mg of soil in the wastewater site ($P_2T_1L_3$, and $P_3T_1L_3$) is 0.01%, river water site ($P_2T_2L_3$) is 0.02% and fresh water or control site ($P_1T_3L_3$, $P_2T_3L_3$ and $P_3T_3L_3$) is 0.017333%.

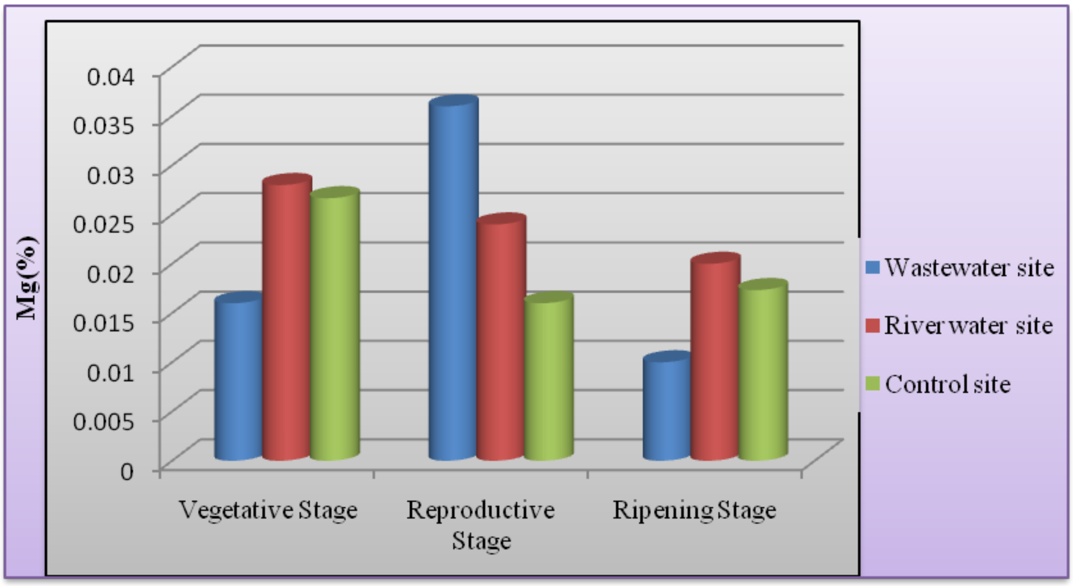

Figure 3.14: Variations of leaf magnesium (Mg^{2+}) at various rice growing stages

Mg^{2+} is observed from Figure 3.14 that, Mg^{2+} concentration is decreasing from vegetative stage to reproductive stage, reproductive stage to ripening stage in the river water and control site except wastewater site. And in wastewater site it is heights in reproductive stage with respect to other two stages. This decrease resulted from the reduction of exchangeable volume occupied by Mg^{2+} as it is replaced by Na cations. It is also known that high concentrations of sodium reduces the uptake of important mineral nutrients, K^+ and Ca^{++} which further reduces cell growth especially for roots.

3.4.6 Variations of leaf sodium (Na^+)

Rice dry-matter production under salinity is positively correlated with shoot potassium concentration with shoot potassium concentration and negatively with sodium concentration in later growth stages (Dutt&Bal, 1985; Heenan*et al.*, 1988). Na^+ is observed from Table 3.3 that, at vegetative stage the average range of leaf Na in the wastewater site of the two selective plots ($P_2T_1L_1$ and $P_3T_1L_1$) is 0.092405%, river water site ($P_2T_2L_1$) is 0.11271% and fresh water or control site ($P_1T_3L_1$, $P_2T_3L_1$, and $P_3T_3L_1$) is 0.09268%. It is also measured that in the reproductive stage the average Na^+ in the wastewater site ($P_2T_1L_2$, and $P_3T_1L_2$) is 0.109545%, river water site ($P_2T_2L_2$) is 0.13483% and fresh water or control site ($P_1T_3L_2$, $P_2T_3L_2$, and $P_3T_3L_2$) is 0.09479333%. At ripening stage the average Na of soil in the wastewater site ($P_2T_1L_3$, and $P_3T_1L_3$) is 0.10954%, river water site ($P_2T_2L_3$) is 0.12534% and fresh water or control site ($P_1T_3L_3$, $P_2T_3L_3$, $P_3T_3L_3$) is 0.09374%.

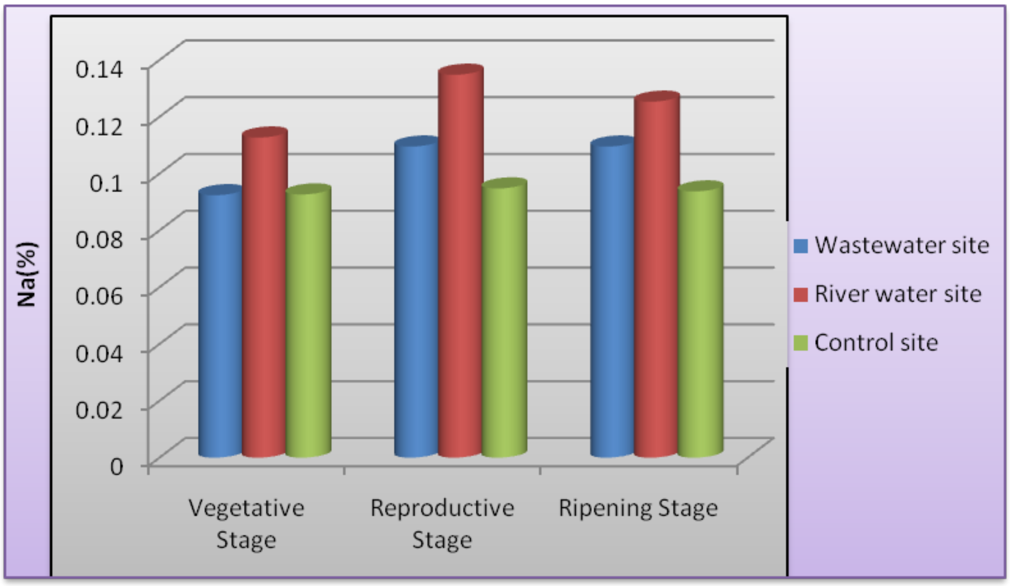

Figure 3.15: Variations of leaf sodium (Na^+) at various rice growing stages

Na^+ is observed from Figure 3.15 to be higher in the reproductive stage compared to the vegetative stage and ripening stage. But, it is found high in ripening stage compared to vegetative stage in the soils of relatively high salinity. Leaf Na^+ content is increased with the increased salinity of soil. The increased Na^+ ion content and decreased K^+ ion uptake disturb ionic balance as observed in most species exposed to salt stress. Due to high uptake and accumulation of K^+ and also enhanced K^+ efflux under salt stress could suppress growth by decreasing the capacity of osmotic adjustment and turgor maintenance or by inhibiting metabolic activities (Amirjani, 2010).

3.5 Chemical Properties of Grain in Three Selective Sites

Potassium (K), Phosphorus (P), Sulfur (S), Calcium (Ca), Magnesium (Mg) and Sodium (Na) were analyzed in the laboratory and the results are provided in Appendix (Table 3.4) and represented in Figure 3.16.

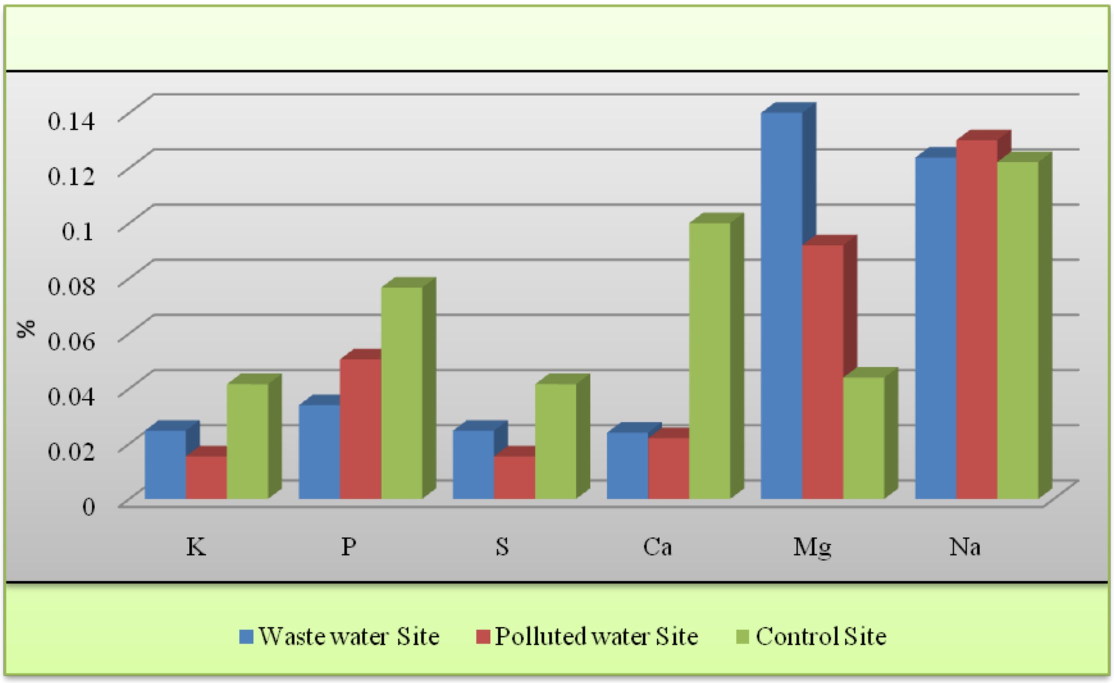

Figure 3.16: Chemical properties of rice grain

From the Table 3.4 and Figure 3.16 it is found that, the concentration of rice grain potassium varied from 0.01 to 0.04%. Potassium concentration is higher in control site rather than that of polluted and wastewater site. K concentration is less in polluted water site this may be due to the presence of some nutrient because source of water is polluted affected river system of the KCC area. Phosphorus is high in control site is 0.07% and low in wastewater site is 0.03%. The decrease in phosphorous and potassium contents of the crop might be attributed to the presence of higher amount of some trace elements in the effluents that have antagonistic relationship with P and K (Muchrimsyah and Mercado, 1990). The maximum concentration of sulfur is in control site 0.04% and lowest in river water site 0.01% these variations may be due to total water consumption by plant shoot. The Ca concentration is highest is control site and lowest in river water site and Mg concentration is highest in wastewater site and lowest in control site this variation may be due to the exchangeable volume which is occupied by Na cations. Na^+ concentration is highest river water site and lowest in control site these variations may be due to toxic ionic effects of excess Na^+ and Cl^- uptake and reduction in nutrient uptake (K^+, Ca^+) because of antagonistic effects.

3.6 Growth and Yield and Associated Parameters of Rice

The Yield Parameters of rice has been given in Appendix (Table 3.5), plant height, root length, panicle length, Tillers per plant, Grains/Panicle, 1000 grain weight, including yield (ton/hectare).

From the (table 3.6) it is observed that the plant height and root length (42.3 and 12.6 inch) is highest in the wastewater site with respect to polluted (41.8 and 12.8 inch) and control water (39.5 and 11.5) site it may be due to nutrient enrichment in the irrigated wastewater. Panicle length and is highest in the control site 10.2 inch lowest in river water site because of which may be due to adequate nutrients supply. Although tiller per plant is highest 24.2 no. in wastewater site compared with river water site18.1 no. and control site it is 20.9 no. But grains per panicle were highest in control site 165.4 no. with respect to other two site wastewater and polluted (154.9 and 143.3) because of it contained considerable amount of macro and micro-nutrients within permissible limit. Weight of 1000 grains is highest in control site 22.2 g with compared to wastewater and river water site (20.3g and 19.7g). Finally we observed that fresh water gave the highest grain yield 4.8 ton/ha and lowest grain yield 3.9 ton/ha is obtained from polluted water used for irrigation where as wastewater site it is 3.9 ton/h although the plant height and root length is highest in this site. Results revealed that fresh water irrigation always gave the highest yield, even in the polluted soil compared to polluted water. Comparison of Yield Performance of three selective sites is given below.

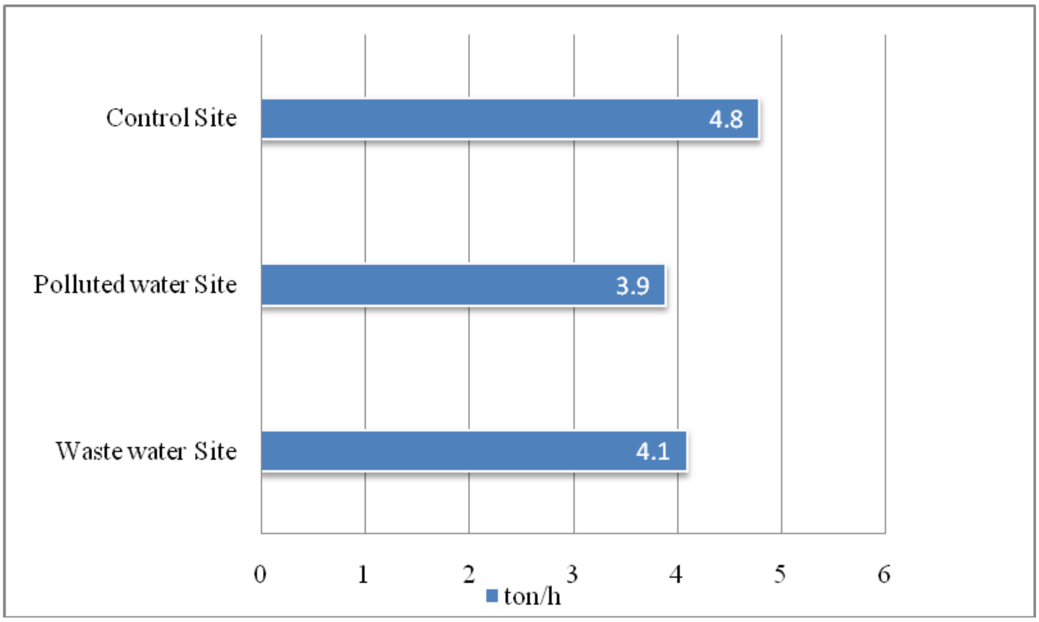

Figure 3.17: Comparison of yield performance of rice

CHAPTER FOUR

CONCLUSION AND RECOMMENDATION

- Non-conventional water is used extensively in the world. Well-planned utilization of wastewater in agriculture will increase food production by more irrigation coverage and improve the livelihood of farmers at the proximity of wastewater sources.
- In some cases the quality of wastewater was found to be good in vegetative stage of rice in the study area in terms of nutrient contents.
- Analysis of different agronomics parameters which are Plant height, root length, panicle length, tillers per plant were high in wastewater site. But grains per panicle, weight of 1000 grains, grain yield were estimated to be higher in control site. Finally the yield of BRRI dhan28 was found to be 4.1, 3.9 and 4.8 ton per hectare, respectively, through the wastewater, river water, and freshwater.
- In the soil analysis the average concentration of selected parameters of soil is high in post harvest stage and low in vegetative stage.
- If we apply non-conventional water in the vegetative stage, more yields can be achieved.
- Further detail study to assess the potential for wastewater reuse in major crops in the south-west coastal Bangladesh should be carried out.

REFERENCES

Ahmed, A. A., Ikeda, M,. Yamada, Y. 1987. Effect of the Supply of Potassium, Calcium, and Magnesium on the Absorption, Translation and Assimilation of Ammonium and Nitrate-nitrogen in Wheat Plants. *Soil Science and Plant Nutrition*, **33**, 585-594.

Amirjani M.R. 2010. Effect of NaCl on Some Physiological Parameters of Rice. *European Journal of Biological Sciences*. 3(1): 06-16.

Amirjiani M.R. 2010. Effect of NaCl on Some Physiological Parameters of Rice. *European Journal of Biological Science*. 3(1): 06-16.

APHA, 2006. Standard Method for the Analysis of Water and Wastewater. *20th Edition. American Public Health Association*, Washington DC, USA.

BARC, 2005. Fertilizer Recommendation Guide -2005.*Bangladesh Agricultural Research Council.Soils Publication No.***45**.Farmgate, New Airport Road, Dhaka-1215.ISBN : 984-32-3166-X. p-45.

BBS (Bangladesh Bureau of Statistics), 2004.Statistical Year Book.Bangladesh Bureau of Statistics.Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

Begum ,R. A. Zaman, M. W. Mondol, A. T. M. A. I. Islam, M. S. andHossain, K. M. F. 2011.Effects of textile industrial waste water and uptake of nutrients on the yield of rice.*Bangladesh J. Agril. Res.* **36(2)**: pp. 319-331.

Bhargava, B.S. and Raghupathi, H.B. 1999. Analysis of Plant Materials for Macro Micronutrients. In: Methods of Analysis of Soils, Plants, Waters and Fertilisers. Tanndon, H.L.S (Editors). *Fertilised Development and Consultation Organization*. New Delhi, India. pp: 49-54.

Das and Rahman,M., R. 2012. Evaluation of Dry Season Water Quality of Mayur River Flowing

DeDatta, S.K. 1981. Principles and Practices of Rice Production. New York, John Wiley, 1981. Pp:618.

Dobermann A and Fairhurst T. H. 2000. Rice: Nutrient Disorders and Nutrient Management. Handbook series, Oxford Graphic Printers Ltd. Pp-139,191.

Dutt, S.K. & A.R. Bal, 1985. Effect of Salinity on Rice Dry Matter Accumulation and Sodium Uptake. *International Rice Research Letter* **10**:pp:26.

Gleick, P.H., 2000. The World's Water 2000–2001. The Biennial Reports on FreshwaterResources. Island Press, Washington, DC. pp. 315.

Haque S. A. 2006. Salinity Problems and Crop Production in Coastal Regions of Bangladesh (review article). Department of Soil Science, Bangladesh Agricultural University, Mymensing, Bangladesh. *Pakistan Journal of Botany,* **38(5)**: 1359-1365.

Heenan D.O., Lewin L.G and McCaffery D.W. 1988. Salinity Tolerance in Rice Varieties at Different Growth Stages. *Australian Journal of Experimental Agriculture*. **28**, 343-349.

Khai, N. Tuan, P. Vinh,N. Oborn, I. 2008.Effects of using wastewater as nutrient sources on soil chemical properties in peri-urban agricultural systems.*VNU Journal of Science, Earth Sciences***24**: pp. 87-95.

Khan, I.U. Khan, M.J.Khan, N.U. Khan, M.J. Rahman, H.U.Bibi, Z. and Ullah, K 2012.Wastewater impact on physiology, biomass and yield of canola (*brassica napus*l.)*Pak. J. Bot* **44(2)**: pp. 781-785.

Kiran D. Ladwani, Krishna D. Ladwani, Vivek S. Manik, D. S. Ramteke 2012.Impact of domestic wastewater irrigation on soil properties and crop yield.*International Journal of Scientific and Research Publications* **2(10)**: pp. 1-3.

Lopes, S.I.G.; Voikweiss, S.J. & Tedesco, M.j. 1994. Desenvolvimento do Sistema Radicular do Sistema Radicular do Arroz Irrigado. *Revista Brasileira de Ciencia do Solo*, **18**. pp: 273-278.

Mancy, K.H. & T. Jaffe, T. 1966. Analysis of Dissolved Oxygen in Natural and Waste Waters. Publ. No. 999-WP-37, U.S. Public Health Serv., Washington, D.C.

Mandhania, S.; Madan; S., and Sawhney, V. 2006. Antioxidant Defence Mechanism under Salt Stress in Wheat Seedlings", *Biology of Plant*, Vol **227**, pp.227-231.

Metcalf and Eddy 2003. Wastewater Engineering-Treatment and Reuse, 4th end. McGraw-Hill, New York.

Mojid, M.A. G.C.L. Biswas, M.A. Wyseure. 2012.Interaction effects of irrigation by municipal wastewater and inorganic fertilisers on wheat cultivation in Bangladesh. *Field Crops Research* **134**: pp. 200-207.

Mojid, M.A.Wyseure,G.C.L.Biswas, S.K. Hossain, A.B.M.Z. 2010.Farmers' perceptions and knowledge in using wastewater for irrigation at twelve peri-urban areas and two sugar mill areas in Bangladesh.*Agricultural Water Management***98**: pp. 79-86.

Muchrimsyah, E.H. and B.T. Mercado. 1990. Lead-phosphate interaction in the germination and vegetative growth of two rice varieties. *Philippine Agriculturist.***73:** 207-2 19.

Nada, M. Abu. Long Term Impact of Wastewater Irrigation on Soil and Crop Quality Parameters in Gaza Strip 2009.*A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science inWater Resources Engineering.***1430.** PP.74-82.

Olsen, S.R.; Cole, C.V.; Watanabe, F.S.; and Dean. A 1954. Estimation of available phosphorus in Soils by extraction with Sodium Bicarbonate. United State Department of Agriculture, USA. Circular No. 939.

Pereira, L.S. Oweis, T. Zairi, A. 2002. Irrigation management under water scarcity.*Agric.Water Manage*. **57**: pp. 175–206.

Pescod, M.B.W., 1992. The urban water cycle including wastewater use in agriculture.*Outlook Agric*. **21**: pp. 263–270.

Petersen, L. 2002. Analytical Methods: Soil, Water, Plant Material, and Fertilizer. Soil Resources Management and Analytical Services, Soil Resources Development Institute (SRDI), Dhaka, Bangladesh. pp-9, 17-19, 47-48.

Ponnamperuma, F.N. 1972. The Chemical of Submerged Soils. *Advances in Agronomy*, **24**: pp:29-96.

Qadir, M. Wichelns, D. Raschid-Sally, L.McCornick, P.G.Drechsel, P. Bahri, A.Minhas, P.S. 2010.The challenges of wastewater irrigation in developing countries.*Agricultural Water Management***97:** pp. 561–568.

Ramesh, R. and Andu, M. 1996. Chemical Methods for Environmental Analysis-Water and Sediment. McMillan India Ltd. Pp. 17-67.

Raschid-Sally, M. Jayakody, P. 2008. Drivers and characteristics of wastewater agriculture in developing countries: results from a global assessment. *International Water Management InstituteResearch Report***127**: pp. 1-26.

Rengel, Z. 1992. The Role of Calcium in Salt Toxicity. Plant Cell Environ. **15**: 625-632.

Rusan, M. M., Hinnawi, S., &Rusan, L. (2006). Long Term Effects of wastewater Irrigation of Forage Crops on soil and Plant Quality Parameters. *215*.

Santos, A.B., Fageria, N.K. & Zimmermann, F.J.P. 2002 Atributes Quimicos do Solo Afetaed Pelo Manejo da Agua e do Fertilizatnte Potassico Na Cultura de Arroz Irrigado. *Revista Brasileira de Engenharia Agricola e Ambiental*, **6**:12-16.

Subramanian, **V.,** 2000. WATER, Quantity- Quality Perspective in South Asia, *Kingston International Publishers*, Surrey, United Kingdom: pp 121-140.

Tabari, M. Salehi, A. Long-term impact of municipal sewage irrigation on treated soil and black locust trees in a semi-arid suburban area of Iran 2009. *Journal of Environmental Sciences***21**:pp. 1438–1445.

Thomas, W. H**.,** 1969. Phytoplankton nutrient enrichment experiments of Baja California and in the eastern equatorial Pacific Ocean. *J. Fish. Res. Bd. Can.* 26: pp. 1133-1145.

Through the Western Fringe of Khulna City. Research Article (unpublished).

Todd, D. K., 1980, Groundwater Hydrology, University of California, Berkeley, *John Wiley & Sons Publ*, 2nd Edition, pp 267-312.

UNEP/WHO, 1996. Water Quality Monitoring – A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. Published on behalf of United Nations Environment Programme and the World Health Organization. The Taylor and Francis Group, London.

UNEP/WHO, 1996. Water Quality Monitoring- A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. Published on behalf of United Nations Environment Programme and the World Helth Organization. The Taylor and Francis Group, London.

Van der Hoek, W.; Hassan, M. Ul.Ensink, J. H. J. Feenstra, S. Raschid-Sally,L S. Munir, R. Aslam, N. Ali; R. Hussain and Y. Matsuno. 2002. *Urban wastewater: A valuable resource for agriculture. A case study from Haroonabad, Pakistan*. Research Report **63**. Colombo, Sri Lanka: International Water Management Institute.

Zelenesksy, G.L. 2000. Rice on Saline Soils in the Russain Federation. *International Rice Commission Newsletter* 49: 60-63.