ASSESSMENT OF IONIC TOXICITY OF BURIGANGA RIVER WATER AND ITS SUITABILITY FOR IRRIGATION, DRINKING, LIVESTOCK AND INDUSTRIAL USES

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CERTIFICATE

This is to certify that the thesis entitled "**Assessment of ionic toxicity of Buriganga River water and its suitability for Irrigation, Drinking, Livestock and industrial uses**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of ***MASTER OF SCIENCE IN AGRICULTURAL CHEMISTRY*** embodies the result of a piece of *bona fide* research work carried out by **Faruk Hossain Khan**, Registration No.04-01354 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any other institutes.

I further certify that such help or sources of information, as have been availed during the course of this investigation have duly been acknowledged.

Dated:
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Dedicated to
My Beloved
Parents

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ABSTRACT

The study was conducted to assess the degree of ionic toxicity and classify the water on the basis of standard criteria for irrigation, drinking, livestock, poultry, aquaculture and industrial purposes of 33 water samples of the River Buriganga nearby Dhaka city. Out of 33 water samples 27 from Buriganga River (11 of dry season and 16 of rainy season) and 6 from deep tubewells (different spots of Dhaka city) were collected from different non-*point (in case of river) and point sources in order to study the dissolved chemical* constituents. The chemical analysis included pH, electrical conductivity (EC), total dissolved solids (TDS) and major ionic constituents like Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Fe^{3+}, Mn^{2+}, B^{3+}, As^{3+}, Cu+, PO_4^{3-}, CO_3^{2-}, HCO_3^{-}, SO_4^{2-} and Cl^{-}, sodium adsorption ratio(SAR), soluble sodium percentage(SSP), residual sodium carbonate(RSC) and hardness(H_T) were *also calculated. The pH values of collected water samples ranged from 6.98 to 8.30 and* were found to be 'suitable' for successful crop production. EC values graded the water samples as 'excellent' to 'good' classes. TDS values of 31 water samples were graded as 'fresh water' with the exception in only 2 samples. Classification based on SAR, all the samples were of 'excellent' class. The SAR values were within the range of 0.15 to 5.05. EC and SAR categorized the samples as 'low' 'medium' and 'high' salinity (Cl, C2 and C3) and low alkali hazard's (S1), combinedly expressed as C1S1 (3 samples), C2Sl (28 samples) and C3Sl (2 samples). On the basis of SSP all samples were 'excellent' and all water samples were rated as 'suitable' for 'irrigation'. Hardness of water reflected that among the surface water 17 samples were found as 'moderately hard', 11 samples were 'hard' and the rest 5 samples belonged to 'very hard'.The concentrations of total cations 1.86 to 17.36 me L^{-1} and anions 1.422 to 16.21 me L^{-1} contents of all water samples were not found to be harmful for field crops. The concentration of Fe of all the samples and Mn concentration of 31 samples (except sample no.9 near Hazaribag and sample no.10 middle of the Buriganga near Azimpur) were found 'suitable' for carbonated beverage, confectionary, laundering, ice manufacture, tanning and textile industries. The results of ionic constituents Cl, Cu, Fe, NO_3 and SO_4 concentrations referred that 25 samples were found suitable for drinking and the rest samples were 'not suitable' for drinking. Mn and Cl statuses of all water were not suitable for livestock consumption. B, Fe, Cu, NO_3 and Zn contents of all samples would be suitable for livestock consumption. The pH vs SAR, EC vs pH, EC vs TDS, EC vs H_T, H_T vs TDS , SAR vs SSP, RSC vs SSP, EC vs SSP, RSC vs H_T, Ca vs HCO_3 and Mg vs HCO_3 combination showed significant correlation. And EC vs RSC and RSC vs H_T combination showed a negative significant correlation. On the contrary, the relationship between PAR vs SSP and pH vs H_T were found insignificant.

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LIST OF ABBREVIATIONS AND ACRONYMS

TDS = Total Dissolved Solids
BARI = Bangladesh Agricultural Research Institute
BAU = Bangladesh Agricultural University
BBS = Bangladesh Bureau of Statistics
BINA = Bangladesh Institute of Nuclear Agriculture
CV = Coefficient of Variation
EC = Electrical Conductivity
SAR = Sodium Absorption Ratio
SSP = Soluble Sodium Percentage
RSC = Residual Sodium Carbonate
AAS = Atomic Absorption Spectrophotometer
PAR = Potassium Absorption Ratio
DTW = Deep Tubewell Water
FAO = Food and Agriculture Organization
Fig. = Figure
STW = Shallow Tubewell Water
HTW = Hand Tubewell Water
i.e. = Id est. (that is)
IW = Irrigation Water
LSD = Least Significant Difference

LIST OF ABBREVIATIONS AND ACRONYMS

SD = Standard Deviation

USEPA = United States Environmental Protection Agency

H_T = Hardness

VH = Very Hard

SAU = Sher-e-Bangla Agricultural University

MH = Moderately Hard

Viz. = Videlicet (namely)

dS cm^{-1} = Deci Siemens per centimeter

% =Percentage

^{0}C = Degree Celsius

cm = Centimeter

g = Gram

Mg L^{-1} = Milligram per Litre

Me L^{-1} = Milli Equivalent per Litre

R^2 = Co-efficient of Determination

m = Meter

r = Correlation of Coefficient

µS cm^{-1} = Micro Siemens per centimeter

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Quality of water is not only essential for irrigation but equally important for drinking, domestic, livestock and industrial purposes. The Buriganga, an attractive river is now polluted with different chemical residues released from different industries. Among these main residues of tannery industry of Hazaribag area, plastic industrious wastes, dying effluents and waste debris of different markets are important. Near about 3 lakh people live in Kamrangir Char from Hazaribagh to Pagla 80 per cent water of the Buriganga River is polluted during dry season (Anonymous, 1997a). There are plenty of industries that are spontaneously polluting our rivers. About 1172 industrial polluting entities are polluting the Buriganga and the tanneries of Hazaribag is the major source (Anonymous, 1997b). The pollutants, in the water are toxic for aquatic animals and it is clear from the reports on fish dying in the river Sitalakhya where poisonous chemicals have been drained into the water from the dying units (Anonymous, 1997c). In the dry season, when the river flow is minimum the polluting loads discharged in the rivers from major urban centre's exceed the assimilation capacity of the rivers Dissolved oxygen (DO) concentration in a long reach of the river Buriganga up to sewage outfall of Pagla was found to be below 4 mg L^{-1}, the minimum DO required to support fish life (Anonymous, 1997c). Of the water supplied in the city, some 222 deep tube wells account 98 percent while two per cent is from surface water source of the Buriganga through Chandnighat Water Treatment Plant. A few days ago British Broadcasting Corporation (BBC) telecast the live scences of polluted Dhaka city under caption "Dhaka is the worst polluted city in the world" (Jalil, 1997). The chemical constituents of water determine its quality as well as its usefulness for irrigation, industrial and domestic usage. All water contains varying amounts of different species of cations and anions. Among them the principal soluble ions are Ca^{++}, Mg^{++}, Na^{+} and K^{+} as cations and Cl^{-}, SO_4^{--}, CO_3^{--} and HCO_3^{-} as anions. Beside these, Cu^{++}, P++, Mn^{+}, Fe^{+++}, Zn^{++}, Si^{++} and F^{-} ions are present in minor amounts. Out of the soluble constituents, Ca^{++}, Mg^{++}, Na^{+}, Cl^{-}, HCO_3^{-}, SO_4^{--} and B^{+} are of prime importance in determining the quality of irrigation water, especially for rice. Certain soluble ions at relatively high concentrations have a direct toxic effect on sensitive crops; these toxic elements are B, Na, Cl and Li. Moreover, specific water may be suitable for irrigation but may not be suitable for drinking and industrial use due to the presence of some other ions at toxic level. Most toxic elements for drinking water are As, Cd, Cr, Cl, Pb, Hg, Fe and Zn. The quality of water is generally judged by its total salt concentrations, relative proportions of cations of sodium adsorption ration (SAR) and the contents of HCO_3. That is why, main important chemical constituents of water constituents are necessary to assess their suitability for irrigation, drinking and domestic use, air-conditioning and industrial usage.

Some investigations on the quality of water in some selected areas of Bangladesh namely, Dinajpur sadar, Kalihati, Madhupur, Pangsha, Baliakandi, Shahzadpur, Jamalpur, Gazipur, Meherpur and Muktagacha Thana have been conducted. Most of the chemical analyses of these investigation pH, EC, Ca, Mg, CO_3, HCO_3, Cl, Na, Cu, Mn, Zn and Fe. But little attention has been given to the concentration of micronutrients (e.g. Cu, Mn, Zn, Fe, As, Cr, Pb, Hg, Cd e.g.). Now a day's analyses of different sources to determine the toxic elements are very important for irrigating crops, domestic usages, drinking and also for industrial water supply. Unfortunately, there is no laboratory for systemic investigation of water quality in Bangladesh. In the study area the surface and groundwater were used for irrigation (for home, kitchen gardening and field crop irrigation), drinking and domestic uses, air conditioning beverage, confectionary, laundering, dying, ice factory, cold storage, brick field and other industries. In view of the above mentioned importance, a study has been conducted to assess the water quality from different non-point sources of the Buriganga River and deep tube wells of neighboring of Dhaka city. The study was conducted at the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka with the following objectives:

i) Analysis of water to determine the chemical constituents present therein and

ii) Classification of water on the basis of standard criteria as regards to suitability or irrigation, drinking, air-conditioning, industrial usage and livestock consumption.

iii) To identify the polluted water sources for future recommendations.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Water is the universal solvent and it's all naturally occurring sources contain variable quantities of inorganic and organic substances. Sometimes, suspended and colloidal materials also occur in it. It is necessary to determine the quality of water and its possible effects on soil properties due to long term irrigation, and its suitability for drinking and industrial usage. A few problem oriented research works relevant to the topic have been carried out home and abroad. But systematic research work on the Buriganga is very limited. However, an effort has been made to review some of the available research reports from home and abroad on irrigation water quality under the following sequences.

2.1 Water quality based on pH

It is an important parameter for ascertaining the reactivity character of water. Acharya *et al.* (2008) found that the pH value ranges between 8.0 and 9.4 in the ground water of Bhiloda taluka of Sabarkantha district (North Gujarat), India. It was observed that 76% of the water samples lied in the range of 6.5- 8.5 prescribed by Bureau of Indian Standards. Islam (1984) stated that pH varies from 6.72 to 7.54 in the round water sample of Matiranga Upazilla under Khagrachari Hill District of Bangladesh. Arefin (2002) stated that the pH values of ground water samples in sadar upazila under Pabna 'district varied from 7.5 to 8.2. The pH values of the ground water of Sherpur upazila under which district ranged from 4.2 to 8.8 (Rahman, 2001). Singh *et al.* (2001) reported that the values of irrigation water samples of Chirawa Block Jhunjhunu district varied from 7.1 m 8.2. Siddique (2000) reported that the pH of ground water samples of Atrai upazila under Naogaon district was found within the limited of 6.88 to 9.84. The pH values of water samples in Tongi aquifers were within the range of 6.69 to 7.63 indicating slightly acidic to alkaline in nature (Sen *et al.*, 2000). The pH values of ground waters collected from Sherpur sadar under Old Brahmaputra Floodplain ranged from 7.64 to 8.90 indicating slightly alkaline to alkaline in nature (Hoque, 2000). Jesmin (2000) found that the pH values of ground water in Gaibandha aquifers ranged from 6.73 to 8.66 reflecting "slightly" acidic to alkaline in nature. The pH value of water samples collected from Mahadebpur and Nachoul upazilas varied from 7.48 to 9.44, 6.74 to 9.33 and to 8.2, respectively (Zaman, 2000).

Ibrahim and Salmon (1992) reported that the pH of irrigation water of Faisalabad (Pakistan) city effluent ranged from 7.0 to 8.2. The pH of groundwater of Madhupur under Tangail district was within the range from 8.2 to 8.5 (Zaman and Majid, 1995). In groundwater samples of Muktagacha, the pH value varied from 7.5 to 8.5 (Mosharaf 1992). Raman and Zaman (1995) conducted a study at Shahzadpur in Thana in Sirajgonj district and reported that the pH ranged from 8.2 to 8.7. The pH of Ground and surface waters of Meherpur reportedly ranged from 7.8 to 8.1 (Quddus and Zaman, 1996). Baddesha *et al.* (1988) worked in Haryana on raw sewage water and found that the pH value varied from 7.0 to 7.5. The pH of groundwater of Phulpur Thana of Mymensingh district was within the range from 8.1 to 8.3 (Shahidullah, 1995). Mohiuddin (1995) worked on water quality of Pangsha Thana in Rajbari district and observed that the pH varied within the range of 8.0 to 8.3. The pH of groundwater at Dinajpur district varied within the limits of 7.69 to 8.33 (Biswas and Khan, 1976). Ranianjulu *et al.* (1992) worked on groundwater samples of Andhra Pradesh (India) and found that the pH value varied within the range of 7.2 to 8.2. In field trials in Santa Victoria do Palmar in rice cv. BR-IRGA it was found that soil pH was increased due to tannery residues (Machado *et al.*, 1984).

2.2 Water quality based on EC

It is a key parameter for assuming the quality status of water from salinity point of view. Water quality on the basis of Electrical Conductivity Acharya *et al.* (2008) found that the maximum electrical conductivity (EC) was 742 μS cm^{-1} (at Sunokh) and the minimum EC was 231 μS cm^{-1} in the ground water of Bhiloda taluka of Sabarkantha district (North Gujarat), India. The result indicates that almost all the water samples are within the permissible limits of 650 μS cm^{-1} except at sampling locations viz, Sunokh (642 μS cm^{-1}), Madhtimba (739 μS cm^{-1}), Padara (1304 μS cm^{-1}) and Jayla (781 μS cm^{-1}). Afraz (2007) carried out a research study to determine the Electrical Conductivity (EC) in metal-polluted irrigation water from a Dek at Thatta Wasiran in Sheikhupura District (Pakistan) over a period of time. The salinity of irrigation water is measured by electrical conductivity (EC) and it reflects salt concentrations (Agawam *et al.,* 1982). Richards (1968) proposed four salinity water quality classes on the basis of EC These classes were 'low salinity water' (CI) containing EC less than 250 μS cm^{-1}; medium salinity water' (C2) having EC from 250 to 750 μS cm^{-1}; high salinity water' (C3) having EC from 750 to 2250 μS cm^{-1} and 'very high salinity water' (C4) containing EC in the range of 2250 to 5000 μS cm^{-1}. The EC values below 250 μS cm^{-1} were considered quite safe. Second class used with moderate leaching, 'high sanity' and very 'high salinity' unsuitable for irrigation. Gupta (1984) claimed that groundwater quality deteriorated with the increasing depth. The EC varied from 0.4 to 7.4 dS cm^{-1} at 13-38 m depth and at the depth of 38-210 m, the EC varied from 31.1 to 44.8 dS cm^{-1}. Whereas EC of groundwater of Madhupur sadar thana ranged from 340 to 1980 μS cm^{-1} (Zaman and Majid, 1994).

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Wilcox (1955) classified the irrigation water on the basis of EC values as 'excellent' containing EC less than 250 μS cm^{-1}, 'good entraining EC from 250-750 μS cm^{-1} 'permissible' from EC 750-2000 μS cm^{-1}, doubtful from 2000-3000 μS cm^{-1} and not suitable when greater than 3000 μS cm^{-1}. Gupta (1986) reported that the groundwater quality of Rajasthan is of low to medium salinity category. Ibrahim and Salmon (1992) reported that the EC of Faisalabad (Pakistan) city sewage effluent varied from 3.0-5.72 dS cm^{-1}. The EC value of groundwater at Madhupur thana of Tangail district varied from 220 to 570 μS cm^{-1} (Zaman and Majid, 1995). Davies *et al.* (1993) investigated the surface water quality in the Thika area of Kenya and found that the maximum level of EC at effluent discharge point along the main rivers was 4420 μS cm^{-1}. The EC values of some sleeted river and groundwater for irrigation at Shahzadpur thana in Sirajong district was found between 500 to 834 μS cm^{-1} (Rahman and Zaman, 1995). In the California metropolitan region, Nightingale and Biabchi (1974) detected that the USA of local groundwater without supplemental surface supplies resulted higher EC by 9.5 per cent.

It was evident that high saline groundwater was mainly responsible for increasing salt Content of irrigated soil, particularly where drainage is poor (Soderstrom and Soderstrom, 1989). Michael (1978) revealed that highly saline water may be suitable in a well drained, light textured, fertile soil, while much saline water may be more harmful for the same crop grown on a heavy textured soil. Singh and Narain (1984) found that the seasonal fluctuations of the quality of irrigation water was relatively small at 26 sites of Agra district of Northern India affected by brackish water and salinity were maximized in June, minimized in December and intermediate in February. Costa *et al.* (1985) classified 160 water samples with respect to salinity and 74.3% belonged to category C1S1 and C2S2, considered as good' quality water, 22.7% belonged to classes C4S1, C4S2, C3S1, C3S2 may be used for irrigation depending upon soil type and crop. Only 3% belonged to class C3S4, C4S3 and C4S4 considered not suitable for irrigation on soils with restricted drainage. Khan and Basak (1986) analyzed used 35 deep tubewell water samples from sadar and Trishal thana under Mymensingh and found few deep tube wells in sadar were in moderate salinity and other selected locations were in low salinity group and were suitable for growing all crops.

Studies of the groundwater quality in the Koilsagar area indicated that the water are of sodium bicarbonate, sodium chloride, mixed cationic- mixed anionic, mixed cationic Na domination and mixed cationic Ca dominating bicarbonate types. Sodium bicarbonate and mixed Mg dominating bicarbonate water were almost prevalent. Graphical representation showed that most of the area had medium salinity- low sodium water useful for irrigation purpose. High salinity- low sodium (C2S1) and high salinity- medium sodium (C3S2) waters were present in some areas (Raju and Goud, 1990). Endale- Bekele *et al.* (1992) analyzed the suitability or the Awash River water quality for irrigation and found that Awash River (Ethiopia) water is medium in salinity with adequate leaching and drainage. Dell 'Atti *et al.* (1994) appraised the water quality in the Lecce province (Italy) and reported that in most cases a high level of salinity and advocated the use of these waters with caution, evaluating the types of cultivations and the geochemical characteristics of the soils. The EC values of Hagari and Tungabhadra rivers in India ware 1640 and 1730 $\mu S\ cm^{-1}$ respectively (Michael, 1978a).

2.3 Water quality based on total dissolved solids (TDS)

It is the total amount of mineral substances present in water left on evaporation. Acharya *et al.* (2008) found that the total dissolved solids (TDS) of the ground water samples ranged from 145 mg L^{-1} to 1910 mg L^{-1} of Bhiloda taluka of Sabarkantha district (North Gujarat), India. Islam *et al.*, (2003) stated that total dissolved solid (TDS) values were between 35-200 mg L^{-1} in the ground water sample of Matiranga upazilla under Khagrachari Hill district of Bangladesh. The TDS values of ground water in sadar upazila under Pabna district varied from 336.26-671.89 mg L^{-1} (Arefin,2002). Rahman (2001) reported that the TDS values ranged from 194.6 to 458.5 mg L^{-1} in ground water in selected aquifers of Bogra. Siddique (2000) revealed that the TDS values of ground water at Atrai upazila under Naogaon district ranged from 242.19 to 479.17 mg L^{-1}. Sen *et al.* (2000) reported that the TDS values of some surface and ground waters collected from Tongi aquifers varied from 123 to 675 mg L^{-1} showing 'freshwater' in quality. The TDS values of ground waters collected from Sherpur sadar under Sherpur district varied within the limit of 112 to 358 mg L^{-1} reflecting 'freshwater' in quality (Hoque, 2000). Jesmin (2000) measured TDS value of ground water in Gaibandha aquifer and found that TDS values varied from 192 to 1000 mg L^{-1}. Carroll (1962) and Freeze and Cherry (1979) revealed that the solid residue almost invariably consists of inorganic constituents and very small amount of organic matter. They classified groundwater into four categories on the basis of total dissolved solids (TDS). There were fresh water (TDS) 0-1000 mg L^{-1}), brackish water' (TDS = 1000-10000 mg L^{-1}, saline water (TDS = 10000-100000 mg L^{-1}) and brine water (TDS> 100000 mg L^{-1}).

The inorganic constituents that occur in groundwater were classified by Davis and De Wiest (1966) and termed them as major, minor, and trace. Among them Na, Mg, Ca, HCO_3 and major, B, CO_3, NO_3, K, Fe are minor and some are trace constituents such as PO_4, Cu, Mn and Mo. The concentrations of trace elements in groundwater are usually less than 1.0 ppm. The total concentration of major elements cover generally more than 90% of the total dissolved solids.

Davies *et al.* (1993) observed in the Thika area of Kenya that the maximum level of TDS at effluent discharge point along the main river was 390 mg L^{-1}; Richards (1968) stated that the TDS of some river waters in the United States ranged from 108 to 2380 mg L^{-1}. TDS values of panchpadra salt lake in India were 215,080 mg L^{-1} (Karanth, 1987). The TDS values of river and groundwater in Shahzadpur were within the range of 348 to 560 mg L^{-1} (Rahman and Zaman, 1995). Hussain *et al.* (1991) found the mean TDS value of groundwater from 15 punjab districts was 1252 mg L^{-1}. Tigris River (Iraq) excellent for irrigation purpose on the basis of TDS along its whole length with some deterioration especially in the middle and southern reaches of the river course. Zaman and Majid (1995) reported that the TDS value of Madhupur groundwater varied from 100 to 600 mg L^{-1}. Another study showed that the TDS values of river and groundwater at Shahzadpur Thana in Sirajgang district varied within the limits of 510 to 560 mg L^{-1} (Rahman, 1993).

2.4 Water Quality based on calcium, magnesium, sodium and potassium

Calcium, magnesium and sodium are considered as major constituent in groundwater, while potassium as minor constituent (Davis and De Weist, 1966). Acharya *et al.* (2008) found that potassium (K) in the ground water ranges from 0.01 me L^{-1} (Jinava) to 0.03 me L^{-1} (Bhatera) of Bhiloda taluka of Sabarkantha district (North Gujarat), India. These authors also found that the sodium content of the ground waters of Bhiloda taluka of Sabarkantha district (North Gujarat), India ranges from 0.5 me L^{-1} (Jinava) to 32.87 me L^{-1} (Sunokh). About 61% of the water samples show sodium higher than the permissible limit of 50 ppm (9me L^{-1}) in irrigation water described by BIS (Bangladesh Institute of Statistics) (1983). Arefin (2002) stated that calcium, magnesium, sodium and potassium contents in groundwater in sadar upazila under Pabna district varied from 0.8 to 3.8, 1.5 to 4.30, and 0.14 to 0.6 me L^{-1}, respectively. Ca, Mg, K and Na contents in groundwater sources of Sherpur upazila under Bogra district ranged from 0.5 to 2.5, 0.8 to 3.6, trace to 2.22 and 0.1 to 1.36 meL^{-1}, respectively (Rahman, 2001). Hoque (2000) reported that Ca, Mg, Na and K contents in all water of Sherpur sadar under Sherpur district ranged from 0.5 to 2.0, 0.4 to 2.0, 0.006 to 0.421 and 0.097 to 2.260 me L^{-1}, respectively. Sen *et al.* (2000) found that in Tongi aquifers the concentrations of Ca, Mg, Na and K in water samples varied from of 0.50 to 3.21, 0.70 to 5.13, 0.20 to 2.28 and 0.12 to 0.59 me L^{-1}, respectively. The contents of Ca, Mg, Na and K in groundwater samples collected from Gaibandha sadar under Gaibandha district varied from 0.72 to 3.01, 1.80 to 6.80, 0.06 to 0.74 and 0.45 to 6.47 me L^{-1}, respectively (Jesmin, 2000). Siddique (2000) analyzed surfaces and ground water samples collected from Atrai upazila under Naogaon district and recorded that the amounts of Ca, Mg, Na and K ranged from 0.50 to 2.20, 0.70 to 4.10, 0.11 to 1.13 and 0.012 to 0.80 me L^{-1}, respectively. Nizam (2000) showed that Ca, Mg, Na and K contents in surface and groundwater samples collected from Bhaluka upazila under Mymensingh district varied from 0.10 to 2.80, 0.40 to 4.40, trace to 0.077 and 0.086 to 0.33 me L^{-1}, respectively. Ismail (1984) reported that Na^+ was the dominant cation over the entire range of electrical conductivity followed by Ca^{2+}, Mg^{2+} and K^+ in water collected from 150 wells in cultivated farms throughout Qatar. Rao *et al.* (1982) analyzed 605 groundwater samples of Bijapur district, Karnataka, India and found that most of the water samples ware of Na-Mg-Ca cationic type. Ophori and Toth (1989) analyzed 167 ground water samples in Ross Creek Basin (Alberta, Canada) and found that waters of the Ca-Mg-HCO_3 and Na-HCO_3 types are dominant in recharge areas and those of the Ca-Mg-SO_4-HCO_3 and Na-SO_4- HCO_3 types prevail in discharge areas. Costa *et al.* (1985) reported that calcium, magnesium, potassium and sodium contents in some river water ranged from 0.23 to 7.18, 0.08 to 5.51, 0.02 to 0.31 and 0.19 to 10.66 me L^{-1} respectively. Calcium, magnesium, potassium and sodium contents of surface and ground sources of Shahzadpur thana ranged from 2.0 to 4.40, 1.09 to 2.19, 0.10 to 0.24 and 0.91 to 1.39 me L^{-1} respectively (Rahman and Zaman, 1995). Quddus and Zaman (1996) state that Ca, Mg, Na and K contents present in surface and groundwater of Meherpur varied from 2.06 to 2.80, 1.01 to 1.60, 0.28 to 0.68 and 0.12-2.90, 1.00-1.30, 0.43-3.05 and 0.05-0.18 me L^{-1} respectively (Zaman and mohiuddin, 1995). Pucci *et al.* (1992) conducted a study on combining unit effects on water quality in the New Jersey Coastal plain and reported the concentrations of calcium and magnesium ranging from 1.7 to 666 mg L^{-1} and 0.3 to 140 mg L^{-1} respectively a study on Arabian Gulf water conducted by Abu-Sharar (1987) revealed that Mg is the predominant bivalent cation with concentration of 5.2 times greater than that of Ca. Some irrigation waters contain enough dissolved K to obviate the need for potassium fertilization (James *et al.*, 1982).

2.5 Water quality based on iron, manganese, zinc and copper

An experiment was conducted by Hoque (2000) to evaluate the water quality of Sherpur upazila under the district of Sherpur. He found that the concentrations of Fe, Mn in those areas ranged from 0.05 to 0.90 and 0.50 to 0.58 mg L^{-1}, respectively, Jesmin (2000) found that the respective concentrations of Fe and Mn in groundwater was collected from Gaibandha aquifer varied from 0.15 to 1.00 and 0.03 to 0.10 mg L^{-1} respectively. Siddique (2000) revealed that the amounts of Fe and Mn in water samples varied from Atrai upazila under Naogaon district ranged from 0.10 to 0.42 and trace to it mg L^{-1}, respectively. Nizam (2000) analyzed 20 water samples collected from the sources of two unions of Bhaluka upazila under Mymensigh district and reported the most of the water samples were 'suitable' for drinking livestock consumption F to the presence of higher amounts of iron (Fe = 0.35-3.11 mg L^{-1}) and manganese (Mn= 0.091- 0.347 mg L^{-1}). An experiment was perfomed by Zaman (2000) to evaluate quality of groundwater collected from Bagmara, Mahadebpur and Nachoul upazilas in the area. He found that the concentration of Fe in those areas varied from 0.005 to 0· 90, 0.010 to 3.722 and trace to 0.44 mg L^{-1}, respectively but the content of Mn in those also ranged from 0.0020 to 0.197, 0.005 to 0.567 and 0.007 to 0.102 mg L^{-1}, respectively. The concentrations of Fe, Mn, Zn and Cu in ground waters of phulpur Thana under Mymensingh district were within the range of 0.10 to 1.30, 0.20 to 0.05, 0.01 to 0.03 and 0.03 mg L^{-1} respectively (Shahidullah, 1995). Rahman (1993) state that the collected surface and groundwater continued Fe, Mn, Zn and Cu within the range of 0.10 to 0.42, 0.030 to 0.064, 0.023 to 0.058 and 0.029 to 0.063 mg L^{-1} respectively and iron was dominant in groundwater compared to surface water. Jonnalagadda and Nenzou (1996) studied the effect of arsenic rich abandoned mine dumps in Zimbabwe on the adjacent Mutate river and sub equinity on the

Odzi and Sawi Rivers. They found the river water sample next to the dumps during the rainy season contained Cu and Mn were 0.072 and 0.057 mg L^{-1}, respectively. The river water in the Thika area of Kenya was analyzed by Davies *et al.* (1993) and found that Cu and Zn were within the safety limits for drinking water, whereas Fe and Mn were in excess. Quddus (1993) indicated that the concentrations of Fe, Mn, Zn and Cu in surface and groundwater of Meherpur sadar Thana varied from traces to 0.05, traces to 0.20, traces to 0.10 and traces to 0.1 mg L^{-1}, respectively. The content of Fe, Mn, Zn and Cu in groundwater of Gazipur Sadar thana varied from traces to 2.3, traces to 0.20 traces to 0.08 and traces to 0.05 mg L^{-1} respectively (Quayum, 1995). Mohiuddin (1995) showed that the collected irrigation water samples of Pangsha thana of Rajbari district contained Fe, Mn, Zn and Cu within the range of 0.10 to 2.00, 0.01 to 0.07 of 02 to 0.06 mg L^{-1} respectively.

2.6 Water quality based on boron

Boron conserved growth promoting and stimulating effect when it is used in optimum concentration and growth retarding and toxic effects in higher concentration. Boron is highly toxic to crops (especially for rice) when its concentration in water is slightly higher than optimum concentration (0.75 to 1.00 mg L^{-1}. Contrary to that some authors reported the optimum concentration of boron should be 0.75 mg L^{-1} for sensitive crops. The concentration of B in surface and ground water collected from Old Brahmaputra Floodplain ranged from 0.02 to 0.45 mg L^{-1} exhibiting no toxicity (Hoque, 2000). An experiment was conducted by Sen *et al.* (2000) to evaluate water quality of Tongi aquifers and found that concentration varied from 0.006 to 7.0 mg L^{-1} and all the waters were 'excellent' in quality for irrigation Jesmin (2000), that all the ground waters collected from

Gaibandha aquifers contained small per cent of B (0.04 TO 1.19 mg L^{-1}). Siddique (2000) found that B concentration in surface groundwater of Lower Atari Basin ranged within the limit of 0.009 to 0.54 mg L^{-1} no B toxicity for sensitive crops. Nizam (2000) stated that B content in surface groundwater samples collected from unions of Bhaluka upazila under Madhupur ranged from 0.06 to 1.10 mg L^{-1}. Alamgir *et al.* (1999) analyzed groundwater of Madhupur Tract and recorded that the concentration of B ranged from 0.10 to 1.0 mg L^{-1} and these waters were not problematic for irrigating agricultural crops. Wilcox (1948) classified irrigation water based on the concentration of boron into five groups, viz, excellent good permissible doubtful and not suitable and for plants into three groups viz sensitive semi-tolerant and tolerant on the basis of boron tolerance.

Biggar and Nielson (1972) classified irrigation water on the basis of boron content in relation to irrigation water quality and showed that less than 0.05 mg L^{-1} boron within safe limits for sensitive crops from 0.5 to 1.0 mg L^{-1} boron for sensitive crops showed slight to moderate injury from 1.00 to 2.00 mg L^{-1} boron for semi tolerant crops showed slight to moderate injury from 2.00 to 4.00 mg L^{-1} boron for tolerant crops showed slight to moderate injury and more than 4.00 mg L^{-1} boron for tolerant crops showed slight to moderate injury and more that 4.0 mg L^{-1} boron hazardous for nearly all crops. Boron content in different kinds of groundwater used for irrigation in Rajasthan, India varied from 0.238 to 7.66 mg L^{-1} (Mondal, 1964). Kanwar and Mehta (1970) reported that boron content of irrigation waters collected from surface dug well ranged from trace to 2.47 mg L^{-1}. Gupta (1983) discussed the occurrence of boron in water the effect of high boron levels on plant growth solid detoxification from boron and tolerance level of boron concentration for irrigation water. Costa *et al.* (1985) reported the only 8% of the samples, our for 160, recorded boron concentration over 1.5 mg L^{-1}. Khan and Basak (1986) conducted the suitability study of groundwater for irrigation use in sadar and Trishal Upazilla under Mymensingh district and reported boron contents in most of the samples were within safe limit for irrigation even for sensitive crops.

Boron content varied from 0.13 to 0.55 mg L^{-1} in irrigation water of Phulpur thana as observed by Shahidullah (1995). Another study showed that the content of boron in groundwater of Gazipur sadar was within 0.15 to 0.54 mg L^{-1} (Quayum, 1995). Boron content was found to vary from traces to 0.92 mg L^{-1} in groundwater sources of some village of Madhupur thana (Zaman and Majid 1995). Rahman and Zaman (1995) reported that the boron concentration in surface and groundwater of Shahzadpur that under Sirajgonj district varied from 0.10 to 0.40 mg L^{-1}. Zaman and Mohiuddin (1995) found that the boron concentration in groundwater of Pangsha that under Rajbari district to be varied from 0.08 to 0.45 mg L^{-1}. Quddus and Zaman (1996) stated that the boron content in surface and groundwater of some village of Meherpur sadar thana ranged from 0.10 to 0.63 mg L^{-1}.

2.7 Water quality based on carbonate, bicarbonate, chloride and sulphate

Hill (1940) and Piper (1944) conducted a study and showed that the concentration of bicarbonate were higher that other ions, Scheller (1995) proposed a diagram presenting the cat ion and anion composition of many samples to be presented on this graph where major trends in the data could be discerned visually, which indicated higher concentration of bicarbonate than those of ions, The highest concentration chlorides was recorded in padara (19.5 me L^{-1}) and the lowest at Bhatera (1.00 me L^{-1}) concentration of SO_4 and Cl in ground water in sadar upazila under padara district was the range of 0.14 to 5.48 me L^{-1} and 0.8 to 1.4 me L^{-1}, respectively (Arefin, 2002). Rahman (2001) revealed that the collected groundwater samples of Sherpur upazila under district contained SO_4 and Cl within the range of trace to 10.30 mg L^{-1} and 0.40 to me L^{-1}, respectively. Sen *et al.* (2000) found that the surface and groundwater in Tongi under the district of Gazipur contained SO_4 within the limit of trace to 1.0 mg L^{-1} and also contained Cl varying from 0.80 to 4.80 me L^{-1}. In all the surface waters of Madhupur Tract, Cl content of tube-well water used for during monsoon and winter seasons were 45.6 and 55.2 mg L^{-1}, respectively Vivis and De Wiest (1996) analyzed some water samples and found that HCO_3 concentrations were higher and SO_4 concentrations ware lower. Nightingale and Bianchi (1974) analyzed the groundwater of California metropolitan region and mentioned that the use of local groundwater without supplemental surface supplies resulted in groundwater Cl concentration higher by 918 percent. Arefin (2002) observed that in Sadar upazila under Pabna district, the amount of CO_3 in ground in all the ground water were not detected and HCO_3 concentration was within the range of 3.5-7 me L^{-1}. Rahman (2001) found that the concentration of HCO_3 varied from 1.5 to 4.5 me L^{-1}. The concentrations of CO_3 and HCO_3 in surface and ground waters ranged from 0.05 to 1.50 me L^{-1} and 0.60 to 3.50 me L^{-1}, respectively (Hoque, 2000). The concentration of HCO_3 ranged from 0.80 to 6.20 me L^{-1} and this anion was dominant in groundwater as compared to surface water in Tongi under Gazipur (Sen *et al.*, 2000). Jesmine (2000) observed that the amount of CO_3 in all the ground waters in Gaibandha aquifers was not detected and HCO_3 concentration was within the range of 1.50 to 6.00 mg L^{-1}. Agrwal *et al.* (1982) found varying quantities of anions in the form of HCO_3, SO_4 and C1 in running surface water. The contents of CO_3, HCO_3 and C1 varied from 0.05 to 0.42, 0.63 to 5.20 and 0.12 to 7.65 me L^{-1} respectively in some river water in Western United States (Richards, 1968).

Most of the groundwater contained HCO_3 and mostly Cl dominant among the anions (Rao *et al.*, 1982). C1 was found to be dominant anion followed by SO_4 and the concentration of CO_3, HCO_3 were low in water samples collected from different wells (Ismail, 1984). The concentration of CO_3, HCO_3 and Cl in groundwater's of Madhupur ranged from 0.04, 0.80 to 2.40 and 0.10 to 0.50 me L^{-1} respectively (Zaman and Majid, 1994). Quddus (1993) observed that the concentration of CO_3, HCO_3 and Cl in surface and ground waters ranged from 0.20 to 0.40, 2.40 to 3.10 and 0.54 to 0.95 me L^{-1} respectively and SO_4 in traces to 7.70 me L^{-1}. Todd (1980) mentioned that irrigation water may contain 0 to 50 mg L^{-1} carbonate and less than 500 mg L^{-1} bicarbonate. A field investigation carried out on the effects of saline water irrigation in a semi-arid region and showed that 70 to 90 percent of SO_4 and Cl ions added retained in upper 2 to 4 meters of the profile. The most common accumulating ion was SO_4 (Magaritz and Nadler, 1993).

Confining unit effects on water quality in the New Jersey coastal Plant (USA) was appraised by Pucci *et al.* (1992) and found sulphate concentration ranging from 1.5 to 2200 mg L^{-1}. Rahman (1993) reported that bicarbonate and chloride in all irrigation water samples from both surface and ground sources in Shahzadpur thana under Sirajgonj district were dominant along with carbonate and sulphate in small amounts. A study conducted on groundwater quality in Lecce province (Italy) revealed that water used for irrigation purposes was enriched with high content of chlorides (Dell' Atti *et al.*, 1994). Zaman and Majid (1995) reported the concentrations of CO_3, HCO_3, C1 and SO_4 in groundwater of some village of Madhupur Thana to vary from 0.04 to 0.40 0.80 to 2.52. 0.20 to 0.80 and 0.12 to 2.16 me L^{-1} respectively. The respective concentrations of CO_3, HCO_3, C1 and SO_4 24-2.25 and 0.13-0.27 Me L^{-1} (Zaman and Mohiuddin, 1995). Quddus and

Zaman (1996) stated that contents of CO_3, HCO_3, Cl and SO_4 in surface and groundwater of some villages of Meherpur sadar ranged from 0.20 to 0.40, 2.60 to 3.10, 0.75 to 0.95 and traces to 7.20 me L^{-1} respectively.

2.8 Water quality based on nitrate

Sangodoyin and Agbawhe (1992) reported that lichgates and effluents from the abattoir sites were found to increase, particularly the NO_3 values of the underlying aquifer. They also mentioned that chemical composition of the groundwater was 250m from the abattoir site was also not satisfactory as a raw water source for dirking purposes. Kato and Ogura (1992) studied the groundwater (spring and deep-well waters) quality in the Kitatama area of Tokyao during the two water ranged from 467 to 653 mg L^{-1}, with high concentration in winter and low concentration in summer. Nitrate-nitrogen levels in groundwater are generally very low. In 91% of the principal aquifers surveyed the level was below 3 mg L^{-1} (Mussman, 1991). He observed many drinking water wells with excess levels of nitrate. Nitrates in groundwater, and relationships with others physicochemical variable were studied in Ahdhra Pradesh, India Nitrate concentration (1) increased with a decrease in pH; (2) increased with the increase in respective in water hardness chloride sulphate and total solids; and (3) bad no detectable change related to fluorine concentration and water table depth (Kumar *et al.,* 1992). Bashkin *et al*. (1989) mentioned that discharge of groundwater into rives leads to nitrate enrichment of surface waters. Nightingale and Biaochi (1974) studied the groundwater quality in the California metropolitan region and observed that the use of local groundwater without supplemental surface supplies resulted in groundwater NO_3 concentration higher by 18.6 per cent. A long observation of a sample well (43 m deep) surrounded by Cherry orchards in the Grand Traverse

Bay of Michigan (USA), Rajagopal (1978) observed that the nitrate-nitrogen concentration ranged from 13.09 to 20.64 mg L^{-1} and had an average value of 15.25 mg L^{-1}.

2.9 Water quality based on sodium adsorption ratio (SAR)

Wilcox (1948) proposed a chart for classifying irrigation water into four classes to represent alkali hazard on the basis of sodium adsorption ration and electrical conductivity. Sen *et al.* (2008) stated that the sodium adsorption ratio (SAR) values varied from 26.40 in the ground water of Bhiloda taluka of Sabarkantha district North India. They also found that about 54% of the water samples of the taluka under have low values (<10.0). Sarfraz *et al.* (2007) carried out a research study to the sodium adsorption ratio (SAR) in metal - polluted irrigation water from a Deck at Thatta Wasiran in Sheikhupura District (Pakistan) over a period of time samples were collected during rice crop (cv. Super Basmati and Basmati 385) 15-day intervals from 3 August to November 2002. The results showed that Deck water had an SAR which was within the safe limit. Mustafa *et al.* (2006) sodium adsorption ratio (SAR) in drainage water (DW) and sewage water (SW) irrigation was 6.90 and 5.06, respectively in Sharkia Gove orate, Egypt, (1972) stated that Sodium Absorption Ratio (SAR) values were between 0.36 in the ground water sample of Matiranga Upazilla under Khagrachari Hill Bangladesh. Arefin (2002) stated that the SAR values of groundwater samples under Pabna district varied from 0.38 to 1.05. The SAR values of of Sherpur upazila in Bogra district ranged from 0.22 to 0.90 (Rahman, (2001) found that the SAR values of Bhaluka upazila under the district of ranged from 0.06 to 0.30. Hoque (2000) analyzed groundwaters of Sherpur in the district of Sherpur and found that the SAR values ranged from 0.07 to 2.69 'low' alkalinity hazard (S1). Jesmin (2000) found that the

SAR values of groundwater collected from at the distrct of Gaibandha aquifers varied from 0.29 to 3.28. The values of SAR varied from 0.12 to 0.89 in groundwater of Lower Atrai Basin in Naogaon district (Siddique, 2000). An experiment was conducted by Zaman (2000) and found that the SAR values of groundwaters collected from ahadebpur upazila of Naogaon district, Bagmara and Nachoul upazil as of Rajshahi district varied from 0.52 to 3.30, 0.74 to 5.06 and 0.36 if to 1.83, respectively indicating 'low' sodium hazard. Mitra and Gupta (1999) revealed that the SAR values of tubewell water of Calcutta in India during monsoon and winter seasons were 0.55 and 0.65, respectively and remarked that on the basis of SAR, all the waters are excellent in quality. Hussain and Ahmed (1999) analyzed groundwater of Muktagacha under the district of Mymensingh and indicated that water samples were graded as 'excellent' to poor in quality. Acharya *et al.* (2008) found that the soluble sodium percentage (SSP) values of the ground water samples of Bhiloda taluka of Sabarkantha district (North Gujarat), India ranged from 12.2 to 91.4. The lowest value of 12.2 per cent was observed in Jinava whereas the highest value of 94.4 per cent was recorded in a water sample from Jinava in India.

Thorne and Thorne (1951) modified the proposed chart of Wilcox and proposed a binomial classification system giving five classes of salt and five for increasing SAR hazards. The U.S. Salinity Laboratory proposed the sodium adsorption ratio (SAR) as a more reliable criterion for the evaluation of sodium hazard in water during 1955. Richards (1968) stated that the SAR value rather than the soluble sodium percentage (SSP) is a more reliable criterion for evaluation of sodium hazard in water and further suggested four types of irrigation waters in respect to SAR values and these were low sodium water (S1) medium sodium water (S2), high sodium water (S3) and very high sodium water (S4). Water classification for

SAR values more than 26 was not suitable for irrigation purpose SAR values from 10 to 26 were considered as god and the SAR values less than 10 were considered excellent (Todd, 1980). Rao *et al.* (1982) analyzed 605 groundwater samples for irrigation collected from five taluka of Bijapur district, Karnataka, India and observed high SAR value (>100 in fairly large number of water samples of Bagalkot region, Singh and Narain (1984) stated that the seasonal fluctuation of quality of ground water was small at 26 sites in a tract of the Agra district of North India. The SAR was maximisal in June, minimimal in December and intermediate in February. According to a diagram for irrigation water, groundwater samples in Madhupur were classified into two categories. Among them, 38 water samples belonged to C2S1 (Majid, 1989). Costa *et al.*, (1985) analyzed and categorized one hundred and sixty water sample for the assessment of water quality it was found that 74.3% samples were under categories C1S1 and were rated good quality water 22.7% were of categories C4S, C4S2, C3S1 and C3S2 and only 3% samples belonged to class C3S4, C3S3 and C4S4, were considered not suitable for irrigation with limited drainage.

Sodium adsorption ratio of irrigation waters significantly correlated with electrical conductivity (Parvathappa *et al.*, 1990). Irrigation with water having EC 10000 µS cm^{-1} and SAR 30 slightly increased the seed yield of *Brassica juncea* and *Eruca sativa* crops compared with irrigation water having EC 1000 µS cm^{-1} and SAR 2.8 or 4.0 (Des and Lal, 1982) Ibrahim and Salmon (1992) reported the SAR of Faisalabad city (Pakistan) sewage effluent used for irrigation that ranged from 10.8 to 23.8. Hussain *et al.* (1991) studied the suitability of groundwater collected from Punjab (Pakistan) and obtained SAR was 8.39. Abu-Sharar (1987) conducted a study on Arabian Gulf water for future use for irrigation and revealed the SAR value relatively high (59.89). SAR values of surface and groundwater of shahzadpur thana under Sirajgonj district were found within the limit of 0.56-0.85 and waters of both the sources were categorized as low sodium water (Rahman and Zaman, 1995). Quayum (1995) reported the SAR ah of war from Gazipur dadar thana of vary from 0.50 to 0.94. Quddus and Zaman (1996) investigated water samples from some villages of Meherpur thana and reported the SAR ah values to vary from 0.21 to 0.49 and were categorized under class S1, which means low sodium water.

2.10 Water quality based on soluble sodium percentage (SSP)

Eaton (1950) used the term SSP to classify water quality and proposed that the water with SSP greater than 60 to be unsafe up to 40 as good and up to 20 as excellent. According to Wilcox (1955) irrigation water containing SSP values <20; 20-40; 40-60; 60-80 were categorized as excellent good permissible doubtful and not suitable respectively. Zaman (2000) observed that the SSP values of groundwater collected from Bagmara, Mahadebpur and Nachoul upazilas in Barind area ranged from 25.53 to 75.61, 21.20 to 79.42 and 17.00 to 51.56 per cent, respectively. Nizam (2000) found that the SSP values of 103 surface and groundwater samples collected from 11 unions of Bhaluka upazila under Mymensingh district ranged from 2.38 to 17.41 percent. In Gaibandha aquifers, the SSP values of groundwater samples varied from 9.20 to 45.75% and all waters under test were 'excellent', 'good' and 'permissible' classes (Jesmin, 2000). In 25% groundwater samples used for irrigation, the computed SSP values varied from 15.99 to 69.67% and all the waters were 'excellent' in quality (Hussain and Ahmed, 1999). Sarker (1997) reported that the SSP value of groundwater in Naryanganj aquifers varied from 6.31 to 91.20% and also stated that all the water samples were categorized into 'excellent', 'good', 'permissible' and 'doubtful' in quality. In 50 groundwater samples of Nachoul at High value; Barind Tract, the SSP values of those waters ranged from 17.00 to 51.56 %. Quddus and Zaman (1996) conducted an experiment to assess the quality of groundwater of Meherpur sadar under Meherpur district and the revealed that the SSP value of those water varied within the limit of 8.14 to 14.7% reflecting 'excellent' in water quality.

Ahmed *et al.* (1993) showed that there was a significant correlation between SAR and SSP in groundwater of different locations of Muktagacha Thana under Mymensingh district and also suggested that out of 30 water samples, 26 were under excellent to good classes and the rest were good to injurious classes. Out of 33 water samples of Phulpur Thana under Mymentisngh district, the SSP values varied from 6.81 to 28.99 (Shahidullah 1995). Among them, 33 samples were found excellent and the rest 8 samples were under good class. The SSP values of 19 surface and groundwater of Shahzadpur than under Sirajgonj district were found within the limit of 13.18 to 21.93 Fourteen samples lied under the category 'excellent" and rest 5 under 'good' (Rahman and Zaman, 1995).

The SSP values of hand tubewell and surface waters of Matiranga Thana under Khagrachari district varied from 20.39 to 69.37 (Helaluddin, 1996). The values of SSP varied from 18.31 to 40.95 in groundwater of Gazipur sadar (Quayum, 1995). In another investigation, Zaman and Majid (1995) analyzed groundwater samples from Madhupur Thana and found the SSP to be varied from 2.14 to 31.50. Twenty samples were excellent and 3 remaining were good. A study conducted by Zaman and Mohiddin (1995) revealed that the SSP value in 15 groundwater samples of pangsha Thana under Rajbari district were between 14,93 and 46.04. They considered water of all the locations as safe for irrigating all types of solid. Quddus and Zaman (1996) observed that the SSP values of 25 surface and groundwater samples from some village of Meherpur sadar ranged from 8.14 to 14.17 and categorized all water under calls excellent.

2.11 Water quality based on residual sodium carbonate (RSC)

Eaton (1950) classified the irrigation water on the basis of residual sodium carbonate; waters containing RSC 1.25 1.25 -2.50 and 2.50 me L^{-1} and categorized as suitable, marginal and unsuitable. Acharya *et al.*, (2008) found that the Residual sodium carbonate (RSC) values varied from -6.60 to 12.20 in the ground water of Bhiloda of Sabarkantha district (North Gujarat), India. Sarfraz *et al.* (2007) carried out a research study to determine the residual sodium carbonate (RSC) in metal-polluted irrigation water from a Nullah Deck at Thatta Wasiran in Sheikhupura District (Pakistan) over a period of time. Water samples were collected during rice crop (cv. Super Basmati and Basmati 385) growth at 15-days intervals from 3 August to 1 November 2002. The results showed that Nullah Deck water, had a RSC of 2.78-4.11 me L^{-1}, which was hazardous for crops. Arefin (2002) reported the RSC values of groundwater samples in sadar upazila under Pabna district varied to -0.10 to 0.10 me L^{-1}. Rahman (2001) stated that the RSC values of groundwater samples of Sherpur upazila in Bogra district were found between -0.1 to 2.40 me L^{-1}. Hoque (2000) analyzed groundwater samples of Sherpur sadar under Sherpur district and reported that the RSC values ranged from -1.10 to -0.10 and 0.00 to 1.90 me L^{-1} showing 'suitable' and 'marginal' water cases. Siddique (2000) reported that in all the groundwater samples collected Lower Atrai Basin RSC values varied from -1.80 to 0.15 me L^{-1} and these waters were rated as 'suitable' and 'marginal' classes. Jesmin (2000) found that in 55 groundwater samples collected from Gaibandha aquifers, RSC value was within the range of 0.10 to 0.61 me L^{-1}.

Zaman (2000) conducted a research work by collecting 90 groundwater samples from Bagmara, Mahadebpur, and Nachoul upazilas and observed that the RSC value fluctuated within the range of -8.1 to 0.8, -6.0 to 2.2 and - 0.75 to 8.8 me L^{-1}, respectively. Nizam (2000) stated that in surface and groundwater samples collected from Madhupur Tract, RSC values fluctuated between -0.30 to 5.8 me L^{-1} and these water samples were 'suitable' and 'not suitable' classes.

According to Eaton's classification, Biswas and Khan (1976) reported that our of 50 groundwater samples of Dinajpur district 45 samples suitable for all crops. 3 samples could be used for selected crops (marginal class) and the rest 2 samples were unsuitable. Gupta (1983) showed the effects of increasing residual sodium carbonate over the range of 2.5 10 me L^{-1} association with high SAR , HCO_3 and CO_3 on the yield of wheat. The yield of wheat was reduced and statistically insignificant. Rao *et al.* (1982) analyzed 605 underground irrigation water samples from five Taluka of Bijapur district Karnataka, India and reported that a considerable number of water samples were of very high salinity as well as of hazardous accumulation of RSC in Sindagi taluka. Vinay *et al.* (1986) showed that the increasing concentration of RSC from 0 to 10, 20 and 30 me L^{-1} in irrigation water decreased the grain and straw yield of wheat increased N.P and Na contents and decreased K. Ca and Mg contents in grain and stray. Increasing RSC levels of irrigation water decreased the yield of maize and wheat crops and also increased soil sodality (pH and SAR) as reported by Muralidhar and Yadav (1991). The RSC value of 19 surface and groundwater samples from Shahzadpur thana, Sirajgonj district were negative which meant all samples were free from residual sodium carbonate and were suitable for irrigation (Rahman and Zaman, 1995). Zaman and Majid (1995) analyzed 23 groundwater sample from some villages of Madhupur thana, Mymensingh and stated that 22 samples were free from residual sodium carbonate and the rest sample showed RSC value of 0.38 me L^{-1}. Zaman and Mohiuddin (1995) conducted a study on 15 groundwater samples of Pangsha thana, Rajbari district and found 14 samples suitable for irrigation as the RSC values were well below 1.25 me L^{-1} and one sample was marginal for irrigation with RSC value of 1.34 me L^{-1}. All 25 surfaces and groundwater samples from some villages of Meherpur sadar showed negative RSC value and thus were suitable for irrigation (Quddus and Zaman, 1996).

2.12 Water quality based on hardness (H_T)

It is commonly known parameter of water impurities which is virtually the summation of the amount of only Ca and Mg constituents. The H_T values of ground water in sadar upazila under Pabna district varied from 183.08 to 376.72 mg L^{-1} (Arefin, 2002). Rahman (2001) reported that the H_T values ranged from 84.9 to 265.9 mg L^{-1} in groundwater in selected aquifers of Bogra. Siddique (2000) stated that the hardness values of waters ranged from 64.90 to 299.49 mg L^{-1} in Lower Atrai Basin. In surface and groundwater samples collected from unions of Bhaluka upazila under Madhupur Tract , the hardness of waters ranged from 29.94 to 304.39 mg L^{-1} indicating 'soft' to 'very hard' waters in category (Nizam,2000).

Hoque (2000) revealed that the hardness (H_T) values of ground waters collected from Sherpur sadar under the district of Sherpur ranged from 36.96 to 159.91 mg L^{-1}. Jesmin (2000) found that in 55 groundwater samples collected from Gaibandha aquifers, the hardness (H_T) of all the ground waters were within the limit of 109.64 to 459.24 mg L^{-1} showing 'moderately A hard' to 'very hard' in quality Sawyer and Mc Carty (1967) classified irrigation water into four classes on the bases of harness (H_T). Water for hardness values from 0 to 75, 75 to 150, 150 to 300 and above 300 mg L^{-1} as $CaCO_3$ were classified as 'soft', 'moderately hard', 'hard' and 'very hard' respectively. The H_T values of all the collected water samples reneged from 94.88 to 184.27 mg L^{-1} at Phulpur thana of Mymensingh district and our of 33 samples, 25 were graded moderately hard and the rest 16 'hard' (Shahidullah,1995). According to Sawyer and McCarty's (1967) classification, irrigation waters collected from different underground sources of Gazipur sadar thana were under 'soft' class (Quayam, 1995). Rhaman and Zaman (1995) analyzed 19 surface and groundwater samples of Shahzadpur thana Sirajgonj district and found HT values to vary from 159.83 to 324.20 mg L^{-1}.They categorized 15 samples as 'hard' and 4 sample as 'very hard'. They opined that the hardness resulted due to abundance of divalent cat ions such as Ca and Mg, after 'Todd (1980). Zaman and Mohiuddin (1995) conducted a study on 15 groundwater of Pahgsha Thana under Rajbari district and observed the H_T values to vary from 114.84 to 199.72 mg L^{-1}. They found 9 samples 'moderately hard' and 6 samples hard. The H_T value for 25 surface and groundwater samples from some villages of Meherpur sadar ranged from 166.47 to 201.38 mg L^{-1} (Quddus and Zaman, 1996).

From the above mentioned available research findings relevant to the present study, it appears that most of the investigations so far have been conducted in different parts of the world on water quality of both surface and groundwater sources. Kept confined their chemical analyses only within pH, EC, Ca, Mg, Na, C1, CO_3 and HCO_3. But little attention has been paid to micronutrients and heavy metal ions present in water. These ions in some cases have been detected in minor quantities and vary writhing narrow range, but some of them often exceed the recommended limit for irrigation, drinking and industrial uses and become toxic.

So an attempt has been made to carry out an investigation of water samples of some parts of Dhaka city and its closed by areas in which micronutrients content was also taken into consideration. Such study can help to build a scientific basis of water management for the betterment of agricultural, drinking, industrial and fisheries sector.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

Water quality is important for its suitability for specific use. An attempt was taken to analyze water samples collected from the Buriganga River in Dhaka district and the chemical analysis was included the estimation of pH, electrical conductivity (EC), total dissolved solids (TDS) and major ionic constituents like $Ca^{2+,}$ Mg^{2+}, K^{+}, Na^{+}, Fe^{3+}, Mn^{2+}, B^{3+}, As^{3+}, $Cu^{2}+$, PO_4^{3-}, CO_3^{2-}, HCO_3^{-}, SO_4^{2-} *and* Cl^{-}. *Water analysis is* the most significant aspect of water management irrespective of its utility. Chemical analyses of water include the determination of the concentrations of inorganic constituents and to some extent, organic substance. It also includes measurement of pH and electrical conductance. Where temperature, colour, turbidity, odour and taste are evaluated in physical analysis. However, analysis of water from different sources to determine its chemical character is important to assess its suitability for irrigation, drinking and industrial usage.

3.1 COLLECTION OF WATER SAMPLES

Thirty three water samples were collected from Dhaka of which 16 during rainy season and another 11 at the time of dry season from the Buriganga river (surface water); and samples from different high-rise buildings and the rest 6 samples from different residential buildings and industries (ground water) during dry season. The dry season samples were collected from the data of March 25 to 30 and the wet season samples were from 20 to 22th August in the year of 2011. Water from all sources has wide use for drinking purposes while the pipeline deep tubewell water is used for air-conditioning, pharmaceuticals, small scale irrigation of ornamental plants for pot and garden culture, beverage, tanning, confectionery and many other industries. It is notable that there is no shallow or hand tubewell used for water supply in the study area. The sites of water sampling for different sources of waters were shown in Figure 1. The information of different water samples collected for analyses were mentioned in Table 1. The water sample was collected in one liter plastic bottles. These bottles were cleaned with dilute hydrochloric acid (1:1) and then washed with tap water followed by distilled water. Before sampling, containers were again rinsed 3 to 4 times with water to be sampled. In case of river water, sample was drawn from different points and few centimeters (10-15 cm) below the surface. The collected samples were sealed immediately to avoid exposure to air. The water carried to the laboratory of Bangladesh Agricultural Research Institute (BARI), Gazipur for testing. The samples were analyzed as quickly as possible on arrival at the laboratory.

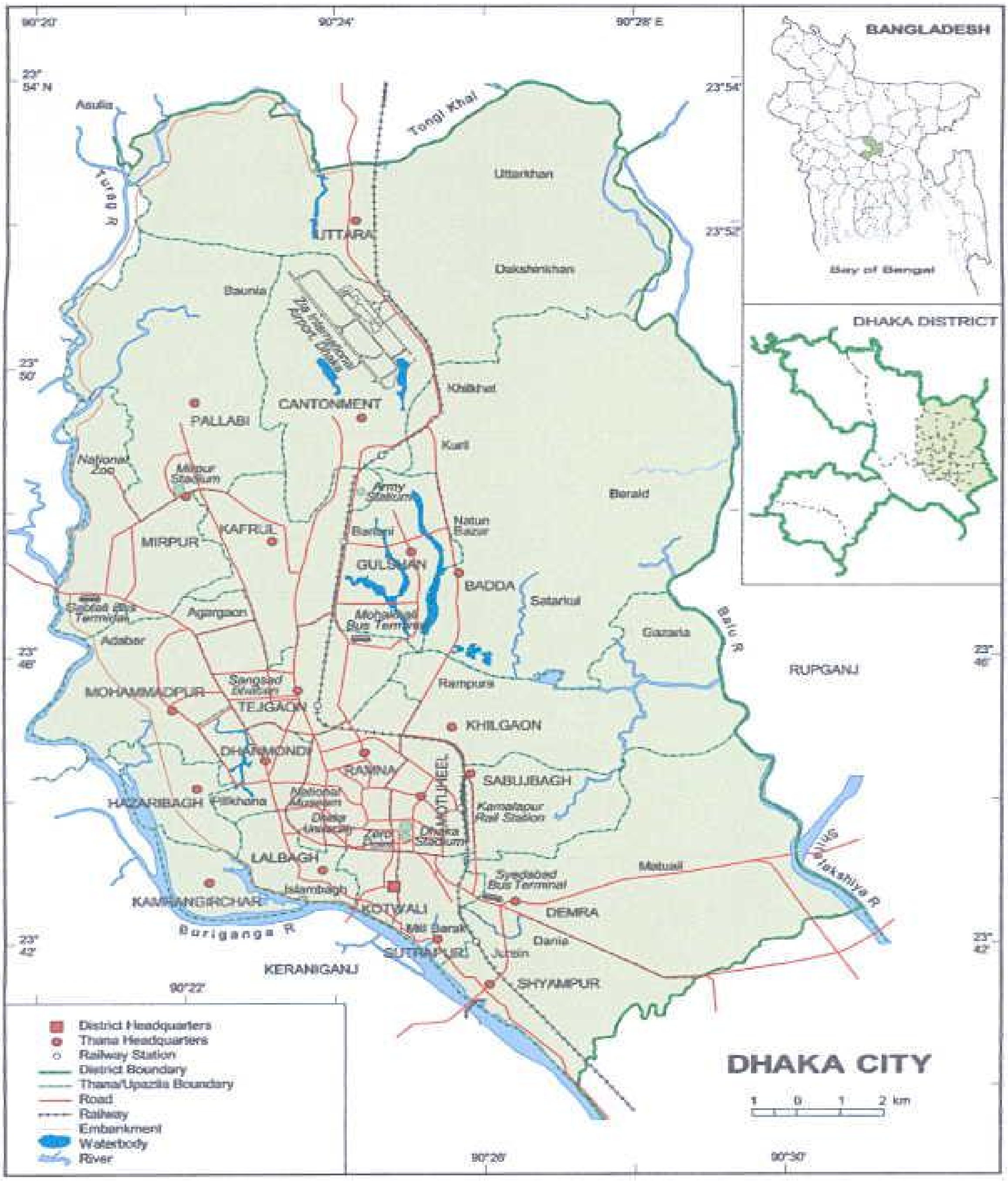

Figure 1. Water sampling sides of Buriganga River along with the map of Dhaka city

Table 1 Information regarding different water sources

Sample No.	Sampling location	Sources of Water	Sampling season
1.	Middle of the Buriganga at Hazaribag	River	Rainy/Wet season
2	Middle of the Buriganga at Sadarghat	River	Rainy/Wet season
3.	Near the Postagola of the Buriganga	River	Rainy/Wet season
4	Near the Ahsan Manzil of the Buriganga	River	Rainy/Wet season
5.	Middle of the Buriganga at Babubazar	River	Rainy/Wet season
6.	Middle of the Buriganga at SSMC Hospital	River	Rainy/Wet season
7.	Near Sadarghat (IWTA) Terminal	River	Winter/Dry season
8.	Near Kallanpur ACME building	River	Winter/Dry season
9.	Near Hazaribag	River	Winter/Dry season
10.	Middle of the Buriganga near Azimpur	River	Winter/Dry season
11.	Near SSMC Hospital	River	Winter/Dry season
12.	Middle of the Buriganga at Lalbag Fort	River	Winter/Dry season
13.	Shilpa Bank Bhaban,Matijheel	Deep Tube well	Winter/Dry season
14.	BRAC,Mahakhali	Deep Tube well	Winter/Dry season
15.	Eastern Town,Banglamotor	Deep Tube well	Winter/Dry season
16.	BIRDEM, Shahabag	Deep Tube well	Winter/Dry season
17.	Delata Hospital,Mirpur	Deep Tube well	Winter/Dry season
18.	SAU ,Dhaka	Deep Tube well	Winter/Dry season
19.	Mid river Zinzira	River	Rainy/Wet season
20.	Mid river Babu Bazar	River	Rainy/Wet season
21.	Mid river off Chadnighat	River	Rainy/Wet season
22.	Opposite bank of Babu Bazar	River	Rainy/Wet season

Table 1. (Continued)

Sample No.	Sampling location	Sources of Water	Sampling Season
23.	Near Bara Katra	River	Rainy/Wet season
24.	Near Char Kamrangiri	River	Rainy/Wet season
25.	Near Lalbag Fort	River	Rainy/Wet season
26.	Middle of the Buriganga Lalbag Fort	River	Rainy/Wet season
27.	Opposite bank of the Buriganga Lalbag Fort	River	Rainy/Wet season
28.	Near Nawabgang of the Buriganga	River	Rainy/Wet season
29.	Near Postagola of the Buriganga	River	Winter/Dry season
30.	Middle of the Buriganga at Postagola	River	Winter/Dry season
31.	Near Buriganga at Postagola	River	Winter/Dry season
32.	Opposite bank of the Buriganga at Hazaribag	River	Winter/Dry season
33.	Middle of the Buriganga near SSMC Hospital	River	Winter/Dry season

Legend:SSMC =Sir Salimullah Medical College
BRAC =Bangladesh Rural Advancement Committee
BIRDEM =Bangladesh Institute of Research and Rehabilitation in Diabetic Endocrine and Metabolic Disorder
IWTA =Inland Water Transport Authority
SAU =Sher-e-Bangla Agricultural University

3.2 ANALYTICAL METHODS OF WATER ANALYSIS

3.2.1 Determination of pH

The pH of water samples were determined electrometrically following the procedure mentioned by Ghosh *et al.* (1983) using pH meters (HI 8424 Model) in the laboratory of Biotechnology Department, Sher-e-Bangla Agricultural University, Dhaka.

3.2.2 Determination of Electrical Conductivity (EC)

The electrical conductivity (EC) of a system actually represents the concentration of total dissolved solids (TDS) or total salinity in water excluding the amount of silica. The EC of collected water samples was determined electrometrically using conductivity meter (Model 8423) according to the method mentioned by Tandon (1995) in the laboratory of Biotechnology Department, Sher-e-Bangla Agricultural University, Dhaka.

3.2.3 Estimation of TDS

Total dissolved solids (TDS) were determined by weighing the solid residue obtained by evaporating a measured aliquot of filtered water samples to dryness according to the procedure described by Chopra and Kanwar (1980).

3.2.4 Estimation of Sodium and potassium

Sodium and potassium were determined with the help of a flame emission spectrophotometer (Model Jenway PEP) at 768 nm for K and 589 nm for Na. The desired spectral line was isolated using interference filters. The percent emission was recorded following the methods outlined by Golterman (1971) and Ghosh *et al.* (1983).

3.2.5 Carbonate and bicarbonate

Carbonates and bicarbonates of water samples were determined by acidimetric method of titration using phenolphthalein indicator ($C_{20}H_{14}O_4$) for carbonate. With dilute sulphuric acid carbonate forms colourless and bicarbonate forms rose red colour complex at the end of titration. The carbonate and bicarbonate were estimated trimetrically by taking 10 m L water samples following the method described by Tandon (1995) and Sing (1984). The reactions are mentioned below.

$Na_2CO_3+H_2SO_4 \xrightarrow{\quad\quad} NaHCO_3+Na_2SO_4$

$NaHCO_3+H_2SO_4 \xrightarrow{\quad\quad} NaSO_4+H_2O+CO_2$

3.2.6 Chloride

Chloride of water samples was analyzed by argent metric method of titration using potassium chromate indictor (K_2CrO_4) which worked in a neutral or slightly alkaline solution. Silver chloride (AgCl) was quantitatively precipitated before red silver chromate (Ag_2ClO_4) was formed. The reactions taking place are as follows:

$AgNO_3+NaC1 \xrightarrow{\quad\quad} AgC1+NaNO_3$

$2AgNO_3+K_2CrO_4 \xrightarrow{\quad\quad} Ag_2CrO_4+ KNO_3$

Chloride was determined titrimetrically following the procedure described by Ghosh *et al.* (1983) and Clesceri *et al.* (1989)

3.2.7 Nitrate nitrogen

Nitrate was determined by phenoldisulphoic method with the help of a spectrophotometer (Coleman junior Model NO. 6A) set at 420 nm wavelength. The water sample was evaporated to dryness over a water bath and after cooling the yellow colour was developed by the reaction between nitrate and phenoldisulphonic acid in presence of ammonia (Ghosh *et al.,* 1983).

3.2.8 Phosphorus

This method involves the formation of molybdophosphoric acid which was reduced to the intensity complex molybdenum blue, by stannus chloride. Phosphorus was determined colorimetrically from the water samples using stannous chloride as a reducing agent as described by Clesceri *et al.* (1989). The colour intensity was read at 660 nm wavelength with a spectrophotometer (Coleman junior Model No. 6A) within 15 minutes after stannous chloride addition following the procedure outlined Olsen *et al.* (1954). The principal of hypothetical reaction is as follows:

$$H_3PO_4+12H_2MoO_4 \longrightarrow H_3P\,(Mo_3O_{10})4+12H_2O$$

3.2.9 Sulphate sulphur

Sulphate was estimated truribidimetrically with the help of spectrophotometer. Turbidimetric reagent ($BaC1_2.2H_2O$) was added in a definite volume of sample. Sulphate ion reacted with barium chloride to form barium sulphate. Readings were taken in spectrophotometer (Model Spectronic Genesys TM_5) after 30 minutes of $BaCl_2$ addition at 425 nm wavelength following the methods of Wolf (1982) and Tandon (1995).

3.2.10 Calcium

Calcium was estimated from Soil Research Development Institute (SRDI). Complex metric titration was used for estimating the calcium from the water samples using disodium ethylene diamine tertraacetate ($Na_2H_2C_{10}H_{12}O_8N_2.2H_2O$) as a chelating agent. This analytical method was carried on eliminating possible interfering ions such as Fe, Mn, Cu, Zn, Ni and PO_4 adding respective masking agents at pH 12 in presence of calcon indicator ($C_{20}H_{13}N_2NaO_5S$). Sodium hydroxide (NaOH) was first added to the water samples for the precipitation of magnesium as insoluble magnesium hydroxide [$Mg(OH)_2$] Potassium feroocyanide [$K_4Fe(CN)_6.3H_2O$] hydroxylamine-hydrochloride ($NH_2OH.HC1$) and triethanolamine ($C_6H_{15}NO_3$) water added to eliminate the interference of various non-target ions (Page *et al.*, 1982).

3.2.11 Magnesium

Magnesium was also estimated from Soil Research Development Institute (SRDI). Magnesium was analyzed by complex metric method of titration using disodium ethylene diamine tertraacetate ($Na_2H_2C_{10}H_{12}O_8N_2.2H_2O$) as a chelating agent. This analytical method was practiced for eliminating possible interfering non-target ions in presence of Eriochrome Black T indicator ($C_{20}H_{12}N_3NaO_7S$) with adjusting the required pH 10. To determine magnesium alone, calcium was first precipitated from water samples as calcium tungstate ($CaWO_4$) with sodium tungstate solution ($Na_2WO_42H_2O$). Potassium ferrocyanide [$K_4Fe(CN)_6.3H_2O$], hydroxylamine-hydrochloride ($NH_2OH.HCl$) and triethanolarnine ($C_6H_{15}NO_3$) were also added to eliminate the competition of competition of various ions (Fe, Cu, Zn, Mn, PO4) by the EDTA molecule in the reaction after (Page *et al.*, 1982).

3.2.12 Zinc, copper, iron and manganese

Zinc, copper, iron and manganese were analyzed by atomic absorption spectrophotometer (Hitachi, Model-170-30) at the wavelengths of 213.8 nm, 324.8 nm, 248.3 nm and 279.5 nm respectively in the laboratory of Soil Chemistry Division, Bangladesh Rice Research Institute following the procedure by Clesceri *et al.* (1989).

3.2.13 Boron

Boron status of water samples was determined by using curcumin-oxalic acid. Suitable amount (20m L^{-1}) of water sample was acidified with 0.05 N HC1 and evaporated carefully to dryness at 55-60^0C in the presence of curcumin forming a red-coloured product (rosocyanine). The colour intensity was read with the help of a spectrophotometer (Coleman Junior Model No. 6A) at 540 nm wavelengths following the methods of Allen *et al.* (1974) and Ghosh *et al.* (1983).

3.3 EVALUATION OF WATER QUALITY OR TOXCITY

Whether a ground of surface water of a given quality is suitable for a particular purpose depends on the criteria or standards of acceptable quality for that specific use. Quality limits the water supplies for dinking, industrial and irrigation because of its extensive development of this purpose. The following formulae related to the irrigation water classes rating were computed from the data obtained by chemical analyses of water samples. The equations were-

3.3.1 Sodium Adsorption Ratio (SAR)

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \qquad \text{(Das, 1983)}$$

3.3.2 Potassium Adsorption Ratio (PAR)

$$PAR = \frac{K^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \qquad \text{(Das, 1983)}$$

3.3.3 Soluble Sodium Percentage (SSP)

$$SSP = \frac{Na^{+} + K^{+}}{Ca^{++} + Mg^{++} + K^{+}} \quad X \quad 100 \qquad \text{(Das, 1983)}$$

3.3.4 Residual Sodium Carbonate (RSC):

$$RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++}) \qquad \text{(Das, 1983)}$$

3.3.5 Hardness or Total Hardness (H_T)

$$H_T = 2.5 \text{ x } Ca^{++} + 4.1 \text{x } Mg \qquad \text{(Das, 1983)}$$

Where, concentrations of ionic constituents for calculating all parameters except hardness in me L^{-1} and in case of hardness as mg L^{-1}.

3.4 CHECKING THE CORRECTNESS OF ANALYSIS

The accuracy of chemical analysis of water samples were checked by means of the following procedure. Electrical conductivity (EC), pH, total dissolved solids (TDS) and major anion-cation constituents were indicated of irrigation water quality. The difference between the sum of cations and sum of anions and the measured or calculated TDS to EC ratio was required for detecting discrepancies. The correctness of analyses of water samples were checked following the methods described by APHA (1995).

3.4.1 Anion-cation balance

The sum of anions and cations expressed as me L^{-1} must be balanced because all potable waters are electrically neutral. The difference between the anion and cation sums falls between acceptable limits (5-10%) and the percentage of difference is calculated on the basis of the following equation.

$$\% \text{ difference} = \frac{\Sigma \text{ cations} - \Sigma \text{ anions}}{\Sigma \text{ cations} + \Sigma \text{ anions}} \text{ x } 100$$

3.4.2 Ratio of measured or calculated TDS to EC

The value of measured TDS and EC are necessary to compare with the calculated TDS and EC values for checking of analysis. The TDS values were calculated from the summation of major cationic and anionic constituents (mg L^{-1}) which are as follows :

3.4.3 Total dissolved solids (TDS)

$$TDS = (CO_3^{--} + HCO_3^{-} + Na^{+} + K^{+} + Ca^{++} + Mg^{++} + SO_4^{--} + NO_3^{-} + Cl^{-} + SiO_3^{-})$$

The electrical conductivity (EC) were also calculated from the summation of cation or anion (me L^{-1}) as follows-

3.4.4 Electrical conductivity (EC) = 100 × Σ cation or anion, me L^{-1}

If calculated TDS or EC is higher or lower beyond the acceptable range than the measured value, the reanalysis is necessary to check the accuracy of chemical analysis. The acceptable criteria for the ratio of calculated or measured TDS to EC is from 0.55 to 0.70. The criteria for acceptable ratio is as follows-

$$1.0 < \frac{\text{Measured TDS}}{\text{Calculated TDS}} < 1.2$$

$$0.9 < \frac{\text{Calculated EC}}{\text{Measured EC}} < 1.1$$

3.5 STATISTICALANALYSIS

Statistical analysis of the data generated out of the chemical analyses of water samples, were done with the help of a scientific calculator (Casio-fx-991MS,S.V.P.A.M) following the standard procedure as described by Gomez and Gomez (1984). Correlation studies were also performed following the standard method of computer programme (SPSS).

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

Water of desirable quality is absolutely essential for domestic, commercial, industrial, agricultural and other beneficial uses including functioning of the ecology of both terrestrial and aquatic systems. The ionic constituents determined were calcium, magnesium, sodium, potassium, iron, zinc, manganese, copper, phosphorus, boron, sulphate, nitrate, carbonate, bicarbonate and chloride found in variable amounts in the water samples. The salient features of the experimental findings presented in the foregoing chapter are discussed under appropriate heading in the light and support of relevant available research reports wherever necessary. The concentrations of major ions (Ca^{++}, Mg^{++}, Na^{+}, K^{+}, $C1^{-}$, CO_3^{--} and HCO_3^{-}) were presented by vertical bar diagrams (Figure 2); where the vertical bar diagrams presented major ionic concentrations.

4.1 The obtained results are described and discussed under the following headings:

4.1.1 pH

The pH values of all water samples varied from 6.98 to 8.30 (Table 2). Samples no. 8 and 30 respectively Near Kallanpur ACME building and near middle Buriganga at Postagola showed pH 6.98 and 8.30 respectively. Sample No.9 and 30 respectively near Hazaribag and near middle Buriganga at Postagola indicated pH values higher than pH 8.0. Except the above two samples, the rest thirty-one samples ranged from 7.15 to 7.84. The pH of all water samples indicated that these samples were neutral to alkaline. The pH values were well within the normal range of irrigation quality. The pH of irrigation water usually varies from 6.0 to 8.5 (Ayers and Westcot, 1985). Although the pH is not directly related to soil plant and animal health, but has been applied widely and successfully over many years to ensure the wholesomeness of water. On the basis of pH value, all water samples were suitable for drinking according to Bangladesh Standard range of pH 6.5 to 8.5 (Anonymous,1996). The higher pH values indicated the presence of appreciable amounts of calcium, magnesium, sodium and bicarbonate (Michael, 1978; Ayers and Westcot, 1985). It indicated that the pH of all water samples under test were within the normal range and these waters might not be harmful for soils and crops.

Table 2. The values of pH , EC and the concentrations of TDS, Ca, Mg, K, Na, Fe, Zn, Mn, Cu, P, B, SO_4, NO_3, HCO_3, and Cl Burigonga River water

Sl. No.	pH	EC (µS cm^{-1})	TDS (mg L^{-1})	Ca (me L^{-1})	Mg (me L^{-1})	K (me L^{-1})	Na (me L^{-1})	Fe (mg L^{-1})	Zn (mg L^{-1})	Mn (mg L^{-1})	Cu (mg L^{-1})	P (mg L^{-1})	B (mg L^{-1})	SO_4 (meL^{-1})	NO_3 (mg L^{-1})	HCO_3 (me L^{-1})	Cl (me L^{-1})
01	7.43	303	183	0.67	1.08	0.32	0.78	Trace	0.05	Trace	0.02	Trace	0.25	Trace	0.20	1.40	1.20
02	7.28	225	145	0.85	1.06	0.16	0.19	0.02	0.05	Trace	0.04	Trace	0.24	0.01	0.25	1.34	1.70
03	7.21	223	144	0.80	0.96	0.20	0.16	0.02	0.07	Trace	0.03	Trace	0.12	Trace	0.09	1.35	1.65
04	7.58	310	206	0.85	1.05	0.44	0.88	0.03	0.01	Trace	0.02	Trace	0.25	0.04	0.20	1.75	1.02
05	7.30	225	140	0.80	1.10	0.12	0.16	Trace	Trace	Trace	Trace	Trace	0.16	Trace	0.14	1.14	0.83
06	7.20	205	125	0.68	0.98	0.12	0.18	0.04	0.10	Trace	0.04	Trace	0.09	Trace	0.06	0.98	0.80
07	7.52	730	470	2.12	3.05	0.70	1.90	0.01	0.05	0.12	0.03	0.435	0.45	0.22	1.24	3.80	2.60
08	6.98	198	123	0.74	0.97	0.13	0.15	0.03	0.06	Trace	Trace	Trace	0.26	Trace	0.34	0.98	0.85
09	8.04	1572	1080	2.80	4.02	1.18	9.36	Trace	0.07	0.2	Trace	0.87	0.46	0.52	1.70	4.85	10.5
10	7.75	1800	1085	2.50	4.15	1.20	8.90	Trace	0.08	0.46	Trace	0.80	0.58	0.52	1.89	5.66	10.0
11	7.15	365	248	1.30	1.70	0.21	0.58	Trace	Trace	Trace	Trace	Trace	0.28	Trace	0.25	2.60	0.85
12	7.66	215	144	0.85	1.05	0.20	0.19	Trace	Trace	Trace	Trace	Trace	0.19	Trace	0.12	1.37	0.60
13	7.30	558	365	1.75	2.85	0.34	0.74	Trace	0.08	Trace	0.02	0.026	0.33	0.04	0.87	2.89	2.40
14	7.44	565	350	1.70	2.93	0.27	0.72	Trace	Trace	Trace	0.01	0.03	0.42	0.04	0.73	2.63	2.58
15	7.68	560	367	1.80	2.85	0.37	0.69	Trace	0.06	Trace	0.02	0.023	0.37	Trace	1.25	3.45	1.65
16	7.60	507	351	1.59	2.50	0.25	0.68	Trace	0.09	Trace	0.02	0.016	0.35	0.01	0.98	3.60	1.30
17	7.39	560	378	1.60	2.31	0.33	0.70	Trace	0.24	Trace	0.15	0.019	0.38	Trace	0.47	4.05	1.03
18	7.43	543	342	1.85	2.65	0.30	0.71	Trace	Trace	Trace	Trace	0.03	0.35	0.06	0.64	2.70	2.50
19	7.65	317	207	0.74	1.07	0.45	0.89	0.03	Trace	0.23	0.10	0.45	0.50	1.66	1.22	1.66	0.78
20	7.48	367	258	0.79	0.89	0.68	1.15	0.02	0.04	Trace	Trace	Trace	0.03	0.15	0.34	2.50	0.65

Table 2. (Continued)

Sl. No.	pH	EC (µS cm^{-1})	TDS (mg L^{-1})	Ca (me L^{-1})	Mg (me L^{-1})	K (meL^{-1})	Na (me L^{-1})	Fe (mg L^{-1})	Zn (mg L^{-1})	Mn (mg L^{-1})	Cu (mg L^{-1})	P (mg L^{-1})	B (mg L^{-1})	SO_4 (meL^{-1})	NO_3 (mg L^{-1})	HCO_3 (me L^{-1})	Cl (me L^{-1})
21	7.74	315	218	0.82	0.83	0.49	0.87	0.02	0.07	Trace	0.02	Trace	0.18	0.06	0.71	1.95	0.90
22	7.40	225	135	0.75	1.10	0.12	0.25	0.15	Trace	0.04	Trace	Trace	Trace	0.18	0.75	0.08	1.15
23	7.30	190	125	0.08	0.73	0.95	0.10	0.14	Trace	0.05	Trace	Trace	Trace	0.12	0.09	1.10	0.70
24	7.48	248	156	0.76	1.33	0.25	0.15	Trace	0.08	Trace	Trace	Trace	0.29	0.02	0.23	1.22	0.98
25	7.84	325	220	0.75	1.30	0.43	0.75	Trace	0.08	Trace	Trace	Trace	0.20	0.11	1.04	2.00	0.90
26	7.32	227	148	0.80	1.27	0.18	0.15	Trace	0.12	Trace	Trace	Trace	0.15	0.02	0.98	1.24	0.78
27	7.58	298	195	0.82	0.98	0.43	0.77	Trace	0.06	Trace	Trace	Trace	0.22	0.85	1.12	1.78	0.85
28	7.52	295	207	0.79	0.98	0.39	0.78	Trace	Trace	Trace	Trace	Trace	0.18	0.10	0.88	1.85	0.72
29	7.48	732	465	2.15	3.08	0.76	1.25	0.04	0.04	Trace	Trace	0.44	0.40	0.21	0.98	3.68	2.68
30	8.30	718	465	2.00	3.18	0.74	1.15	0.01	0.04	Trace	Trace	0.63	0.34	0.25	1.15	3.65	2.70
31	7.64	717	455	1.98	3.25	0.71	1.20	0.04	0.01	Trace	Trace	0.48	0.58	0.22	1.04	3.25	3.15
32	7.20	298	194	1.12	1.65	0.15	0.25	Trace	Trace	Trace	Trace	Trace	0.18	Trace	Trace	2.00	0.65
33	7.32	725	465	2.10	2.91	0.75	1.15	0.01	0.15	Trace	0.12	0.84	0.15	0.22	0.65	4.40	2.25
Range	6.98 to 8.30	190 to 1800	123 to 1085	0.08 to 2.80	0.73 to 4.15	0.12 to 1.18	0.10 to 9.36	Trace to 0.15	Trace to 0.24	Trace to 0.46	Trace to 0.15	Trace to 0.87	Trace to 0.58	Trace to 1.66	0.06 to 1.89	0.08 to 5.66	0.60 to 10.50
S($\bar{x}$)	7.49	478.6	307.9	1.26	1.84	0.43	1.17	0.041	0.07	0.18	0.05	0.36	0.29	0.24	0.69	2.39	1.97
SD	0.26	363	231.9	0.66	1.08	0.29	2.09	0.043	0.05	0.16	0.04	0.34	0.14	0.37	0.49	1.30	2.30
%CV	3.47	75.84	75.31	52.38	58.69	67.44	178.6	104.9	71.42	88.89	80.0	94.44	48.28	154.2	71.01	54.39	116.8

Foot Note: S($\bar{x}$) = Mean Value, SD = Standard Deviation, %CV = Percent Co-efficient of Variance

4.1.2 *Electrical conductivity (EC)*

The electrical conductivity i.e. total concentration of soluble salts in water samples ranged within the limit of 190 to 1800 microsiemence per centimeter (μS cm^{-1}) and these values were reported in Table 2. The EC values of 20 samples (60.60%) were less than the mean value and the next 13 samples (39.40%)were higher than the mean value. Irrigation water were categorized into four salinity classes (Richards, 1968) with respect to EC. On the basis of this classification, 10 samples were 'low salinity' (<250 μS cm^{-1}), 21 samples were 'medium salinity' (<750 μS cm^{-1}) and 2 samples were 'high salinity' (<2250 μS cm^{-1}) water. The high salinity might be due to the release of waste water enriched with undesirable substances from tanning industries of Hazaribag area. According to Wilcox (1955), 2 samples were 'permissible' 21 samples were 'good' and the rest 10 samples were of 'excellent' quality. The water samples collected from the surface water (river water) were 'high salinity' and water samples collected from groundwater (deep tube well supply water) were 'medium salinity' according to Richards (1968). In case of river water the EC values of dry season samples were higher than the wet season samples. According to Wilcox (1995) as reported in appendix I, ground water of such quality (i.e. <250 to 2000 μS cm^{-1}) can be used for irrigation purpose without harmful effects on soils and crops but moderate leaching will be required.

4.1.3 Total dissolved solids (TDS)

Total dissolved solids would be considered as one of the major criteria for judging water quality for irrigation, drinking and industrial usage. The TDS values of collected water samples varied from 123 to 1085 mg L^{-1} (Table 2) with mean value of 307.9 mg L^{-1} and SD value 231.87. Out of 33 samples, about 60.60% TDS values (20 samples) were found below the mean value and remaining 39.40%

samples (13 samples) were found above the mean value. The highest TDS value (1085 mg L^{-1}) was detected in mid of the Buriganga near Azimpur (sample no. 10) (Table 2). All water samples (except sample no. 9 and 10) contained far less than 1000 mg L^{-1} TDS and were considered to be 'fresh water' (Carroll, 1962; Freeze and cherry, 1979). Todd (1980) reported that if the value of TDS exceeds 500 mg L^{-1} is considered 'not desirable'. In addition to these Parvathappa *et al.* (1990) in dictated that the degree of soil properties deterioration depends on the total dissolved salt contents in irrigation water. The water under study area would not affect the osmotic pressure of the soil solution and cell sap of the plants. The value of TDS is directly proportional with that of total soluble mineral ions and other dissolved substances in water bodies. Similar observations were expressed by Quayum (1995) ; Rahman and Zaman (1995) .The TDS value of 2 samples ranged from 1042 to 1085 mg L^{-1}. The similar results were obtained in United States by Richards (1968) in some river waters. The higher TDS value might be due to the release of polluted water bodies from tanning industries of Hazaribag and other sources. These waters were 'brackish water' (Freeze and Cherry, 1979) and were not suitable for irrigation and drinking.

4.1.4 Total cationic constituents

The amounts of cations of all water samples were reported in Table 2 and Figure2. The summation of cations varied from 1.86 to 17.36 me L^{-1} respectively sample number 23 and 9 which were presented in Table 5. Among the cations Ca, Mg, K and Na were dominated ranging from 0.08 to 2.80 (sample number 23 and 9), 0.73 to 4.15 (sample number 23 and 10), 0.12 to 1.18 (sample number 5, 6, 22 and 9) and 0.10 to 9.36 (sample number 23 and 9) me L^{-1} , respectively (Table2). Similar results were obtained by Costa *et al.*, (1985) in some river waters. According to

Todd (1980), irrigation water usually contains less than 2.5 me L^{-1} or 100mg L^{-1} calcium and 2.08 me L^{-1} or 50 mg L^{-1} magnesium. Water containing high calcium and magnesium may combine with carbonate, bicarbonate and sulphate and thereby clog the pipe of water supply. This problem was not observed in the study area, which was similar to the findings reported from Gazipur sadar Thana by Quayum (1995). In the river Buriganga, the dry season samples contained higher amount of Ca, Mg, Na and K in comparison to rainy season. Higher amount of Na concentrations were not observed in wet season sample.

Besides these, the higher limits of phosphorus, iron, zinc, manganese and copper were 0.87, 0.15, 0.24, 0.46 and 0.15 mg L^{-1}, respectively. The lower limits of these ions were undetectable (traces). Concentrations of P, Fe, Zn and Cu of all 33 samples were found below the 'recommended limit' for irrigation (Ayers and Westcot, 1985). The Mn concentrations of all water samples were suitable for irrigation. This might be due to the release of waste water from tanning industries and other sources. The concentration of boron of all water samples were below the recommended limit for irrigation. Only 12 samples were found to be 'excellent' over the recommended limit for sensitive crops and the rest 21 samples were found 'good' for sensitive crops (Table 3).

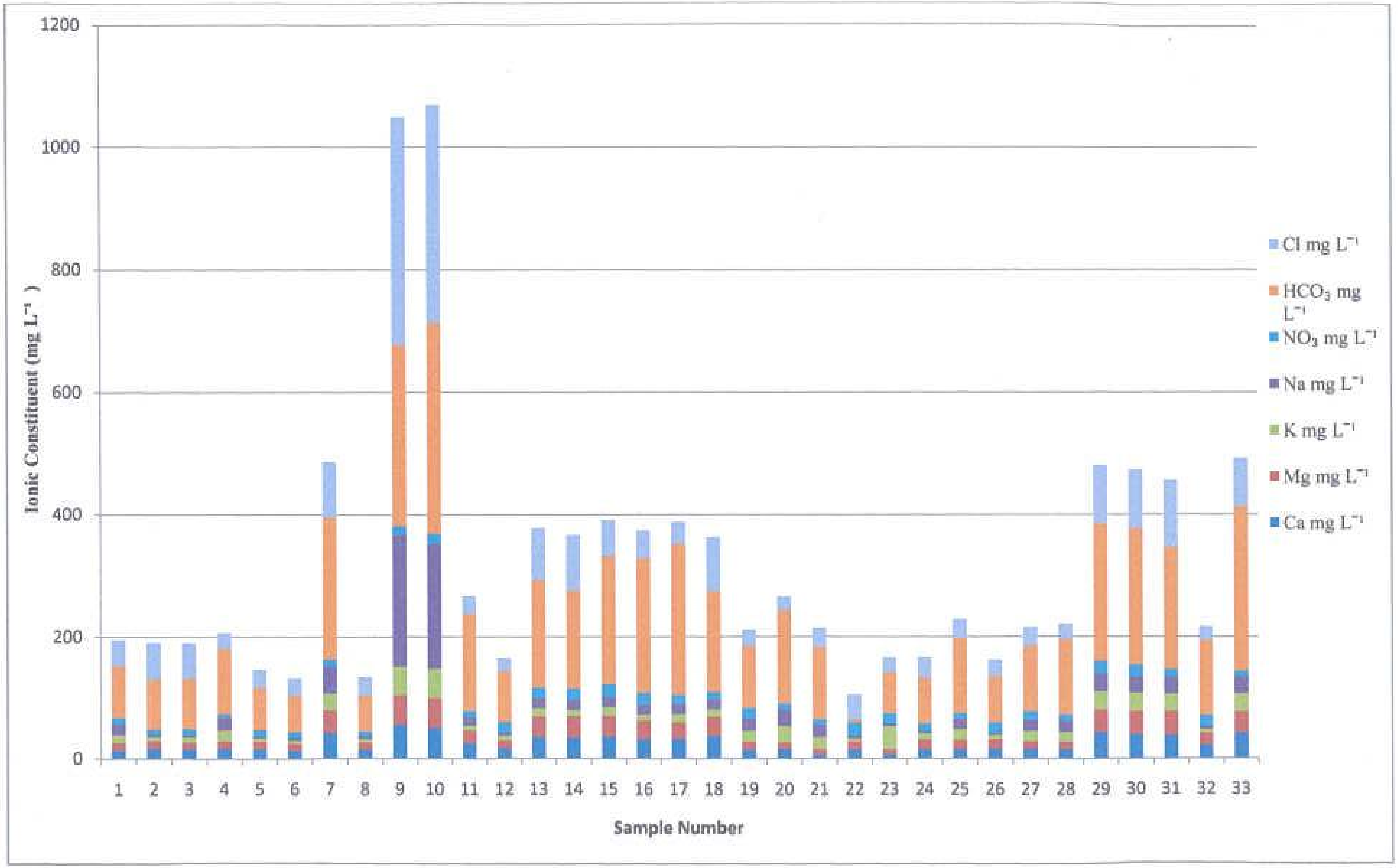

Fig. 2 Bar diagrams for representing major ionic constituent of Buriganga River water

4.1.4.1 Calcium

The concentrations of Ca in water samples were within the range of 0.08 to 2.80 me L^{-1} (Table 2) and the mean value was 1.26 me L^{-1}. About 51.51 per cent values were below than the mean (1.26) and the rest 48.49 per cent values were greater than that of mean. Standard deviation (SD) was 0.66 and co-efficient of variation (CV) was found to be under 52.38 percent. The highest concentration (2.8 me L^{-1}) was found at Hazaribag in Buriganga (sample no. 9) and the lowest value (0.08 me L^{-1}) was found at Boro Katra in Buriganga (sample no. 23).The concentration of Ca which largely depended on solubility of $CaCO_3$ and $CaSO_4$. Irrigation water containing less than 20 me L^{-1} Ca was "suitable" for crops plants (Ayers and Westcot, 1985). On the basis of Ca content all the water samples can safely be used for irrigation and would not affect the soils.

4.1.4.2 Magnesium

Magnesium content of water samples varied from 0.73 to 4.15 me L^{-1} (Table 2) and the mean value was 1.84me L^{-1}. About 60.60 per cent values (20 samples) lied below the mean and 39.40 per cent (13 samples) above the mean. Standard deviation (SD) was 1.08 and co-efficient of variation (CV) was found to be under 58.69 percent. The highest concentration (4.15 me L^{-1}) was found at middle of the Buriganga near Azimpur (sample no. 10) and the lowest value (0.73 me L^{-1}) was found at Near Bara Katra in Buriganga (sample no. 23). The concentration of Mg which also largely depended on solubility of $CaCO_3$ and $CaSO_4$. Irrigation water containing less than 20 me L^{-1} Ca was "suitable" for crops plants (Ayers and Westcot, 1985). On the basis of Mg content all the water samples can safely be used for irrigation and would not affect the soils.

4.1.4.3 Potassium

The concentration of K in collected water samples ranged from 0.12 to 1.18 me L^{-1} (Table 2) with 0.43 me L^{-1} as mean value 57.58 per cent values (19 samples) were below the mean and 42.42 per cent values (14 samples) were above the mean. The highest concentration (1.18 me L^{-1}) was found at Hazaribag in Buriganga (sample no. 9) and the lowest value (0.12 me L^{-1}) was found at opposite bank of Babubazar in Buriganga (sample no. 22). The standard deviation and coefficient of variation were 0.29 and 67.44 per cent respectively. The detected quality of K in all the collected samples had no significant influence on water quality for irrigation.

4.1.4.4 Sodium

The concentration of Na in different water samples were within the range of 0.10 to 9.36 me L^{-1} (Table 2) and the mean value was 1.17 me L^{-1}. About 81.82 per cent (no. of samples 27) values were below the mean (1.17) and the rest 18.18 percent (no. of samples 6) values were greater than that of mean. Standard deviation (SD) was 2.09 and co-efficient of variation (CV) was found to be under 178.63 per cent. The highest concentration (9.36 me L^{-1}) was found at Hazaribag in Buriganga (sample no. 9) and the lowest value (0.10 me L^{-1}) was found at Boro Katra in Buriganga (sample no. 23). Irrigation water containing less than 20 me L^{-1} Ca was "suitable" for crops plants (Ayers and Westcot, 1985). On the basis of Na content all the water samples can safely be used for irrigation and would not serious affect on the soils.

4.1.4.5 Iron

All water samples contained small amount of Fe which varied from traces to 0.15 mg L^{-1} (Table 2). The obtained mean value was 0.041 mg L^{-1}. About 75.76 per cent value (25 samples) were below the mean and 24.24 percent (8 samples) were above the mean. The highest concentration (0.15 mg L^{-1}) was found at opposite bank of Babubazar in Buriganga (sample no. 22). The standard deviation and coefficient of variation were 0.043 and 104.9 percent respectively. The detected quality of Fe in all the collected samples had slightly significant influence on water quality for irrigation.

4.1.4.6 Zinc

The collected water samples contained little amount of Zn that varied from traces to 0.24 (Table 2) and the mean value was 0.07mg L^{-1}. About 90.91 percent values (30 samples) were found below the mean and 9.09 percent values (3 samples) were above the mean. Out of five sources, Zn content were recorded higher in tubewell water trace from 0.15 mg L^{-1}(sample no.33) and lower in river water (trace to 0.03 mg L^{-1}). The calculated standard deviation and coefficient of variation were 0.05 and 71.42 percent respectively. The detected quality of Zn in all the collected samples had slightly significant influence on water quality for irrigation.

4.1.4.7 Manganese

Manganese was present in little amount from trace to 0.46 mg L^{-1} shown in (Table 2). The obtained mean value was 0.18 mg L^{-1}. Out of 33 samples, only 2 water samples (6.06%) were above the mean. Rests of 31 samples (93.94%) were found below the mean. The highest amount of Mn 0.46 mg L^{-1} was found in the middle of the Buriganga near Azimpur (sample no.10) and the lowest amount (trace to 0.10 mg L^{-1} were recorded among several sources. Standard deviation and coefficient of variation were 0.16 and 88.89 percent respectively. Irrigation water containing less than 20 me L^{-1} Mn was "suitable" for crops plants (Ayers and Westcot, 1985). On the basis of Mn content all the water samples can safely be used for irrigation and would not affect the soils and under test were not toxic for long term irrigation.

4.1.4.8 Copper

All water samples contained very little amount of Cu which varied from trace to 0.15 mg L^{-1}(Table 2). Out of 33 only 1 sample (3.03%) contained 0.15 mg L^{-1} copper. Cu contents in rest of 32 samples (96.97%) were detected in traces amount and below the mean value (0.05 mg L^{-1}) and not detected by Atomic Absorption Spectrophotometer (AAS). The standard deviation and coefficient of variation were 0.04 and 80.0 percent respectively. According to Ayers and Westcot (1985) the acceptable limit of Cu in irrigation water containing less than 20 me L^{-1}. On the basis this limit of Cu content all the water samples can safely be used for irrigation and would not serious effect on the soils.

4.1.4.9 Phosphorus

Small amount of phosphorus traces to 0.87 mg L^{-1} were found in all water samples. The mean value was 0.36 mg L^{-1} (Table 2). About 75.76 percent values (25 samples) were found to be lower than the mean value while 24.24 percent (8 samples) were recorded above the mean. The highest concentration (0.87 mg L^{-1}) was found at Hazaribag in Buriganga (sample no. 9). The standard deviation and coefficient of variation were 0.34 and 94.44 per cent respectively (Table 2). On the basis of P content all the water samples can be used for irrigation but long term irrigation would be affected the soils.

4.1.4.10 Boron

Water samples contained small amount of B that varied from trace to 0.58 mg L^{-1} (Table 2) having mean value 0.29 mg L^{-1}. About 57.58 per cent values (19 samples) lied below the mean and 42.42 per cent (14 samples) above the mean. Standard deviation (SD) was 0.14 and co-efficient of variation (CV) was found to be under 48.28 per cent. The highest concentration (0.58 mg L^{-1}) was found at Azimpur near the Buriganga (sample no. 10). On the basis of B content all the water samples can safely be used for irrigation and would not affect the soils.

4.1.4.11 Arsenic

Arsenic concentration in all water samples were tested qualitatively but not a single sample was detected to be polluted with arsenic. This result indicated that As contents in all water samples were below 0.05 mg L^{-1} and was not detectable.

4.1.5 Total anions

The estimated anions namely SO_4, NO_3, HCO_3, and Cl were presented in Table 2 and Figure 3.

The results of these anions have been described under the following below:

4.1.5.1 Sulphate

The concentration of sulphate was within the range of traces to 1.66 me L^{-1} (Table 2). About 81.82 per cent (27samples) values were below than the mean (0.24) and the rest 18.18 percent (no. of samples 6) values were greater than that of mean. Standard deviation (SD) was 0.37 and co-efficient of variation (CV) was found to be fewer than 154.2 per cent. The highest concentration (1.66 me L^{-1}) was found at near Zinzira in Buriganga (sample no.19). Irrigation water containing less than 20 me L^{-1} SO_4 was "suitable" for crops plants (Ayers and Westcot, 1985). On the basis of SO_4 content all the water samples can safely be used for irrigation and would not affect the soils and under test were not toxic for long term irrigation.

4.1.5.2 Nitrate

The concentration of nitrate ranged from 0.06 to 1.89 mg L^{-1} (Table 2). The recorded mean value was 0.69 mg L^{-1} indicated that 48.49 percent water samples (16 samples) were fund to be lower than the mean and 51.51 percent were (17 samples) above the mean. The respective standard deviation and percent co-efficient of variations were 0.49 and 71.01. The highest concentration 1.89 me L^{-1} was found at near Azimpur in Buriganga (sample no. 10). The standard deviation and coefficient of variation were 0.49 and 70.01 per cent respectively (Table 2). On the basis of content all the water samples can be used for irrigation but long term irrigation would be affected the soils.

4.1.5.3 Carbonate

The water samples were free from carbonate. Titrimetric estimation did not record detectable amount of carbonate.

4.1.5.4 Bicarbonate

Bicarbonate content of water samples ranged from 0.08 to 5.66 me L^{-1} with a mean value of 2.39 me L^{-1} (Table 2). Out of 33 samples analyzed, 45.45 per cent (15 samples) were higher than the mean value and the rest of 18 samples analyzed, (54.54%) were detected lower in the mean value (2.39 me L^{-1}). Standard deviation and co-efficient of variation (CV %) were 1.30 and 54.49 respectively. The highest concentration (5.66 me L^{-1}) was found at near Azimpur in Buriganga (sample no. 10) and the lowest value (0.08 me L^{-1}) was found opposite bank of Buriganga at Babubazar (sample no.22).The concentration of HCO_3 was recorded comparatively higher among the ionic constituents. On the basis of HCO_3 content all the water samples were toxic for irrigation because HCO_3 content exceeded the recommended limit as mention appendix VII.

4.1.5.5 Chloride

The concentration of chloride content of water samples ranged from 0.60 to 10.50 me L^{-1} (Table 2) with an average value of 1.97 me L^{-1} (Table 2). Out of 33 samples 30.30 percent (10 samples) were found to be higher than mean value and the rest of 23 samples (69.70%) were detected lower than mean value (1.97 me L^{-1}). Standard deviation and co-efficient of variation (CV %) were 2.30 and 116.8 respectively. The highest concentration (10.50 me L^{-1}) was found at near Azimpur in Buriganga (sample no. 9) and the lowest value (0.60 me L^{-1}) was found opposite middle of the Buriganga at Lalbag Fort (sample no. 12). The concentration of Cl was recorded comparatively higher among the ionic constituents. On the basis of content all the water samples can be used for irrigation but long term irrigation would be affected the soils.

In my study the dominant anions were HCO_3 and Cl in groundwater which is also similar with the values of previous findings found bicarbonate and chloride to be dominant (Rao *et al.*, 1982). The contents of carbonate, bicarbonate, and chloride in ricer waters carried from 0.05 to 0.42, 0.63 to 5.20 and 0.12 to 7.65 me L^{-1} respectively (Richards, 1968) and had no possibility of hazard on soil. Usually, normal irrigation water may contain 0 to 50 mg L^{-1} / 0.83 me L^{-1} carbonate and 500 mg L^{-1} / 8.19 me L^{-1} bicarbonate (Todd, 1980). These findings were at par with that of Raman and Zahman (1995), and Quddus and Zaman (1996). In the study area, the concentration of bicarbonate and chloride carried from 0.80 to 5.66 and 0.60 to 10.50 me L^{-1} respectively. Bohn *et al.* (1985) opined that the 'bicarbonate toxicities' associated with some waters generally originated from deficiencies of iron or other micronutrients caused due to high PH. The present findings were at par with that of Bohn *et at.* (1985) Sample no. 9 and 10 showed higher concentrations (10.0 to 10.50me L^{-1}) of chloride probably due to the release of polluted water from different industries. Waters containing bicarbonate had no possibility of alkali hazard on the soil of the study area. The amounts of chloride and sulphate of all samples might not be hazardous and can safely be used (Ayers and Westcol, 1985) without harmful effect on all types of soils and crops.

All the waters were free from carbonate. Bohn *et al.* (1985) reported that the concentration of carbonate should be negligible at pH <9.0 perhaps, this may be the reason of detecting the samples carbonate free, as because the pH of the samples Ranged from 6.98 to 8.30. In the investigated area, all waters samples contained small amount of nitrate (0.06 to 1.89 mg L^{-1}) and had little influence on irrigation water quality.

4.1.6 Correctness of chemical analyses of water samples

The correctness of chemical analyses of water samples was cheeked by means of anion-cation balance and ratio of TDS to EC. The percent differences between the anion and cation summation were found within the limit of 0.2394 to 11.911 (Table 5), while the acceptable range being 5-10 percent (Clesceri *et al.*, 1989). The acceptable ratio of TDS to EC was from 0.55 to 0.70 as mentioned by Clesceri *et al.* (1989). The obtained ratio, the chemical analyses of TDS and EC values of water samples were seemed to be accurate and reproducible.

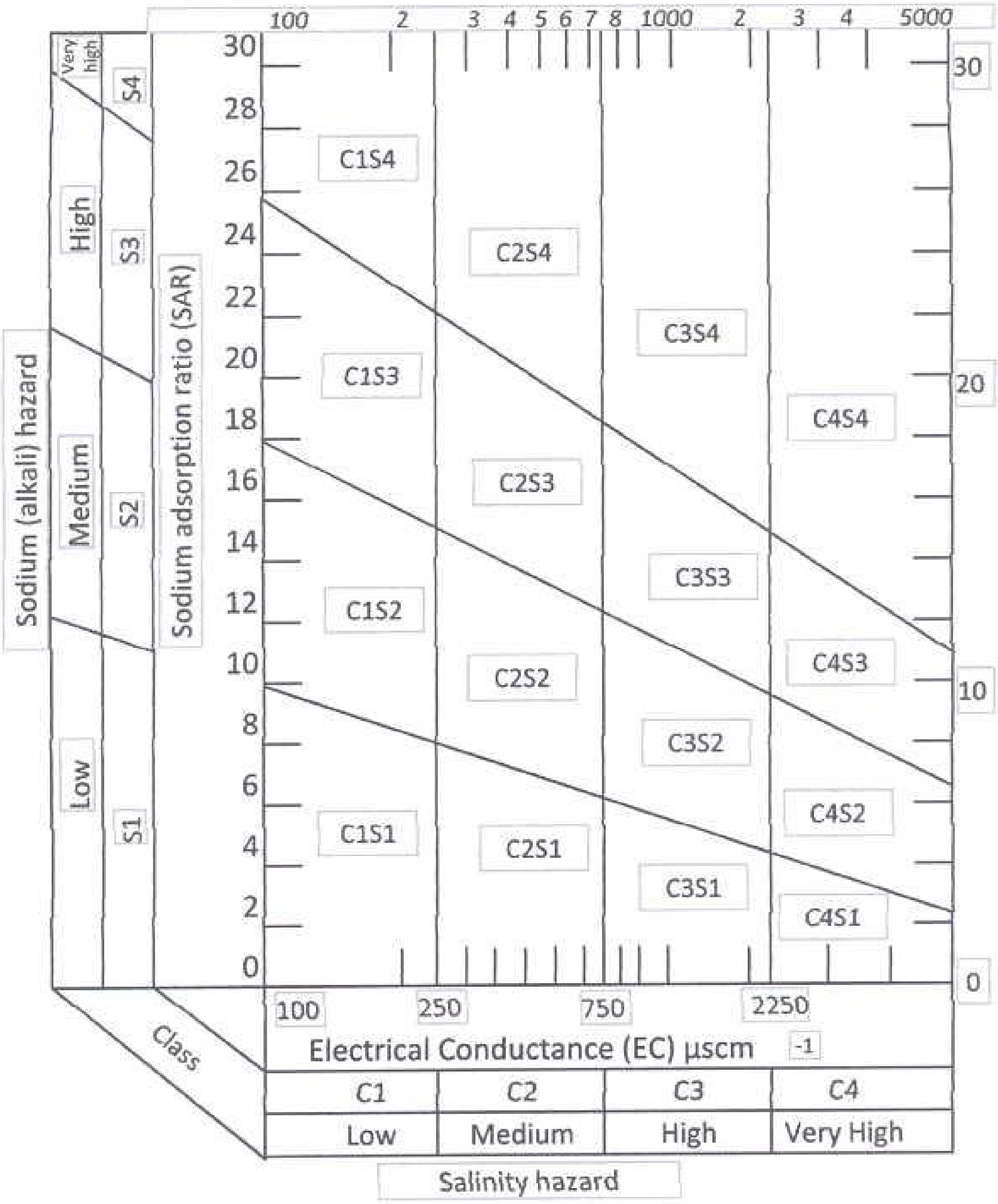

Fig. 3 Diagram for the classification of irrigation waters (Richards, 1968)

4.1.6.1 Sodium adsorption ratio (SAR)

Results pertained to Table 3 indicated that sodium adsorption ratio of all collected surface and Sodium adsorption ratio of all water samples ranged within the limit of 0.15 to 5.05 (Table 3). The average SAR value was 0.82. About 75.76 per cent (25 samples) values were found below the mean and 24.24 per cent (8 samples) were above the mean. The calculated standard deviation and co-efficient of variation (CV %) were 1.12 and 136.5 respectively. The degree of SAR is very important for irrigation water supplies as because clay particles can easily adsorb large quantities of Na and may stand in between soil productivity and successful crop production.

All water samples, classified on the basis of criteria as shown in Table 3 (Todd, 1980), were found to be 'excellent' for irrigating agricultural crops and the results further indicated that a considerable amount of Ca and Mg existed in water samples and this was favorable for good structural and tilts condition of the soil and would also improve the permeability of air and water. The results confirmed the findings of Quddus (1993), Shahidullah (1995) and Zaman and Rahman (1997). Out of 33 samples, only 7 samples showed higher values of SAR possibly due to higher content of Na. This might be due to release of waste water from tanning industries as because NaCl is widely used in the processing of animal skin.

Table 3. Classification of Burigonga River water basis of the B, EC, TDS, SAR, PAR, SSP, RSC and H_T

Sample No.	B (mgL^{-1})		EC (μScm^{-1})		TDS (mgL^{-1})		SAR		PAR		SSP (%)		RSC (mgL^{-1})		Hardness (mgL^{-1})		Alkalinity & Salinity hazard class
	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	
01	0.25	Ex	303	Good	183	FW	0.55	Ex	0.34	Ex	38.2	Good	-0.35	Suit	86.64	MH	C2S1
02	0.24	Ex	225	Ex	145	FW	0.20	Ex	0.16	Ex	16.1	Ex	-0.57	Suit	94.65	MH	C2S1
03	0.12	Ex	223	Ex	144	FW	0.17	Ex	0.21	Ex	17.3	Ex	-0.41	Suit	87.23	MH	C2S1
04	0.25	Ex	310	Good	206	FW	1.31	Ex	0.66	Ex	60.1	Doubt	0.85	Suit	94.16	MH	C2S1
05	0.16	Ex	225	Ex	140	FW	0.16	Ex	0.12	Ex	11.2	Ex	-0.76	Suit	94.12	MH	C2S1
06	0.09	Ex	205	Ex	125	FW	0.19	Ex	0.13	Ex	17.3	Ex	-0.68	Suit	81.62	MH	C2S1
07	0.45	Ex	730	Good	470	FW	1.18	Ex	0.44	Ex	34.2	Good	-1.37	Suit	256.1	Hard	C2S1
08	0.26	Ex	198	Ex	123	FW	0.16	Ex	0.14	Ex	14.3	Ex	-0.73	Suit	84.73	MH	C2S1
09	0.46	Ex	1572	Per	1080	BW	5.05	Ex	0.64	Ex	61.4	Doubt	-1.97	Suit	337.8	VH	C3S1
10	0.58	Ex	1800	Per	1085	BW	4.86	Ex	0.66	Ex	61.5	Doubt	-0.99	Suit	48.64	Soft	C1S1
11	0.28	Ex	365	Good	248	FW	0.47	Ex	0.17	Ex	21.4	Good	-0.40	Suit	329.2	VH	C3S1
12	0.19	Ex	215	Ex	144	FW	0.19	Ex	0.21	Ex	17.1	Ex	-0.53	Suit	148.7	Hard	C2S1
13	0.33	Ex	558	Good	365	FW	0.49	Ex	0.23	Ex	19.2	Ex	-1.71	Suit	94.16	MH	C2S1
14	0.42	Ex	565	Good	350	FW	0.47	Ex	0.18	Ex	17.6	Ex	-2.00	Suit	227.7	Hard	C2S1
15	0.37	Ex	560	Good	367	FW	0.45	Ex	0.24	Ex	18.5	Ex	-1.20	Suit	202.5	Hard	C2S1
16	0.35	Ex	507	Good	351	FW	0.48	Ex	0.20	Ex	18.5	Ex	-0.49	Suit	193.7	Hard	C2S1
17	0.38	Ex	560	Good	378	FW	0.51	Ex	0.47	Ex	17.3	Ex	0.14	Suit	229.2	Hard	C2S1
18	0.35	Ex	543	Good	342	FW	0.47	Ex	0.74	Ex	18.3	Ex	-1.80	Suit	222.88	Hard	C2S1
19	0.50	Ex	317	Good	207	FW	0.93	Ex	0.74	Ex	42.5	Per	-0.15	Suit	89.77	MH	C2S1
20	0.03	Ex	367	Good	258	FW	1.25	Ex	0.54	Ex	52.1	Per	0.82	Suit	83.13	MH	C2S1

Table 3. (Continued)

Sample No.	B (µS cm^{-1})		EC (µScm^{-1})		TDS (mgL^{-1})		SAR		PAR		SSP(%)		RSC (mgL^{-1})		Hardness (mgL^{-1})		Alkalinity & Salinity hazard class
	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	Value	Class	
21	0.18	Ex	315	Good	218	FW	1.24	Ex	0.13	Ex	45.1	Per	0.30	Suit	54.84	MH	C2S1
22	0.18	Ex	225	Ex	135	FW	0.26	Ex	1.48	Ex	16.6	Ex	-1.77	Suit	91.62	MH	C2S1
23	0.12	Ex	190	Ex	125	FW	0.16	Ex	0.24	Ex	56.4	Per	0.29	Suit	39.92	Soft	C1S1
24	0.29	Ex	248	Ex	156	FW	0.15	Ex	0.43	Ex	16.1	Ex	-0.87	Suit	103.44	MH	C2S1
25	0.20	Ex	325	Good	220	FW	0.74	Ex	0.18	Ex	36.5	Good	-0.05	Suit	101.46	MH	C2S1
26	0.15	Ex	227	Ex	148	FW	0.15	Ex	0.45	Ex	13.6	Ex	-0.83	Suit	55.24	Soft	C1S1
27	0.22	Ex	298	Good	195	FW	0.81	Ex	0.42	Ex	40.0	Good	-0.02	Suit	89.22	MH	C2S1
28	0.18	Ex	295	Good	207	FW	0.82	Ex	0.47	Ex	39.8	Good	0.08	Suit	87.72	MH	C2S1
29	0.40	Ex	732	Good	465	FW	0.77	Ex	0.46	Ex	27.8	Good	-1.55	Suit	259.03	Hard	C2S1
30	0.34	Ex	718	Good	465	FW	0.71	Ex	0.44	Ex	26.7	Good	-1.53	Suit	256.46	Hard	C2S1
31	0.58	Ex	717	Good	455	FW	0.74	Ex	0.44	Ex	26.8	Good	-1.98	Suit	257.4	Hard	C2S1
32	0.18	Ex	298	Good	194	FW	0.21	Ex	0.12	Ex	12.6	Ex	-0.77	Suit	137.43	MH	C2S1
33	0.15	Ex	725	Good	165	FW	0.73	Ex	0.48	Ex	27.5	Good	-0.61	Suit	248.17	Hard	C2S1
Range							0.15 to 5.o5		0.12 to 1.48				-2.0 to 0.85		39.92 to 337.8		
$S(\bar{x})$							0.82		0.39				-0.65		147.5		
SD							1.12		0.28				1.15		86.35		
%CV							136.5		71.79				77.8		58.53		

Legend: Ex=Excellent; FW=Fresh Water; Per= Permissible; Suit=Suitable; Unsuit= Unsuitable; Mar=Marginal; H= Hard; VH=Very Hard; C1=Low Salinity; C2=Medium Salinity; C3= High Salinity; S1=Low Alkanity.EC, B, TDS, SAR, PAR, SSP, RSC, and H_T Classification based on Appendix I, II, III, IV, V and VI. Alkanity and Salinity hazard classification based on Figure3.

4.1.6.2 Potassium adsorption ratio (PAR)

The potassium adsorption ratio of all 33 water samples varied from 0.12 to 1.48. The obtained mean value was 0.39 (Table 3). About 48.49 (16 samples) per cent PAR values were found below the mean and the rest 51.51 per cent (17 samples) were above. Standard deviation and per cent co-efficient of variation were 0.28 and 71.79 respectively.

4.1.6.3 Soluble sodium percentage (SSP)

Soluble sodium percentages carried from 11.2 to 61.5 (Table 3). Out of 33 samples 7 samples belonged to 'permissible' category, 10 lied under the class 'good' and the rest 16 were under 'excellent' category. However, these results indicated that the water samples would not be problematic for irrigating crops. The higher SSP values of 7 samples were possibly due to the relatively higher concentration of Na in river water during dry season. It may be mentioned here that, in dry season the volume of water reduces but discharge of pollutants remains same, therefore, degree of pollution increase spontaneously. Similar results had been observed by Ahmed *et al.* (1993), Quayum (1995) and Helaluddin (1996). All the ions were expressed in me L^{-1} according to the classification by Wilcox (1955).

4.1.6.4 Residual sodium carbonate (RSC)

The residual sodium carbonate of all 33 water samples ranged from -2.0 to 0.85 me L^{-1} (Table 3). Of them 81.81 per cent values were negative indicating these samples were free form residual sodium carbonate and 18.19 percent values were positive. Out of 33 collected water samples, 31 were found free from residual sodium carbonate (RSC) while the rest 2 samples ranged from 0.82 to 0.85 me L^{-1} sample no.20 and 4 (Table 3). Eaton (1950) and Gosh *et al.* (1983) mentioned that waters having RSC value less than 1.25 me L^{-1} can safely be used for irrigation (appendix V) water of the study areas would not create any problem as the RSC ranged from -2.0 to 0.85 me L^{-1}.

4.1.6.5 Total hardness (H_T)

The results pertained to Table 3 indicated that the values of hardness varied from 39.92 to 337.8 mg L^{-1} (Table 3) with an average value 147.53. About 39.39 per cent values of hardness were found to be higher than the mean value and the rest 60.61 per cent values were below the average (184.30 mg L^{-1}). Standard deviation and co-efficient of variation (CV %) were 86.35 and 58.53 respectively. The lower values of standard deviation and co-efficient of variation indicate that the variation of the calculated values among the water sources are comparatively low. On the contrary higher values of standard deviation and co-efficient of variation denote wide variation among the samples for a specific parameter. The computed hardness values of all water samples ranged from 39.92 to 337.8 mg L^{-1}. These results were in good agreement with that of Rahman and Zaman (1995). According Sawyer and McCarty (1967) 23 samples 'moderately hard' 5 samples were 'hard' and the rest 5 samples were belonged to the category 'very hard'. Hardness resulted due to abundant presence of divalent cations such as Ca and Mg in waters (Todd. 1980).

4.1.6.6 Classification of water on the basis of irrigation standard

Out of 33 water samples, all samples were suitable for irrigation on the basis of pH, B, Cl, Fe, and Cu concentration. For sulphate, 30 samples were suitable and 3 samples were not suitable for irrigation; for bicarbonate, 11 samples were suitable and 22 samples were not suitable for irrigation; For Mn 29 samples were suitable and 4 samples were not suitable for irrigation(Table4)

4.1.6.7 Classification of water on the basis of drinking standard

Out of 33 water samples, all samples (except 2 samples no. 9 and 10) were suitable for drinking on the basis of chloride concentration below 250 mg L^{-1} / 7.04 me L^{-1} was presented in Appendix VIII. Iron, zinc, copper, sulphate and nitrate concentrations all water samples were within the limit for drinking purposes. Concentration of Mn ion was also the recommended limit (0.05 mg L^{-1}) for drinking purpose. All water samples were suitable for drinking purposes. Hardwinarto (1989) reported that water of 5 km section to karang Mumus River crossing Samarinda was unfit for drinking. Drinking water standards on the basis of Cl, Cu, Fe, Mn, SO_4 and Zn contents as per U.S. Environmental protection Agency (1975) were presented in Appendix VIII. The present study was near about similar with Hardwinarto (1989) and also similar with Rahman (1993) and Quddus and Zaman (1996).

4.1.6.8 Classification of water on the basis of industrial usage

With regard to TDS, all waters were suitable for most of the purposes except confectionary and paper pulp uses. For carbonated beverage, 2 samples (sample no. 9 and 10) were not suitable because normal value of TDS is 850 mg L^{-1} but sample no. 9 and 10 got 1080 and 1085 mg L^{-1} (Table 2).

In respect to hardness, waters of the stubby area would not be suitable for laundering, rayon manufacture, textile industry and confectionary but could suitably be used for tanning industries (Appendix XI). It can be mentioned here that all the deep tube well waters normally used for carbonated beverage were within the recommended limit (200-250 mg L^{-1}). **The pH values varied** from 6.98 to 8.30. All samples would be unsuitable for laundering because normal value of pH is 6.0 to 6.8. Except 4 samples , all water samples were suitable for tanning, Out of 33 water samples, only 1 sample (sample no.8) were not suitable for confectionary. but may be used as the pH. **The concentration of Cl** ranged from 0.60 to 10.50 me L^{-1}. It would not create any problem for carbonated beverage, textile and brewing industries. All the water samples were unsuitable for sugar industry. Except 7 samples location of which are near to Hazaribag area contained higher amounts of Na and Cl indicating Pollution of water caused due to addition of wastes from tanning and other industries. Industrial water supplies were categorized on the basis of TDS, Hardness, pH, Cl, SO_4, Fe and Mn (Appendix XI) according to U.S. Environmental Protection Agency (1975).

4.1.6.9 Classification of water on the basis of livestock consumption

Out of 33 water samples, all samples (except sample no. 5, 6, 19, 20, 23,26, 28 and 32) were not suitable for drinking on the basis of chloride concentration because normal value of chloride concentration is 30 mg L^{-1} /0.84 me L^{-1} was got sample no. 5, 6, 19, 20, 23,26, 28 and 32)Table 2. Iron, copper and nitrate concentrations all water samples were within the limit for drinking purposes because normal value was respectively 0.30, 0.50, 100 mg L^{-1}. Concentrations of Mn ion of sample nos. 7, 9, 10 and 19 were higher than the recommended limit (0.05 mg L^{-1}) for drinking purpose. Hardwinarto (1989) reported that water of 5 km section to karang Mumus River crossing Samarinda was unfit for drinking. The present study was near about similar with Hardwinarto (1989) and also similar with Rahman (1993) and Quddus and Zaman (1996). Drinking water standards on the basis of Cl, Cu, Fe, Mn, SO4 and Zn contents as per U.S. Environmental protection Agency (1975) were presented in Appendix VIII.

Table 4. Suitability of the water for irrigation purpose

Elements	For waters used continuously maximum concentration on all soils (mg L^{-1})	Obtained range value for the sample water (mg L^{-1})	Remark
pH	6.5-8.40	6.98 - 8.30	Suitable
Boron(B)	0.75	Trace to 0.58	Suitable
Bicarbonate (HCO_3)	92.00	4.88 to 345.26	11 Suitable and 22 not suitable
Chloride(Cl)	142.00	21.3 to 111.83	Suitable
Iron (Fe)	5.00	Trace to 0.15	Suitable
Manganese (Mn)	0.20	Trace to 0.46	29 Suitable and 4 not suitable
Copper (Cu)	0.20	Trace to 0.15	Suitable
Sulfate (SO_4)	20.00	Trace to 79.68	30 Suitable and 3 not suitable

Source: Ayers R.S. and Westcott, D.W.1985. Water Quality for Agriculture .FAO Irrigation and Drainage paper 29(Rev.1):40-96.

Table 5. Suitability of the water for drinking purpose

Constituents	Recommendation maximum concentration limits (mg L^{-1})	Obtained range value for the sample water (mg L^{-1})	Remark
Chloride(Cl)	250.0	21.3 to 111.83	Suitable
Iron (Fe)	0.30	Trace to 0.15	Suitable
Manganese (Mn)	0.05	Trace to 0.46	29 Suitable and 4 not suitable
Copper (Cu)	1.00	Trace to 0.15	Suitable
Nitrate (NO_3)	45.00	0.06 to 1.89	Suitable
Sulfate (SO_4)	250.0	Trace to 79.68	Suitable
Boron(B)	1.00	Trace to 0.58	Not Suitable
Total dissolved solids (TDS)	500.00	123 to 1085	31 Suitable and 2 not suitable

Source: USEPA (United States Environment Protection Agency) 1975 Federal Register **40**(248):59566-59588

Table 6. Suitability of the water for livestock purpose

Constituents	Recommendation maximum limits (mgL^{-1})	Obtained range value for the sample water ($mg\ L^{-1}$)	Remark
Boron(B)	5.00	Trace to 0.58	Suitable
Iron (Fe)	0.30	Trace to 0.15	Suitable
Manganese (Mn)	0.05	Trace to 0.46	29 Suitable and 4 not suitable
Copper (Cu)	0.50	Trace to 0.15	Suitable
Nitrate + Nitrite + (NO_3-N + NO_2-N)	100.00	0.06 to 1.89	Suitable
Chloride(Cl)	30.00	21.3 to 111.83	13 Suitable and 20 not suitable
Total dissolved solids (TDS)	10,000.00	123 to 1085	Suitable

Source: EBS (Environmental Studies Board) 1972. National Academy of Sciences, National Academy of engineering, U.S.A.

Table 7. Suitability classification of Buriganga water for irrigation drinking, livestock, poultry, aquaculture and industrial based on Cl, Mn and Fe

Sample No.	Cl (mg L^{-1})		Mn (mg L^{-1})		Fe (mg L^{-1})	
	Suit	Unsuit	Suit	Unsuit	Suit	Unsuit
1.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
2.	IR,DL,PL,BW,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
3.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
4.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
5.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
6.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
7.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
8.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
9.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
10.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB

Table 7. (Continued)

Sample No.	C (mg L^{-1})		Mn (mg L^{-1})		Fe (mg L^{-1})	
	Suit	Unsuit	Suit	Unsuit	Suit	Unsuit
11.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
12.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
13.	IR,DR,PL,BW,TX	LS,AQ,SG,BW	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX PP,LS	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
14.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
15.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
16.	IR,DR,PL,BW,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
17.	IR,DR,PL,CB,TX	LS,AQ,SG,BW	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
18.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
19.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
20.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB

Table 7. (Continued)

Sample No.	C (mg L^{-1})		Mn (mg L^{-1})		Fe (mg L^{-1})	
	Suit	Unsuit	Suit	Suit	Unsuit	Suit
21.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
22.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
23.	IR,DR,PL,CB,TX	LS,AQ,SG,BW	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
24.	IR,DR,PL,BW,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
25.	IR,DR,PL,CB,TX	LS,AQ,SG,BW	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
26.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
27.	IR,DR,PL,BW,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
28.	IR,DR,PL,BW,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
29.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
30.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB

Table 7. (Continued)

Sample No.	C (mg L^{-1})		Mn (mg L^{-1})		Fe (mg L^{-1})	
	Suit	Unsuit	Suit	Suit	Unsuit	Suit
31.	IR,DR,PL,CB,TX	LS,AQ,SG,BW	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
32.	IR,DR,PL,CB,TX	LS,AQ,SG	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB
33.	IR,DR,PL,BW,TX	LS,AQ,SG,BW	IR,LS,AQ,AC,CB IM,BW,PP,LD	TN,TX	IR,LS,LD,DR	PL,AQ.AC,BW SG,CF,PP,TN,CB

Legend:

IR = Irrigation
DR = Drinking
LS = Livestock
PL = Poultry
AQ =Aquaculture
Suit = Suitable

BW = Brewing
CB = Carbonated Beverage
CF = Confectioner
IM = Ice Manufacture
LD = Laundering
Unsuit = Unsutable

PP = Paper and Pulp
RM = Rayon Manufacture
SG = Sugar Industries
TN = Tanning
TX = Textile

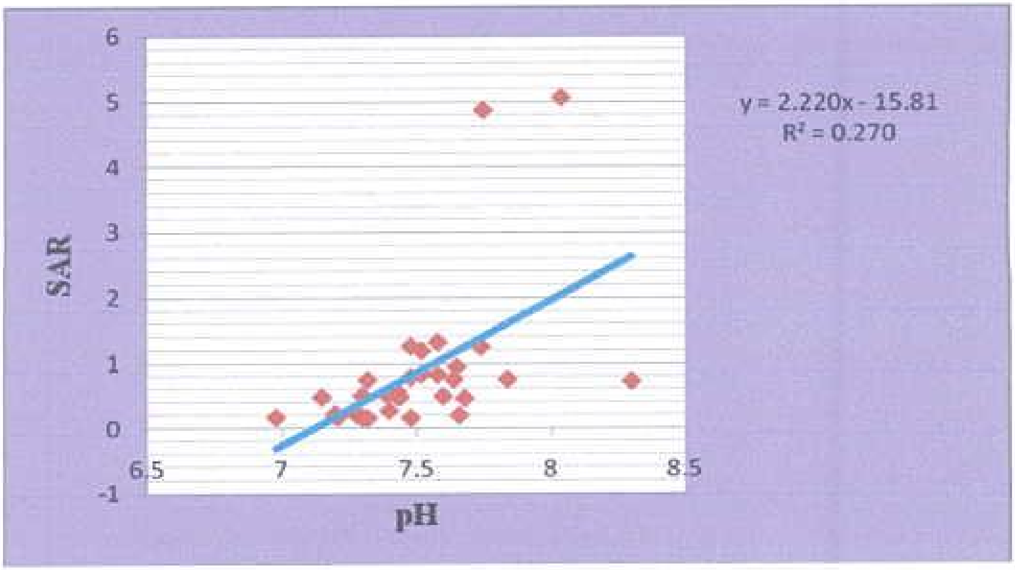

Fig. 4 Relationship between pH and SAR

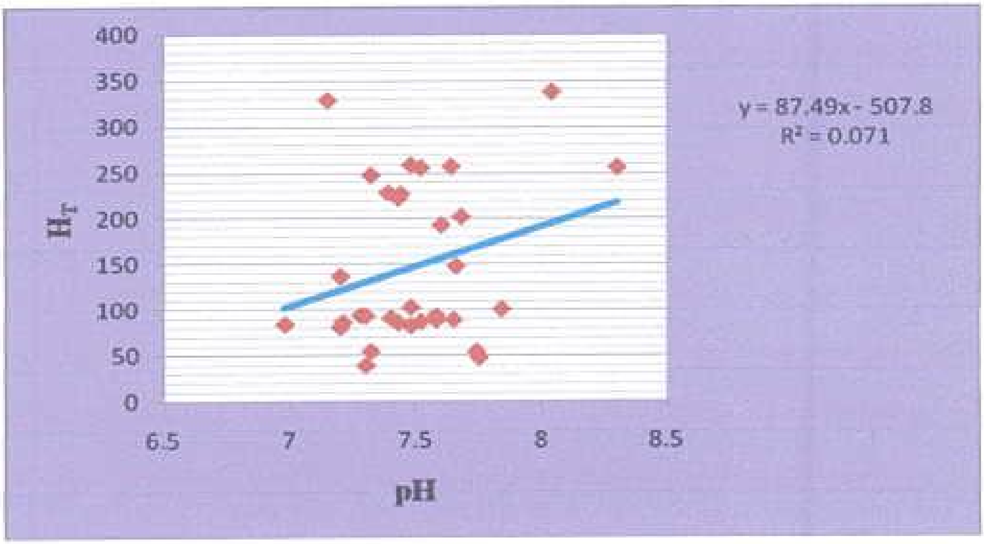

Fig. 5 Relationship between pH and H_T

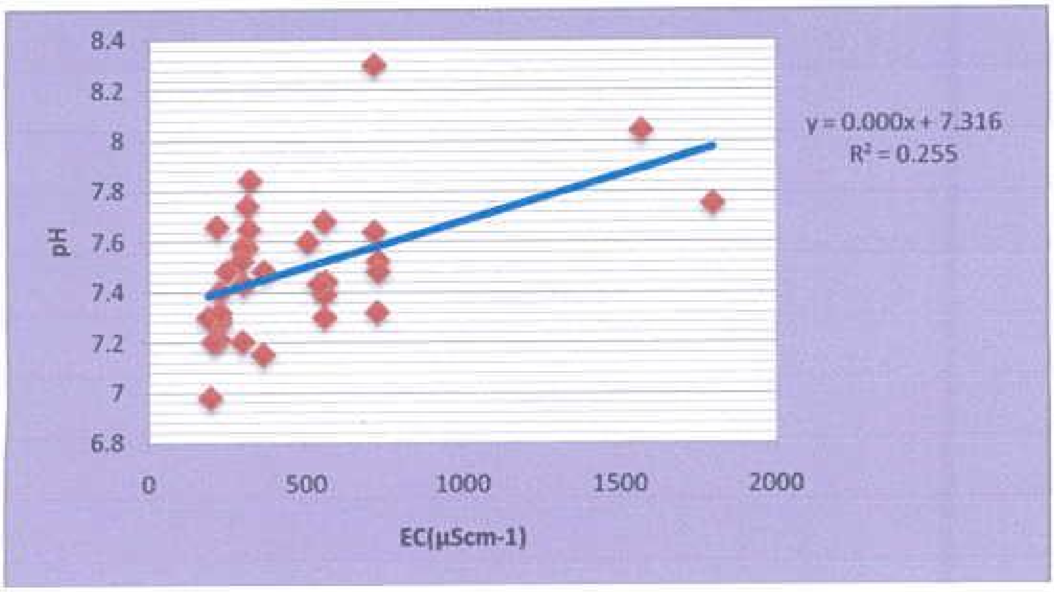

Fig. 6 Relationship between EC ($\mu S\ cm^{-1}$) and pH

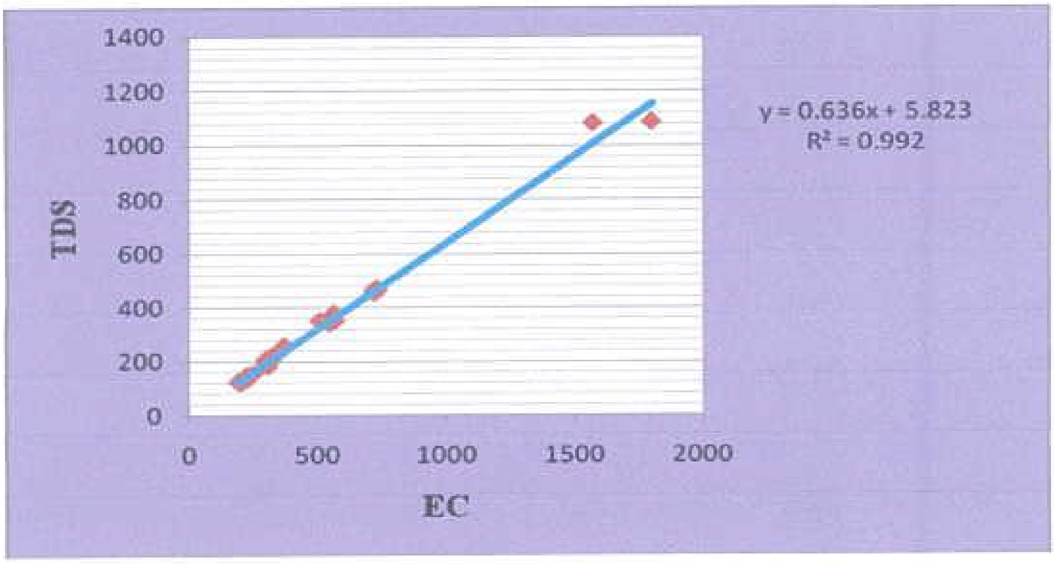

Fig. 7 Relationship between EC ($\mu S\ cm^{-1}$) and TDS

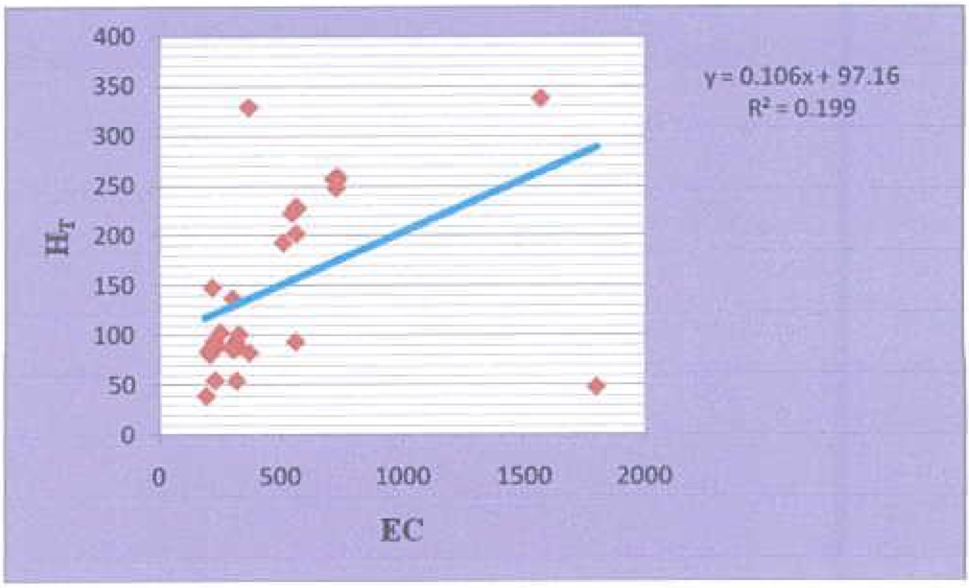

Fig. 8 Relationship between EC ($\mu S\ cm^{-1}$) and H_T

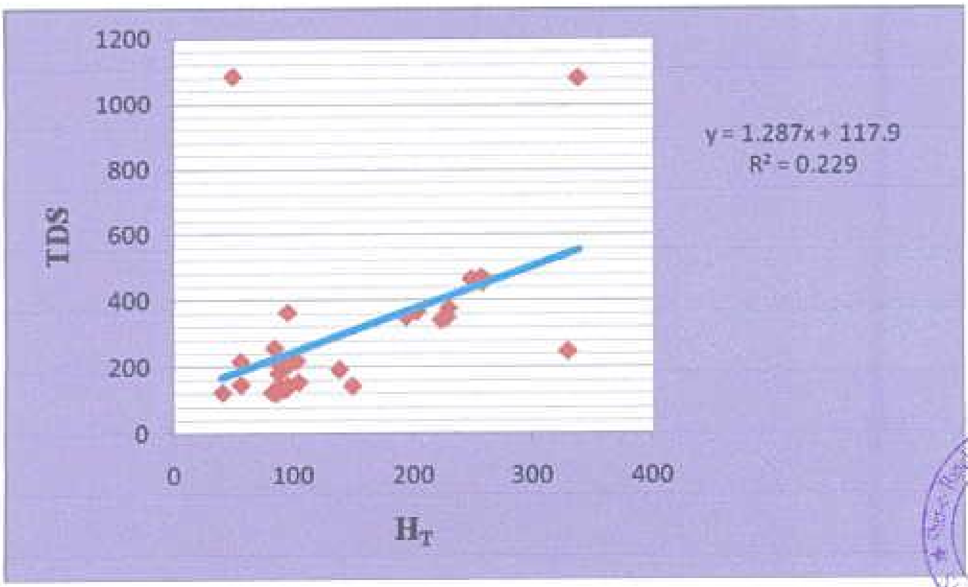

Fig. 9 Relationship between H_T and TDS

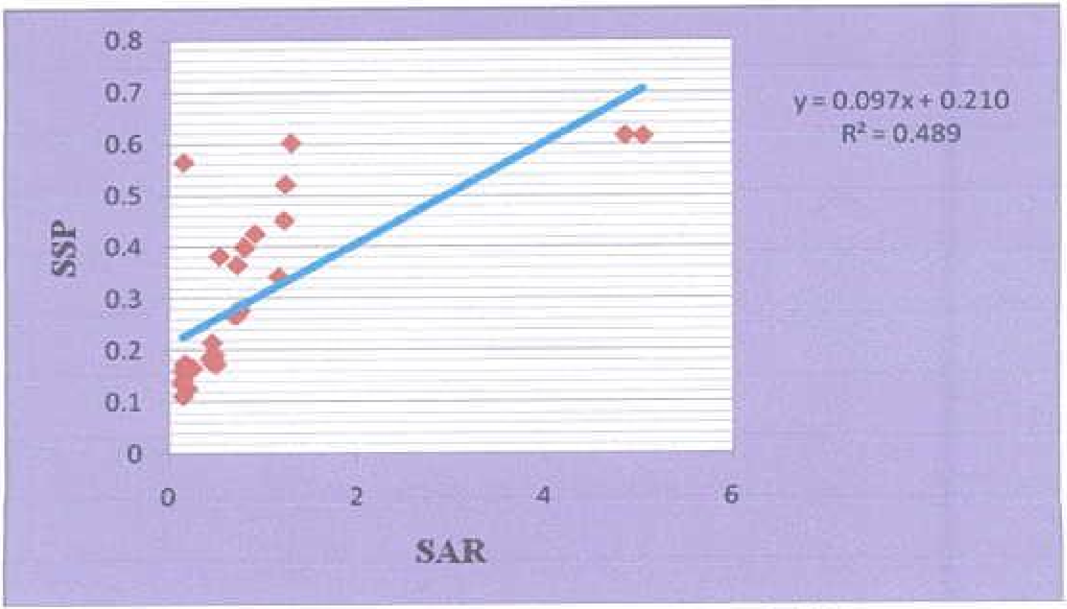

Fig. 10 Relationship between SAR and SSP

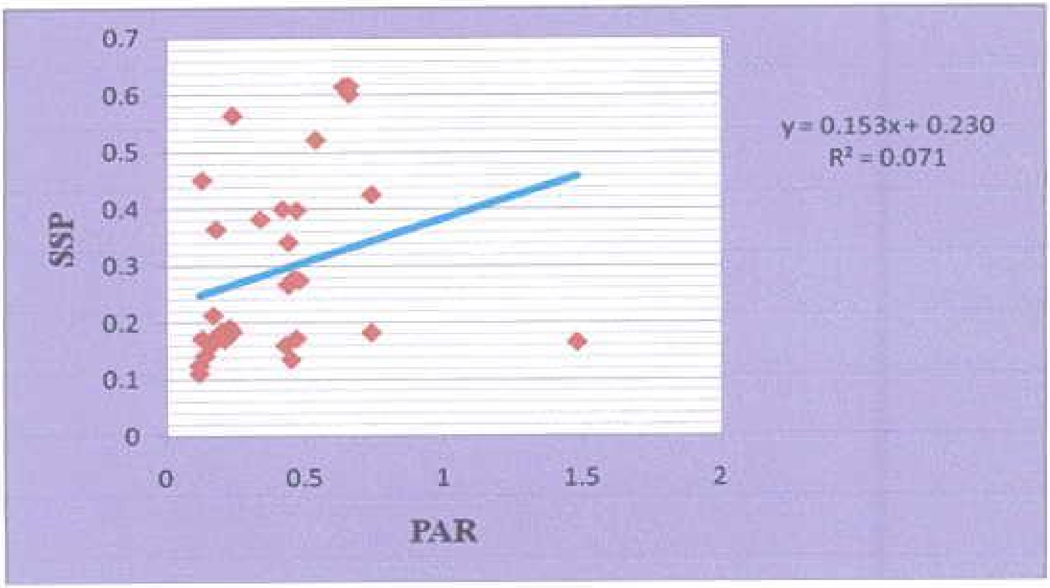

Fig. 11 Relationship between PAR and SSP

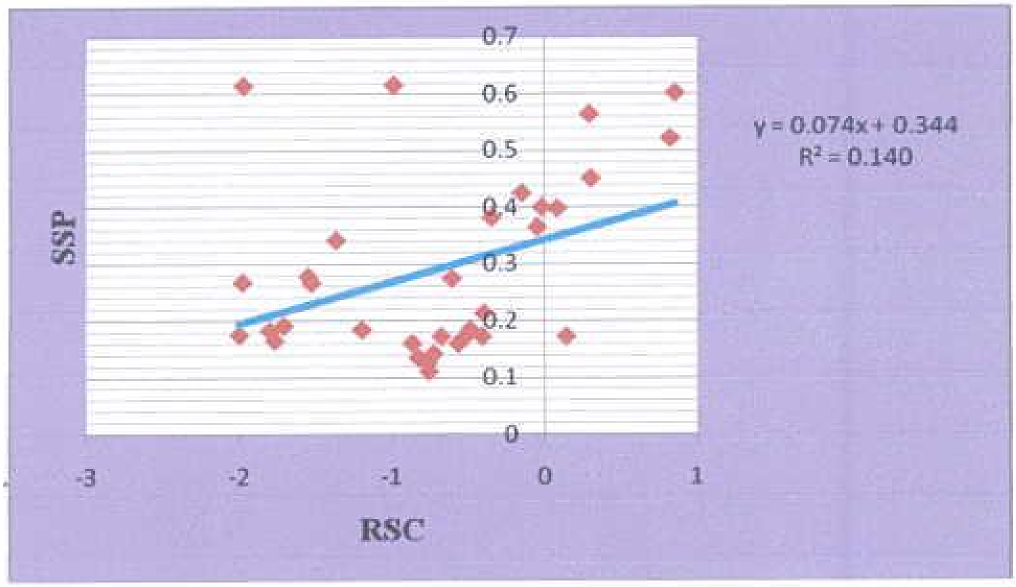

Fig. 12 Relationship between RSC and SSP

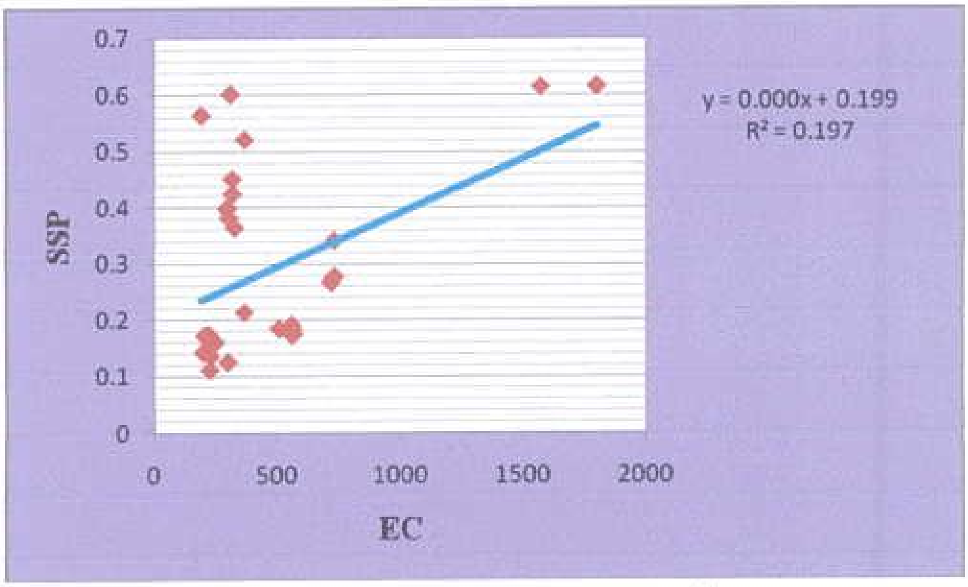

Fig. 13 Relationship between EC (μS cm^{-1}) and SSP

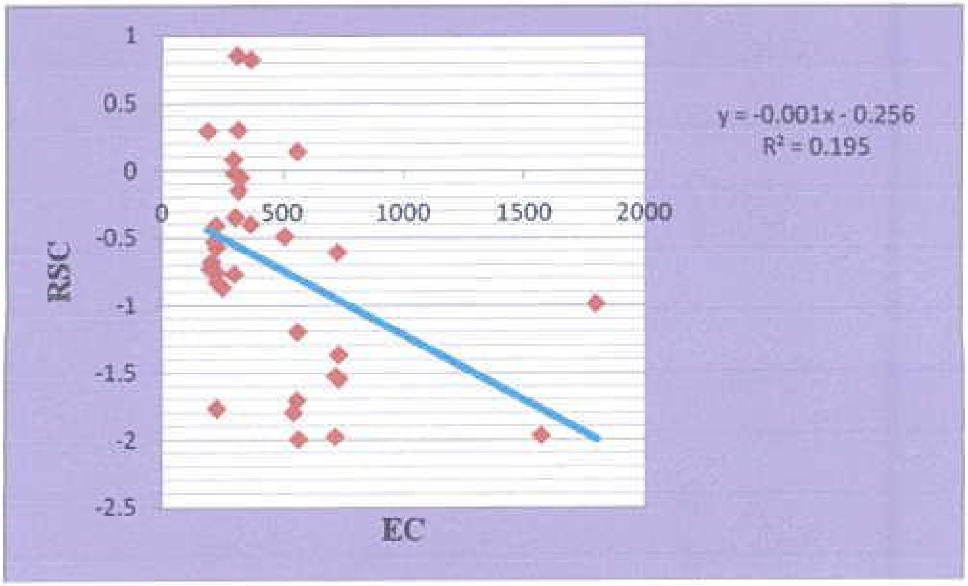

Fig. 14 Relationship between EC ($\mu S\ cm^{-1}$) and RSC

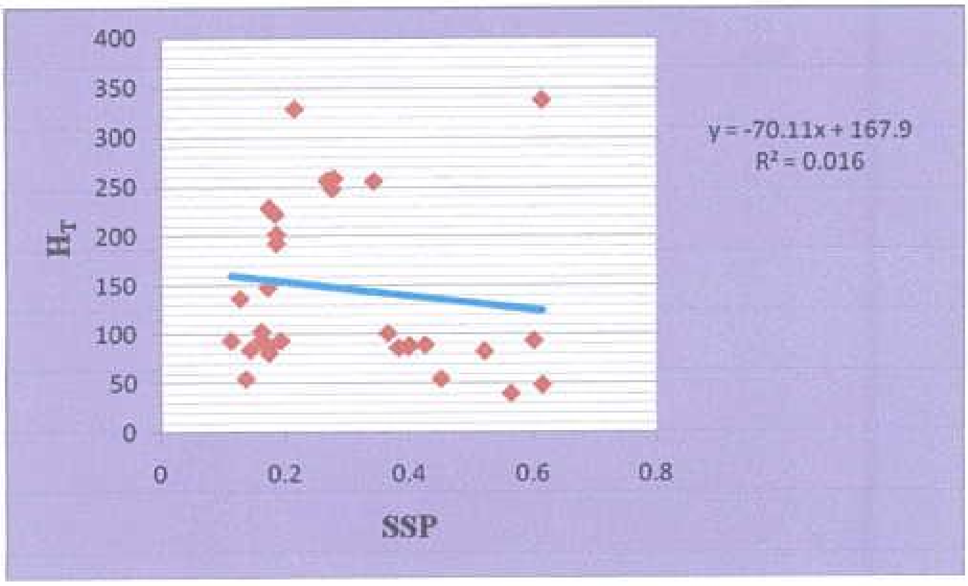

Fig. 15 Relationship between SSP and H_T

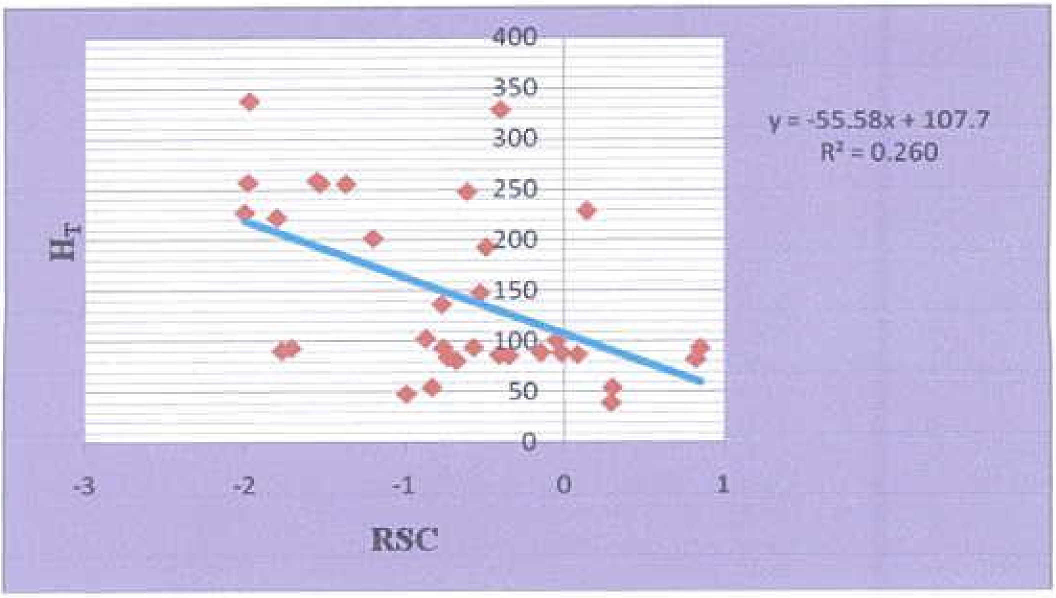

Fig. 16 Relationship between RSC and H_T

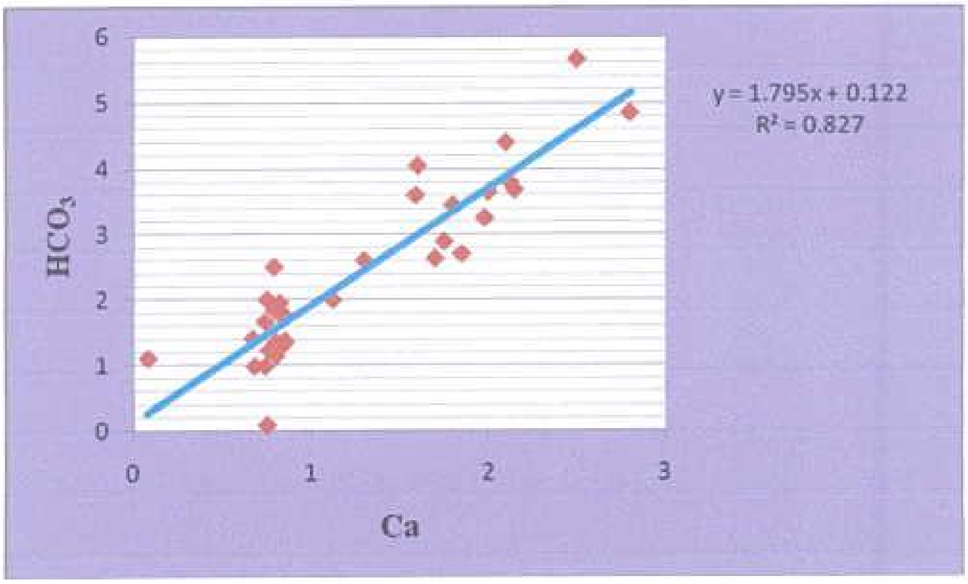

Fig. 17 Relationship between Ca and HCO_3

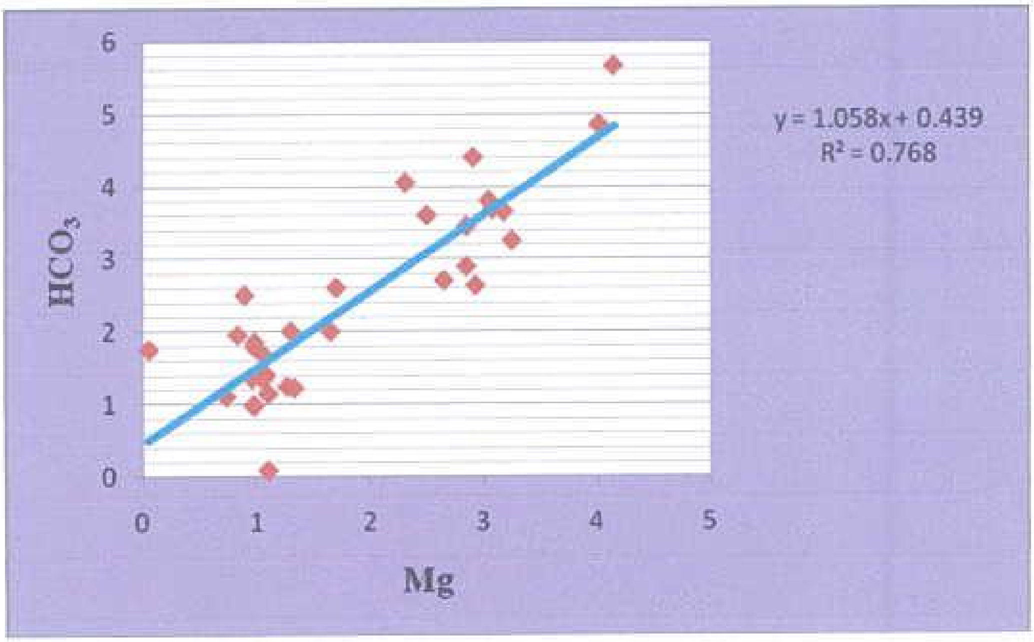

Fig. 18 Relationship between Mg and HCO$_3$

Sulphate contents varied from trace (below detectable range) to 0.546 me L^{-1} and these concentrations would not affect carbonated beverage, sugar and textile industries. Fe and Mn concentrations of all water samples ranged from trace to 0.22and trace to 0.05 mgL^{-1} respectively (Table 2) and were suitable for air – conditioning. The concentration of Fe in all water sample were beyond the recommended limit for carbonated beverage, confectionary, laundering, ice manufacture, tanning and textile industries. Except 4 samples (Sample no. 13, 17 20 and 31) all waters were suitable for brewing, carbonated beverage, confectionary, ice manufacture, laundering, paper and pulp, textile and tanning industries in respect to Mn concentration. Similar type of result had been observed by Davies *et al.* (1993).

4.1.6.10Classification of water for living consumption

The concentration of Cu, Fe, Mn and Zn were considered for classifying water samples for drinking usage of livestock considering the status of copper, iron and zinc, all waters would be suitable for the livestock consumption. As regards to the recommended limit of manganese concentration, all water samples would not be suitable except trace values. About 65.21 per cent sample pertaining to Cl contained higher than the recommended limit (30 mg L^{-1}) and the SO_4 concentration of all waters were below the recommended limit (60 mg L^{-1}) and these were reported in Tables 2. These findings were at par with that of according to Ayers and Westcot (1985), and Dell 'Attic *et al.* (1994).

4.1.5.11 Correlation

The computed regression line recorded the fact that a significant positive correlation pH and Sodium Adsorption Ratio (SAR) (Fig. 4); Electrical Conductivity (EC) and pH (Fig.6); Electrical Conductivity (EC) and Total Dissolved Solution(TDS) (Fig.7); Electrical Conductivity (EC) and Hardness(H_T) (Fig.8); Hardness(H_T) and Total Dissolved Solution(TDS) (Fig.9); Sodium Adsorption Ratio (SAR) and Soluble Sodium Percentage (SSP) (Fig. 10); Residual Sodium Carbonate (RSC) and Soluble Sodium Percentage (SSP) (Fig12); Electrical Conductivity (EC) and Soluble Sodium Percentage (SSP) (Fig.13). Ca and Hydrogen carbonate (HCO_3) (Fig.16); Mg and Hydrogencarbonate (HCO_3) (Fig.17). These reflected a synergistic relation between the above combinations. On the contrary, pH and Hardness (H_T) (Fig.5); Potassium Adsorption Ratio (PAR) and Soluble Sodium Percentage (SSP) (Fig.11); Electrical Conductivity (EC) and Residual Sodium Carbonate (RSC) (Fig.14); Soluble Sodium Percentage (SSP) and Hardness(H_T) (Fig 15) were found inversely related representing an antagonistic behavior.

The co-efficient of correlation between SSP and SAR reflects that the sodium adsorption by soil particles will increase with the increasing amount of soluble Na and may create alkali hazard in soil and may hinder successful crop production. The relationships between EC and PH indicated that the values of EC increases along with the increase of pH, SAR- pH and SSP-pH reflecting higher amounts of Na caused to increase Ph, and SAR-EC and SSP-EC expressing increase amount of Na increased EC value. On the other hand, co-efficient of correlation between RSC and EC denotes that EC increases with the decreasing amount of RSC. All the above mentioned statistical parameters are important in relation to the use of water for irrigation, drinking and industrial supplies.

All the dominant cations and anions were highly significant. Among them, Ca and Mg (r =0.975), Na and Cl (r = 0.962), Ca and HCO_3 (r =0.910),Mg and HCO_3 (r = 0.895) and K and Na (r=0.744) were remarkable (Table 8). These results indicated that an increase of one element will or may increase the concentration of the other and synergistic behaviors amongst the dissolved ions in water sources were observed.

Table 8. Checking correctness of Burigonga River water analysis

Sl. No.	Anion-Cation-balance			Total dissolved solids (mg L^{-1})		Ratio of measured TDS to calculated TDS	Electrical Conductivity (EC)		Ratio of measured EC to calculated EC	Ratio of measured or calculated TDS to calculated EC
	∑Cation me L^{-1}	∑Anion me L^{-1}	Difference %	Measured	Calculated		Measured	Calculated		
01	2.85	2.60	4.51	183	182.27	1.004	303	285	1.06	0.642
02	2.26	2.21	1.12	145	143.96	1.007	225	226	1.34	0.642
03	2.12	2.07	1.19	144	142.18	1.013	223	212	1.43	0.679
04	2.22	2.12	2.30	206	202.28	1.018	310	222	1.36	0.928
05	2.18	1.97	5.01	140	136.81	1.023	225	218	1.39	0.642
06	1.96	1.78	4.78	125	123.93	1.009	205	196	1.55	0.638
07	7.77	6.64	7.88	470	468.29	1.004	730	777	0.39	0.605
08	1.99	1.84	4.03	123	122.37	1.005	198	199	1.52	0.618
09	17.36	15.90	4.38	1080	1062.05	1.017	1572	1736	0.17	0.622
10	16.75	16.21	1.64	1085	1079.49	1.005	1800	1675	0.18	0.648
11	3.79	3.45	4.64	248	246.14	1.008	365	379	0.80	0.654
12	2.29	1.97	7.46	144	142.94	1.007	215	229	1.32	0.629
13	5.68	5.34	3.09	365	363.88	1.003	558	568	0.53	0.643
14	5.62	5.26	3.32	350	348.02	1.006	565	562	0.54	0.623
15	5.71	5.12	5.45	367	366.10	1.002	560	571	0.53	0.643
16	5.02	4.92	1.00	351	349.33	1.005	507	502	0.60	0.699
17	4.94	4.88	0.61	378	373.07	1.013	560	494	0.61	0.765

Table 8. (Continued)

Sl. No.	Anion-Cation-balance			Total dissolved solids (mg L^{-1})		Ratio of measured TDS to calculated TDS	Electrical Conductivity (EC)		Ratio of measured EC to calculated EC	Ratio of measured or calculated TDS to calculated EC
	$\sum$Cation me L^{-1}	$\sum$Anion me L^{-1}	Difference %	Measured	Calculated		Measured	Calculated		
18	5.51	5.266	2.2643	342	340.83	1.003	543	539	1.007	0.63
19	3.15	3.12	0.4785	207	205.95	1.005	317	315	1.006	0.66
20	3.51	3.301	3.0686	258	256.93	1.004	367	351	1.046	0.74
21	3.01	2.924	1.4493	218	209.71	1.040	315	301	1.047	0.72
22	2.22	1.422	11.911	135	133.84	1.009	225	222	1.014	0.61
23	1.86	1.842	0.4862	125	123.37	1.013	190	186	1.022	0.67
24	2.49	2.221	5.7100	156	154.88	1.007	248	247	1.004	0.63
25	3.23	3.025	3.2774	220	218.18	1.008	325	323	1.006	0.68
26	2.40	2.059	7.6475	148	146.54	1.010	227	224	1.013	0.66
27	3.00	2.351	11.129	195	193.29	1.009	298	295	1.010	0.66
28	2.94	2.682	4.5891	207	206.16	1.004	295	294	1.003	0.70
29	7.24	6.581	4.7681	465	463.62	1.003	732	724	1.011	0.64
30	7.07	6.614	3.3324	465	464.28	1.002	718	707	1.016	0.66
31	7.14	6.632	3.6886	455	453.48	1.003	717	714	1.004	0.64
32	3.17	2.651	8.916	194	192.06	1.010	298	295	1.010	0.66
33	6.91	6.877	0.2394	165	463.60	1.003	725	691	1.049	0.24

Table 9. Regression and Correlation analysis of quality criteria

Quality criteria	Correlation co-efficient (r)	Regression equation
pH vs SAR	0.520**	**y = 2.220x -15.81**
pH vs H_T	0.267 ^{NS}	**y = 87.49x + 507.8**
EC vs pH	0.505**	**y = 0.001x + 7.316**
EC vs TDS	0.996**	**y = 0.636x + 5.823**
EC vs H_T	0.446**	**y = 0.106x + 97.16**
H_T vs TDS	0.479**	**y = 1.287x+117.9**
SAR vs SSP	0.700**	**y = 0.153x + 0.230**
PAR vs SSP	0.267 ^{NS}	**y = 0.074x + 0.344**
RSC vs SSP	0.375*	**y = 0.001x + 0.199**
EC vs SSP	0.444**	**y = 0.001x+0.256**
EC vs RSC	-0.128 ^{NS}	**y = -70.11x +167.9**
SSP vs H_T	-0.128 ^{NS}	**y = -55.58 x + 107.7**
RSC vs H_T	-0.511**	**y = 1.795x + 0.122**
Ca vs HCO_3	0.910**	**y = 1.058x + 0.439**
Mg vs HCO_3	0.895**	**y = 1.965x + 0.140**

Legend:

** Correlation is significant at the 1% level

* Correlation is significant at the 5% level

^{NS} Non Significant

Tabulated value of 'r' with 31df =0.3490 at 5% level and 0.4481 at 1% level of significance

Table 10. Relationship between water quality factors

Parameters	pH	EC	TDS	SAR	PAR	SSP	RSC	H_T
pH	1	.505**	.526**	.520**	.237^{NS}	.468**	-.143^{NS}	.267^{NS}
EC		1	.996**	.881**	.254^{NS}	.444**	-.442**	.446**
TDS			1	.889**	.247^{NS}	.455**	-.432*	.479**
SAR				1	.298^{NS}	.700**	-.141^{NS}	.180^{NS}
PAR					1	.267^{NS}	-.200^{NS}	.037^{NS}
SSP						1	.375*	-.128^{NS}
RSC							1	-.511**
H_T								1

Legend:

** Correlation is significant at the 1% level
* Correlation is significant at the 5% level
^{NS} Non Significant
Tabulated value of 'r' with 31df =0.3490 at 5% level and 0.4481 at 1% level of significance

Tabled 11. Correlation co-efficient (r) among ions

	pH	EC	TDS	Ca	Mg	K	Na	Fe	Zn	Mn	Cu	P	B	SO_4	NO_3	HCO_3	Cl
pH	1	.505**	.526**	.420*	.431*	.559**	.481**	-.220 ^{NS}	-.249 ^{NS}	.602 ^{NS}	-.167 ^{NS}	.490 ^{NS}	.393*	.273 ^{NS}	.634**	.462**	.452**
EC		1	.996**	.864**	.873**	.777**	.921**	-.395 ^{NS}	.022 ^{NS}	.784 ^{NS}	.257 ^{NS}	.678**	.669**	.179 ^{NS}	.745**	.875**	.949**
TDS			1	.870**	.870**	.783**	.926**	-.416 ^{NS}	.030 ^{NS}	.739 ^{NS}	.270 ^{NS}	.679**	.656**	.178 ^{NS}	.747**	.882**	.948**
Ca				1	.975**	.559**	.644**	-.466 ^{NS}	.057 ^{NS}	.599 ^{NS}	.183 ^{NS}	.559*	.692**	.022 ^{NS}	.678**	.910**	.747**
Mg					1	.588**	.638**	-.317 ^{NS}	.048 ^{NS}	.668 ^{NS}	.100 ^{NS}	.483 ^{NS}	.743**	.000 ^{NS}	.697**	.895**	.758**
K						1	.744**	-.019 ^{NS}	-.170 ^{NS}	.554 ^{NS}	.306 ^{NS}	.915**	.520**	.248 ^{NS}	.589**	.693**	.718**
Na							1	-.479 ^{NS}	-.036 ^{NS}	.734 ^{NS}	.106 ^{NS}	.654*	.514**	.265 ^{NS}	.667**	.676**	.962**
Fe								1	-.320 ^{NS}	-.795 ^{NS}	-.199 ^{NS}	-.587 ^{NS}	.243 ^{NS}	-.087 ^{NS}	-.191 ^{NS}	-.561*	-.317 ^{NS}
Zn									1	.884 ^{NS}	.903**	-.224 ^{NS}	-.122 ^{NS}	-.048 ^{NS}	-.067 ^{NS}	.202 ^{NS}	-.070 ^{NS}
Mn										1	1.01**	.526 ^{NS}	.979*	.388 ^{NS}	.804 ^{NS}	.762 ^{NS}	.702 ^{NS}
Cu											1	.453 ^{NS}	.090 ^{NS}	.597 ^{NS}	.015 ^{NS}	.407 ^{NS}	-.187 ^{NS}
P												1	.157 ^{NS}	.361 ^{NS}	.587*	.576*	.638*
B													1	.375 ^{NS}	.665**	.623**	.597**
SO_4														1	.478*	.085 ^{NS}	.169 ^{NS}
NO_3															1	.667**	.663**
HCO_3																1	.704**
Cl																	1

Legend: ** Correlation is significant at the 1% level

* Correlation is significant at the 5% level

^{NS} Non Significant

Tabulated value of 'r' with 31df =0.3490 at 5% level and 0.4481 at 1% level of significance

Table 12. Water suitability rating against different criteria

Use		pH	TDS	H_T	Cl	SO_4	Fe	Mn
			(mg L^{-1})					
Textile	Recommended	-	-	0-50	100	100	0.1-1.0	0.05-1.0
	Obtained	-	-	39.92-337.8	21.3-111.83	Trace- 79.68	Trace- 0.15	Trace- 0.46
	Remark	-	-	2 Suit and 31 not suit	32 Suit and 1 not suit	All suit	All suit able	All suit able
Confectionary	Recommended	>7.0	50-100	70	-	-	0.1-0.2	0.20
	Obtained	6.98-8.30	123 - 1085	39.92-337.8	-	-	Trace- 0.15	Trace- 0.46
	Remark	1 Suit and 32 not suit	Not suit	5 Suit and 28 not suit				31 Suit and 2 not suit
Laundering	Recommended	6.0-6.8	-	0-50	-	-	0.2-1.0	0.20
	Obtained	6.98-8.30		39.92-337.8			Trace- 0.15	Trace- 0.46
	Remark	Not suit		2 Suit and 31 not suit			All suitable	31suit and 2 not suit
Rayon Manufacture	Recommended	7.8	-	55	-	-	-	-
	Obtained	6.98-8.30		39.92-337.8				
	Remark	3 Suit and 30 not suit		3 Suit and 30 not suit				
Sugar	Recommended	-	-	-	20	20	0.10	-
	Obtained				21.3-111.83	Trace- 79.68	Trace- 0.15	
	Remark				All not suit	4 Suit and 29 not suit	All suitable	
Tanning	Recommended	6.0 - 8.0	-	50-500	-	-	0.1-0.2	0.1-0.2
	Obtained	6.98-8.30		39.92-337.8			Trace- 0.15	Trace- 0.46
	Remark	31suit and 2 not suit		All suitable			All suitable	All suitable

4.1.5.12 Salient findings of the investigation

It may be concluded from the above discussion that out of 33 water samples analyzed, 25 samples were found to be suitable for irrigation, considering all the criteria discussed above. And 29 samples were found suitable for drinking. For the industrial usage Air-conditioning none of the waters was found suitable all the industries considered for discussion because prerequisites of water quality for a specific industry varies widely from another, Hardly, 32 samples were detected suitable for livestock consumption.

Chapter V

Summary and Conclusion

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SUMMARY AND CONCLUSION

A study was conducted to determine the water quality of the River Buriganga and neighboring in Dhaka city. Out of 33 samples, 27 from Buriganga river's water (11 of dry season and 16 of rainy season) and 6 from deep tubewells during dry season were collected from different non-point (in case of river) and point sources for analyses of dissolved chemical constituents and to classify the water according to their suitability for irrigation, drinking and industrial usage.

Water samples were classified on the basis of EC, TDS, SAR, SSP, RSC and H_T. The pH values of collected water samples ranged from 6.98 to 8.30 and were found to be 'suitable' for successful crop production and drinking. EC values graded the water samples as 'excellent' to 'good' classes. Out of 33 groundwater samples, all were in 'good' class. TDS values of 31 water samples were graded as 'fresh water' with the exception only 2 samples. Classification based on SAR, all the samples were of 'excellent' class. As because the SAR values were within the range of 0.15 to 5.05. EC and SAR categorized the samples as 'low' 'medium' and 'high' salinity (Cl, C2 and C3) and low alkali hazard's (Sl), combined expressed as ClSl (3 samples), C2Sl (28 samples and C3Sl (2 samples). On the basis of SSP all samples were 'excellent' and all waters were rated as 'suitable' for 'irrigation'. Hardness of water reflected that among the surface waters 17 were found as 'moderately hard', 11 samples were 'hard' and the rest 5 samples belonged to 'very hard'. The concentrations of total Cations (1.86 to 17.36 me L^{-1}) and anions (1.422 to 16.21 me L^{-1}) contents of all water samples were not found to be harmful for field crops. To use the above 7 water samples, drainage should be improved and plants with good salt tolerance should be selected. Surface water samples of dry season contained Ca^{2+}, Mg^{2+}, Na^{2+}, HCO_3^- and Cl^- predominantly along with K^+ and p^{5+} ions in lesser quantities in comparison to groundwater but the concentrations of those ions in wet season sample of surface water were lower than those of groundwater. The status of iron (traces to 0.15 mg L^{-1}) was found within the 'safe' limit (mg L^{-1}) for irrigation. The concentrations of Zn, Cu and p of all the samples were also within the 'safe' limit but that of Mn of only 3 (sample no. 10 and 19) were above the recommended limit (0.20 mg L^{-1}) In respect to irrigation. Boron statuses of 14 samples were 'good' for sensitive crops and the rest 19 samples were 'excellent'. The ionic concentrations of water anoles were in the descending order of magnitude as

$Cl^- > Na^+ > Mg^{++} > Ca^{++} > K^+ > SO_4 > PO_4 > NO_3 > B^{+++} > Mn^{++} > Fe^{+++} > Zn^{++} > Cu^{++} > CO_3^-$.

Total dissolved solids of all the water samples were suitable for most of the purposes except confectionary uses. About 93.75 per cent samples were 'suitable' for carbonated beverage and 21.17 per cent for paper and pulp industries. Hardness of all samples would be suitable only for tanning and unsuitable for textile, rayon manufacture, and confectionary and laundering pH values of all samples were found 'not suitable' for laundering but 'suitable' for confectionary. Out of 33 water samples, all samples (except sample no. 5, 6, 19, 20, 23,26, 28 and 32) were not suitable for drinking on the basis of chloride concentration because normal value of chloride concentration is 30 mg L^{-1} /0.84 me L^{-1} was got sample no. 5, 6, 19, 20, 23,26, 28 and 32)Table 2. Iron, copper and nitrate concentrations all water samples were within the limit for drinking purposes because normal value was respectively 0.30, 0.50, 100 mg L^{-1}. Concentrations of Mn ion of sample nos. 7, 9, 10 and 19 were higher than the recommended limit (0.05 mg L^{-1}) for drinking purpose.. Sulphate statuses of all waters were found 'suitable' for carbonated beverage, sugar (except sample no. 9 and 10) and textile industries. The nitrate concentrations of all waters were within the 'safe' limit (10.0 mg L^{-1}) for drinking purposes. Fe and Mn contents were 'suitable' for air conditioning. The concentration of Fe of all the samples and Mn concentration of 31 samples (except sample no.9 and 10) were found 'suitable' for carbonated beverage, confectionary, laundering, ice manufacture, tanning and textile industries. The results of Cl, Cu.Fe, Mn, Zn and SO_4 reflected that 25 samples were found suitable for drinking and the rest samples were 'not suitable' for drinking. Mn statuses of all waters were suitable for livestock consumption except sample no. 7, 10 and 18. Fe, Cu and Zn contents of all samples would be suitable for livestock consumption. The pH vs SAR, EC vs pH, EC vs TDS, EC vs H_T, H_T vs TDS , SAR vs SSP, RSC vs SSP, EC vs SSP, RSC vs H_T, Ca vs HCO_3 and Mg vs HCO_3 combination showed significant correlation. And EC vs RSC and RSC vs H_T combination showed a negative significant correlation. On the contrary, the relationship between PAR vs SSP and pH vs H_T were found insignificant.

On the basis of chemical composition it can be concluded that the wet season sample of the River Buriganga and deep tubewells water were found to be suitable for irrigation, drinking, domestic, livestock and industrial usage but some of the dry season samples of river water were rated to be toxic for all the above purposes.

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Appendices

APPENDICES

Appendix I. Water classification on the basis of EC to SSP

Water class	Electrical Conductivity(EC) ($\mu S\ cm^{-1}$)	%SSP
Excellent	<250	<20
Good	250-750	20-40
Permissible	750-2000	40-60
Doubtful	2000-3000	60-80
Not suitable	>3000	>80

Source: Wilcox. V.1995.Classification and use of irrigation water. USDA. Circular no. 969. Washington D.C.P.19.

Appendix II. Water classification on the based on B concentration

Water class	Boron ($mg\ L^{-1}$)		
	Sensitive	Semi-tolerant crops	tolerant crops
Excellent	<0.33	<0.67	<1.00
Good	0.33-0.67	0.67-1.33	1.00-2.00
Permissible	0.67-1.00	1.33-2.00	2.00-3.00
Doubtful	1.00-1.25	2.00-2.50	3.00-3.75
Unsuitable	>1.25	>2.50	>3.75

Source: Wilcox,L.V.1995.Classification and use of irrigation water. USDA. Circular no.969 .Washington D.C.P.19.

Appendix III. Water Classification as per TDS

Water class	Total Dissolved Solids (mg L^{-1})
Fresh water	0-1,000
Brackish water	1,000-10,000
Saline water	10,000-100,000
Brine water	>100,000

Source: Freeze, A.Z and Cherry, J.A 1979.Ground. Prentice Hall Inc. Englewood Cliffs. New Jersey 07632.p.84.

Appendix IV. Water Class rating based on SAR

Water Class	Sodium Absorption Ratio (SAR)
Excellent	<10
Good	10-18
Fair	18-26
Poor	>26

Source: Todd, D.K.1980 .Groundwater Hydrology, 2nd edn. John Wiley and Sons Inc. New York 10016.p.304

Appendix V. Water Classification according to RSC

Suitability of water	Residual Sodium Carbonate (RSC) (me L^{-1})
Suitable	<1.25
Marginal	1.25-2.50
Unsuitable	>2.50

Source: Eaton, F.M.1950.Significance of carbonate in irrigation waters .Soil Sci.67:12-133.

Appendix VI. Classification of water on the basis of hardness (mg L^{-1})

Water Class	Hardness (mg L^{-1})
Soft	0-75
Moderately hard	75-150
Hard	150-300
Very hard	>300

Source: Sawyer. C.N. and MC. Carty, P.L.1967.Chemistry for sanity Engineers.2nd.edn. McGraw Hill, New Yark.P.518

Appendix VII. Recommended maximum concentration of quality factor and different ions for irrigation water.

Elements	For waters used continuously on all soils (mg L^{-1})
pH	6.5-8.40
Arsenic(As)	0.10
Boron(B)	0.75
Bicarbonate (HCO_3)	92.00
Carbonate (CO_3)	0.10
Chloride(Cl)	142.00
Iron (Fe)	5.00
Manganese (Mn)	0.20
Copper (Cu)	0.20
Phosphate (PO_4)	2.00
Sulfate (SO_4)	20.00

Source: Ayers R.S. and Westcott, D.W.1985. Water Quality for Agriculture .FAO Irrigation and Drainage paper 29(**Rev.1**):40-96.

Appendix VIII. Recommended concentration of different ions for drinking water.

Constituents	Recommendation limits (mg L^{-1})
Arsenic(As)	0.01
Chloride(Cl)	250.0
Iron (Fe)	0.30
Manganese (Mn)	0.05
Copper (Cu)	1.00
Nitrate (No3)	45.00
Sulfate (SO_4)	250.0
Boron(B)	1.00
Total dissolved solids (TDS)	500.00

Source: USEPA (United States Environment Protection Agency) 1975 Federal Register 40(248):59566-59588.

Appendix IX . Recommended level of toxic substance in drinking water for livestock use.

Constituents	Recommendation limits (mgL^{-1})
Arsenic(As)	0.20
Boron(B)	5.00
Iron (Fe)	0.30
Manganese (Mn)	0.05
Copper (Cu)	0.50
Nitrate + Nitrite + (NO_3-N + NO_2-N)	100.00
Chloride(Cl)	30.00
Total dissolved solids (TDS)	10,000.00

Source: EBS (Environmental Studies Board) 1972. National Academy of Sciences, National Academy of engineering, U.S.A.

Appendix X. water quality standards for aquaculture

Parameter	***Concentration (mg L^{-1})***
Chloride(Cl)	<0.003
Hardness(H_T)	10-40
Iron (Fe)	<0.001
Manganese (Mn)	<0.01
pH	6.50-8.00
Sulfate (SO_4)	<50
Total dissolved solids (TDS)	<400

Source: Meade ,J.W.1989.Aquiaculture Management. New York. Van Nostra and Reinhold.

Note : Concentrations are mg L^{-1} except for pH.

Appendix XI. Recommended concentrations of different ions for industrial water supply.

Use	pH	TDS	H_T	Cl	SO_4	Fe	Mn
		(mg L^{-1})					
Air- conditioning	-	-	-	-	-	0.05	0.50
Brewing	6.5-7.0	500-1500	-	60-100	-	0.10	0.10
Carbonated beverage	-	850	200-250	250	250	0.1-0.2	0.20
Confectionary	>7.0	50-100	70	-	-	0.1-0.2	0.20
Ice Manufacture	-	170-1300	-	-	-	0.20	0.20
Laundering	6.0-6.8	-	0-50	-	-	0.2-1.0	0.20
Paper pulp	-	100-200	100	-	-	0.10	0.05
Rayon Manufacture	7.8	-	55	-	-	-	-
Sugar	-	-	-	20	20	0.10	-
Tanning	6.0-8.0	-	50-500	-	-	0.1-0.2	0.1-0.2
Textile	-		0-50	100	100	0.1-1.0	0.05-1.0

Source: USEPA (United States Environment Protection Agency) Federal Register 40(**248**):59566-59588.December 24,1975.