Hydrochemistry of Surface and Ground Water Used for Boro Rice Cultivation of Khulna District, Bangladesh

Md. Tipu Sultan, Shaikh Motasim Billah and Md. Lokman Bhuiyan

Abstract: *Bangladesh is a land of mighty rivers and innumerable tributaries, heavy rainfall and recurring floods. Nearly 75 per cent of the country's population depends either directly or indirectly on agriculture (BBS, 2006). This study deals with the surface and ground water used in rice cultivation of Khulna district, which is located in the south-western part of Bangladesh. The objective of this study is to characterize the surface and ground water in terms of different dissolved elements in relation to the suitability of the water for irrigation purposes of Khulna district of South-western Bangladesh. To analyze the water quality for irrigation of Boro rice of Khulna district, the water samples both surface and ground water were collected from different Upazillas. A reconnaissance survey was conducted in different areas of sampling sites. Collected samples were immediately analyzed for finding important chemical parameters such as - pH, Electrical Conductivity (EC), Phosphorus($PO4^{3-}$), Potassium (K), Nitrogen (N), Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Total Hardness (HT). From the analysis, it was observed the ionic concentration and other chemical parameters showed variations in different water sources of the area. EC and PO43- concentrations were prevailed in ground water than surface water where the N (NO_{3-}-N + NH_{4+}-N) and K+ concentration showed reversed condition. Therefore, it can be concluded that, all the sources of surface water and ground water has the risk of sodicity hazard as well as alkali hazard for irrigation that should be treated properly to use.*

Key words: Biochemistry, concentration level, south-western Bangladesh, irrigation, agriculture, surface and ground water.

Introduction

In Bangladesh, optimum use of irrigation water should play an important role in increasing agricultural production. Overall development of the country's agricultural sector will require year round use of irrigation facilities. Irrigation plays a vital role in this country for half of the year (mainly in dry season) when water scarcity seriously handicaps farming operation (Nargis et al., 2009). The rice crop alone occupies 90 - 95 percent of the irrigated area and only 5 - 10 percent is left for other crops (BBS, 2006). It implies that about 57% of total cultivable lands are irrigated. Both surface and groundwater is used for the purpose. At present more than 70% of the irrigated area is served by groundwater and less than 30% by surface water (Sattar, 2009). Boro rice in Bangladesh of different variety covering more than 4.5 million ha, is entirely irrigated production, mostly with underground water. As a result, besides the increased cost of irrigation, groundwater level is also declining due to excessive withdrawal threatening the environment. Water resources are becoming scarce worldwide. Bangladesh is also no exception. About 60 percent areas are covered by shallow tube-well water for irrigation (BBS, 2006). This resource is not unlimited and in intensive tube well areas water level is

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declining gradually in each dry season. Irrigated agriculture is dependent on an adequate water supply of usable quality. Quality is defined by certain physical, chemical and biological characteristics. Therefore, some of the important physical and chemical properties of irrigation is necessary to be known to assess its suitability for irrigation (Michael, 1992). Characteristics of irrigation water that define its quality vary with the source of the water. There are regional differences in water characteristics, mainly based on geology and climate. The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients (Ayers and Westcott, 1985). To evaluate the quality of irrigation water, we need to identify the characteristics that are important for plant growth, and their acceptable levels of concentrations.

Methodology

Methodology is the guiding framework for researcher to contain and harmonize the scientific investigation. It is divided into three phases: conceptualization, data collection and analysis.

Framework of the research work

For successful completion of this research work the framework which was followed are presented in below Figure 1.

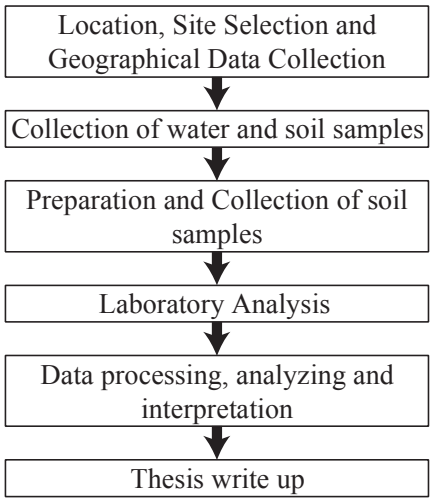

Figure 1. Analytical framework of the research work.

Analysis was conducted in the laboratory of Soil, Water and Environment Discipline of Khulna University and in the Advanced Analytical laboratory of the Department of Soil, Water and Environment, University of Dhaka to determine the parameters both of water and soil samples of Khulna district.

Location of the study area

Khulna district is situated in Khulna Division of Bangladesh consisting of 9 Upazilas. It is 4395 square kilometers, located between 21°41' and 23°00' North latitude and in between 89°14' and 89°45' East longitude. It is 12 feet above from mean sea level.

Khulna district is under Gopalganj-Khulna Bills Agro-ecological Zone. The physiography is Beel centered. The sampling sites of Khulna District are referred in below Figure 2.

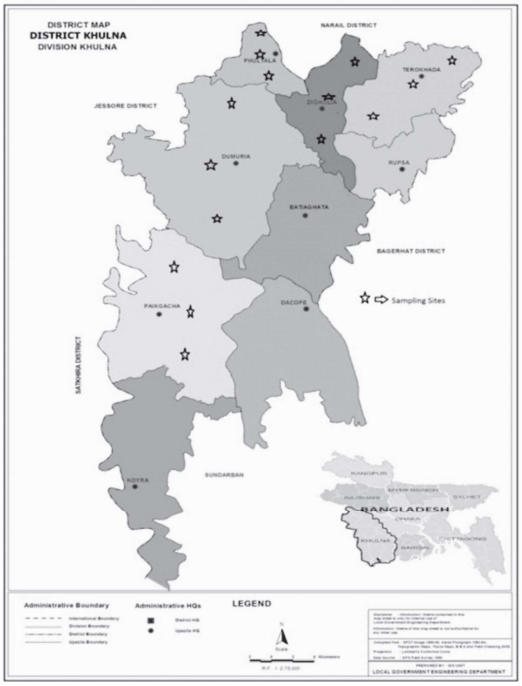

Figure 2. Map of the sampling sites

Table 1: Description of sampling sites (BPC, 2001b)

Sampling Place	GPS reading	Location	Major Crops	Area (Km^2)
Dumuria	22^0 39′ to 22^0 56′ N and 89^0 15′ to 89^0 32′E	Khulna District	Paddy, Jute, Vegetables etc.	454.23
Paikgacha	22^0 28′ to 22^0 43′ N and 89^0 14′ to 89^0 28′E	Khulna District	Paddy, Jute, Vegetables, wheat, pulse, sesame etc.	411.19
Phultala	22^0 54′ to 23^0 01′ N and 89^0 23′ to 89^0 29′E	Khulna District	Paddy, Jute, Vegetables, potato, pulse, turmeric, tobacco etc.	87.41
Dighalia	22^0 50′ to 22^0 59′ N and 89^0 33′ to 89^0 40′E	Khulna District	Paddy, Vegetables, wheat, mustard, sesame etc.	77.17
Terokhada	22^0 50′ to 22^0 59′ N and 89^0 34′ to 89^0 45′E	Khulna District	Paddy, Coconut, Sugarcane etc.	189.48

Collection of water samples

A research was conducted to evaluate the suitability of groundwater and surface water for irrigated agriculture of Khulna District. Hydro-geological studies were carried out on January, 2017. Water (both surface and groundwater) samples were collected and the hydraulic heads were observed at different sampling sites. The sampling sites cover

maximum upazilas of Khulna district. A reconnaissance survey was conducted in different areas of sampling sites and the samples were collected from 5 Upazilas among 9 Upazilas of the district. The groundwater samples were collected from shallow tube-wells. Surface water samples were collected from the reservoir beside the crop field which water is used in irrigation purposes. Dry, cleaned and high density PVC bottles without any contamination were used as containers for sampling.

Preparation of Water Samples: The collected water samples were filtered through Whatman no. 42 filter paper (25 µm pore size) before chemical analysis. These were later used for various chemical analyses.

Data processing and data analysis: Data were processed and arranged by Microsoft Word and Microsoft Excel (Version 2013). Graphs were drawn by using Microsoft Excel (Version 2013) and Sigma plot (Version 10).

Statistical Analysis: The collected data were compiled and tabulated in proper form and were subjected to statistical analysis. The statistical analyses were carried out by using Computer Programs of Statistical software Minitab (Version 17.0).

Acidity (pH)

The pH of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 7.31, 7.21, 7.16, 7.25 and 7.1 respectively. The pH of surface water of these sources were 7.59, 7.24, 7.39, 7.54 and 7.29 respectively which are presented in below Figure 3.

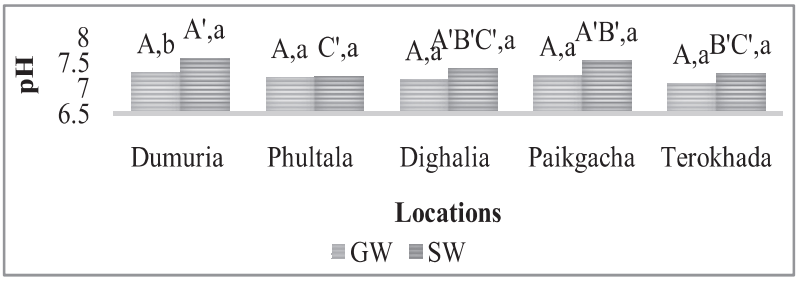

Figure 3. pH of ground and surface water sources in Khulna District.

In all cases, the pH of surface water was higher than that of ground water. The pH of both of ground and surface water are within the permissible limit (6.5 - 8.5) for irrigation in agriculture (Bauder et al., 2011; BECR, 1997).

Electrical Conductivity (EC)

The Electrical Conductivity (EC) of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 2.57 dS m^{-1}, 2.83 dS m^{-1}, 2.73 dS m^{-1}, 2.17 dS m^{-1} and 1.93 dS m^{-1} respectively. The EC of surface water of these sources were 2.03 dS m^{-1}, 1.07 dS m^{-1}, 0.57 dS m^{-1}, 1.43 dS m-1 and 0.6 dS m^{-1} respectively which are presented in below Figure 4.

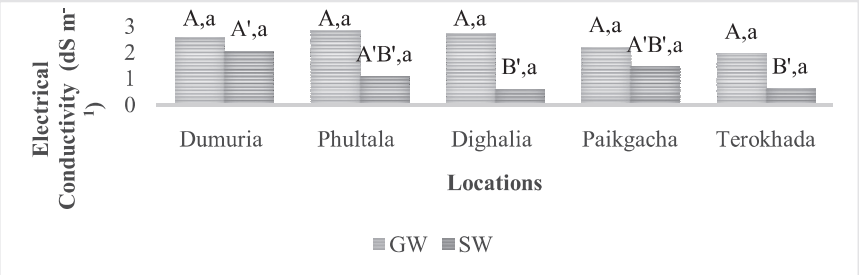

Figure 4. Electrical Conductivity of ground and surface water sources of Khulna District.

In all cases, the EC of ground water was higher than that of surface water but exhibited insignificant difference. The higher values of EC for groundwater is indicator of higher ionic contents, probably due to the high anthropogenic activities in the region and geological weathering conditions acquiring high contents of the dissolved minerals. The relatively high value of EC in groundwater could be due to the intrusion of lake water in to groundwater system of the area (Dinka et al., 2015). The EC value ground water exhibited insignificant difference (at 5% significance level) in respect of surface water of the locations.

Available Potassium (K)

The Potassium (K+) content of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 4.84 mg l^{-1}, 3.35 mg l^{-1}, 11.07 mg l^{-1}, 6.46 mg l^{-1} and 11.65 mg l^{-1} respectively. The K+ of surface water of these sources were 8.65 mg l^{-1}, 13.84 mg l^{-1}, 30.10 mg l^{-1}, 18.51 mg l^{-1} and 11.76 mg l^{-1} respectively which are presented in below Figure 5.

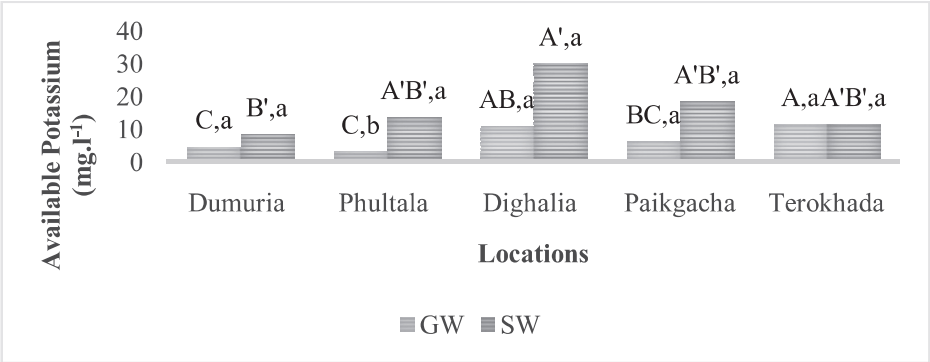

Figure 5. Available Potassium of ground and surface water sources in Khulna.

It is evident that the K+ of ground water showed variable behavior among different locations of Khulna district and from statistical point of view the K+content of Terokhada was significantly (p ? 0.05) increased in respect of Dumuria, Phultala and Paikgacha (Fig. 4.8). The K+ of surface water showed variable behavior among different locations of Khulna district and from statistical point of view the K+ content of Dighalia was significantly (p ? 0.05) increased in respect of Dumuria and other sources showed insignificant difference (Figure 5). The K+ content of surface water was higher than that of ground water in all sources. The K+ content of ground water is in a wide range of low to very high content and the surface water is in high to very high content.

Available Phosphorous (P)

The Phosphorous (PO43-) content of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 0.613 mg l^{-1}, 0.697 mg l^{-1}, 0.753 mg l^{-1}, 0.47 mg l^{-1} and 0.533 mg l^{-1} respectively. The PO4 of surface water of these sources were 0.267 mg l^{-1}, 0.104 mg l^{-1}, 0.64 mg l^{-1}, 0.303 mg l^{-1} and 0.6 mg l^{-1} respectively which are presented in below Figure 6.

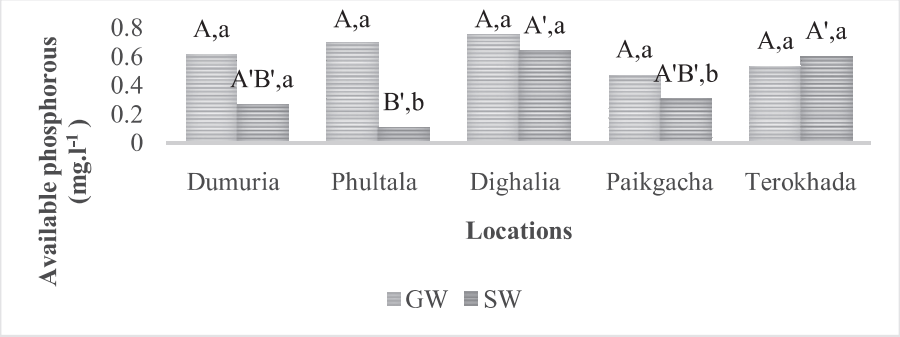

Figure 6. Available phosphorous of ground and surface water sources in Khulna.

From statistical point of view the $PO4^{3-}$ content exhibited insignificant difference (at 5% significance level) among the locations (Figure 6). On the other hand, the $PO4^{3-}$ content of surface water of Phultala was significantly (p ? 0.05) decreased in respect of Dighalia and Terokhada (Figure 6). The $PO4^{3-}$ content of ground water was higher than that of surface water in all sources except Terokhada.

Available Nitrogen (N)

The available Nitrogen (NO_3^--N + NH_4+-N) content of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 10.883 mg l^{-1}, 1.484 mg l^{-1}, 23.249 mg l^{-1}, 8.358 mg l^{-1} and 5.441 mg l^{-1} respectively. The Nitrogen content of surface water of these sources were 12.861 mg l^{-1}, 4.947 mg l^{-1}, 5.936 mg l^{-1}, 3.242 mg l^{-1} and 6.431 mg l^{-1} respectively which are presented in below Figure 7.

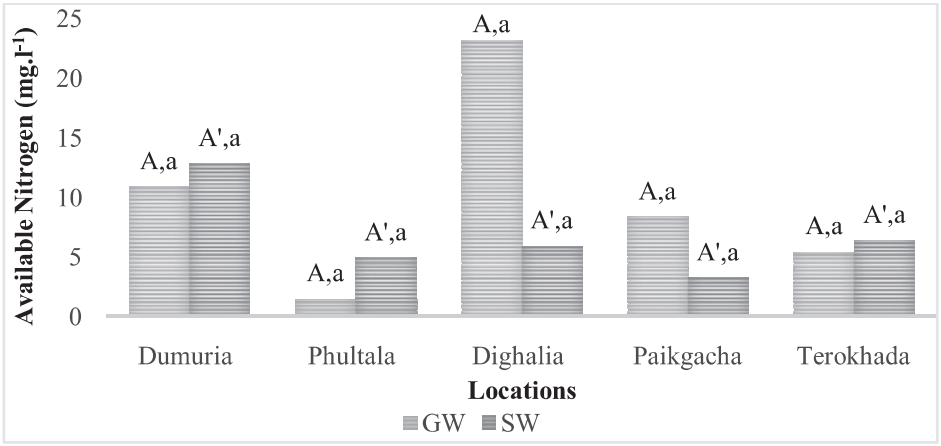

Figure 7. Available Nitrogen of ground and surface water sources in Khulna.

The Nitrogen content of ground water ranged from 1.484 to 23.249 mg l^{-1}. Statistical point of view the Nitrogen exhibited insignificant difference (at 5% significance level) among the locations due to the wide range (very high to very low) of Nitrogen content of the areas (Figure 9). On the other hand, the Nitrogen values of surface water ranged from 3.242 to 12.861 mg l^{-1}. The content of nitrogen in groundwater is derived from the biosphere (Saleh et al., 1999). The nitrate in water samples is probably derived from application of nitrogen fertilizers in the agricultural fields.

Sodium Adsorption Ratio (SAR)

The Sodium Adsorption Ratio (SAR) of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 10.87,18.61, 8.99, 3.04 and 6.72 respectively. The SAR of surface water of these sources were 13.19, 11.69, 11.82, 19.66and 4.82 respectively which are presented in Figure 8.

Figure 8. Sodium Adsorption Ratio of ground and surface water sources in Khulna.

The SAR of ground water ranged from 3.04 to 18.61. The highest SAR (18.61) of ground water was in Phultala and lowest (3.04) in Paikgacha and The highest SAR (19.66) of surface water was in Paikgacha and lowest (4.82) in Terokhada.

Magnesium Adsorption Ratio (MAR)

The Magnesium Adsorption Ratio (MAR) of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 27.7%, 37.52%, 20.39%, 25.88% and 18.21% respectively. The MAR of surface water of these sources were 45.8%, 29.18%, 22.59%, 13.33% and 16.33% respectively which are presented in Figure 9.

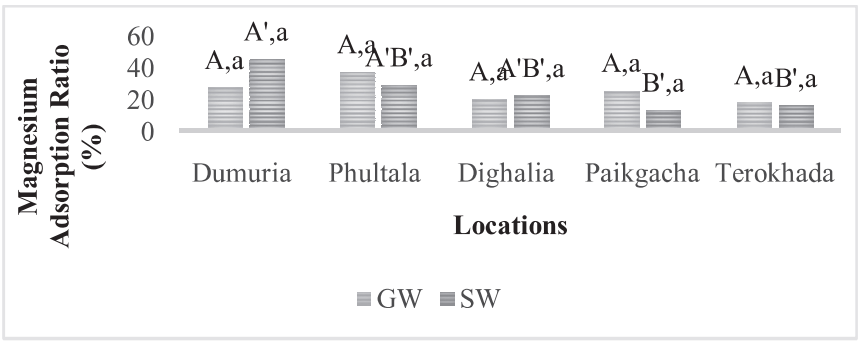

Figure 9. Magnesium Adsorption Ratio of ground and surface water sources in Khulna.

The MAR of ground water ranged from 18.21 to 37.52%. The highest MAR (37.52%) of ground water was in Phultala and lowest (18.21) in Terokhada. On the other hand, the MAR of surface water ranged from 13.33 to 45.8% and The highest MAR (45.8%) of surface water was in Dumuria and lowest (13.33%) in Paikgacha. As, both of ground and surface water had the MAR value below 50, all the sources are suitable to use in irrigation purposes (Gupta and Gupta, 1987).

Sodium Ratio (SR)

The Sodium Ratio (SR)of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 0.74, 0.87, 0.65, 0.49 and 0.58 respectively. The SR of surface water of these sources were 0.85, 0.84, 0.78, 0.78 and 0.73 respectively which are presented in Figure 10.

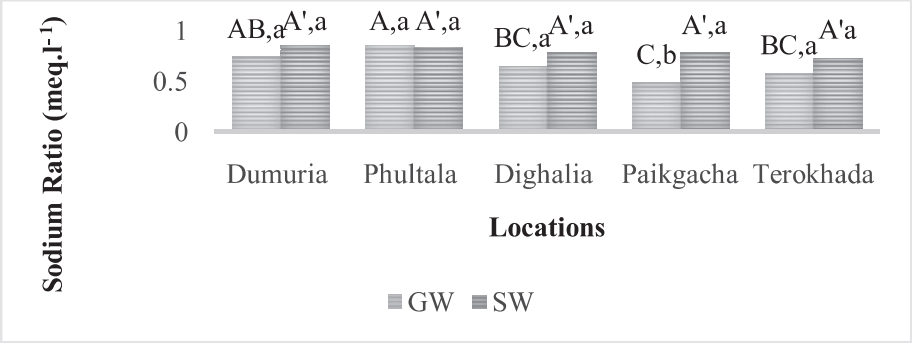

Figure 10. Sodium Adsorption Ratio of ground and surface water sources in Khulna.

The SR of ground water ranged from 0.49 to 0.87. All the SR values of both of surface and ground water are good (SR < 1) for irrigation purposes ((NDLI, n.d.). As, the SR of ground water is low than surface water (except Phultala) is preferable to use for irrigation.

Total Hardness (HT)

The Total Hardness (HT) of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 600.13 mg l^{-1}, 534 mg l^{-1}, 615.12 mg l^{-1}, 484.3mg l^{-1} and 429 mg l^{-1} respectively. The HT of surface water of these sources were 403.52 mg l^{-1}, 228.9 mg l^{-1}, 189.25 mg l^{-1}, 316.55 mg l^{-1} and 208.9 mg l^{-1} respectively which are presented in Figure 11.

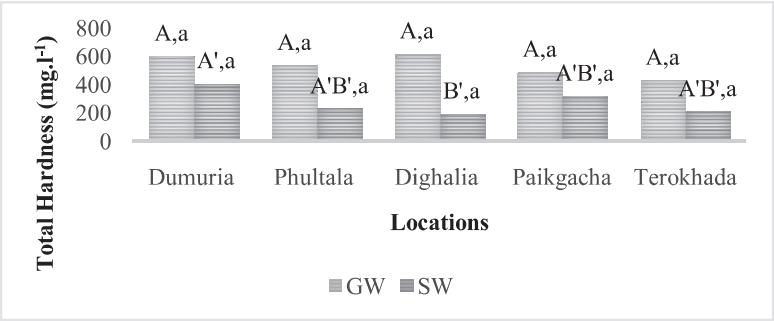

Figure 11. Total Hardness of ground and surface water sources in Khulna.

The highest HT (615.12 mg l^{-1}) of ground water was in Dighalia and lowest (429 mg l^{-1}) in Terokhada. from statistical point of view the HT of Dighalia was significantly (p ? 0.05) decreased in respect of Dumuria and other sources exhibit insignificant difference (Fig. 4.25). The high value (> 120 mg l^{-1}) of HT in both of ground and surface water indicates hard water (Hem, 1970). According to the TH classification (Sawyer and McCarty, 1967), the surface water and the ground water of the study area is very hard (150-300 mg l^{-1}).

Summary and Conclusion

Different hydro-chemical properties of irrigation water of Khulna District were compared with the national and international water quality standards set for irrigation. This may be attributed to variations in natural (geochemical) processes and anthropogenic activities within the region. EC and $PO4^{3-}$ concentrations were prevailed in ground water than surface water where the N (NO_3--N + NH_4+-N) and K+ concentration showed reversed condition. pH and $PO4^{3-}$ concentrations were within permissible limit to both of ground and surface water. EC of collected surface water samples was excellent but ground water had slight to moderate restriction to use for irrigation. The content of K+ crossed the permissible limit in both of surface and ground water but surface water exhibited more toxic level. Therefore, it can be concluded that, all the sources of surface water and ground water has the risk of sodicity hazard as well as alkali hazard for irrigation that should be treated properly to use and if possible, the surface water should use for irrigation with proper treatment to lessen the pressure on ground water reservoir.

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