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Irrigation water quality of surface and ground water used for *Boro* rice cultivation in Khulna district in Bangladesh

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Abstract

Bangladesh is a land of mighty rivers and innumerable tributaries, heavy rainfall and recurring floods. Nearly 75 percent of the country's population depends either directly or indirectly on agriculture. This study deals with the quality of surface and ground water used in rice cultivation of Khulna district, which is located in the south-western part of Bangladesh. This study was carried out to characterize the surface and ground water in terms of different dissolved elements in relation to the suitability of the water for irrigation purposes in Khulna. To analyze the water quality for irrigation of *Boro* rice, 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),Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Soluble Sodium Percentage (SSP),Sodium to Calcium Activity Ratio (SCAR), Sodium Ratio (SR), Residual Sodium Bi-carbonate (RSBC), Kelly's Ratio (KR), Permeability Index (PI) and Total Hardness (H_T). From the analysis, it was observed the ionic concentration and other chemical parameters varied in different water sources of the area. SAR, SSP, SCAR and KR are high in all sources where surface water contained most but SR, MAR, H_T and Permeability were in favorable concentration in both sources in Khulna District. Therefore, the sodicity and alkalinity hazards risk have been found to both of the water sources to use in irrigation purposes.

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 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

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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.
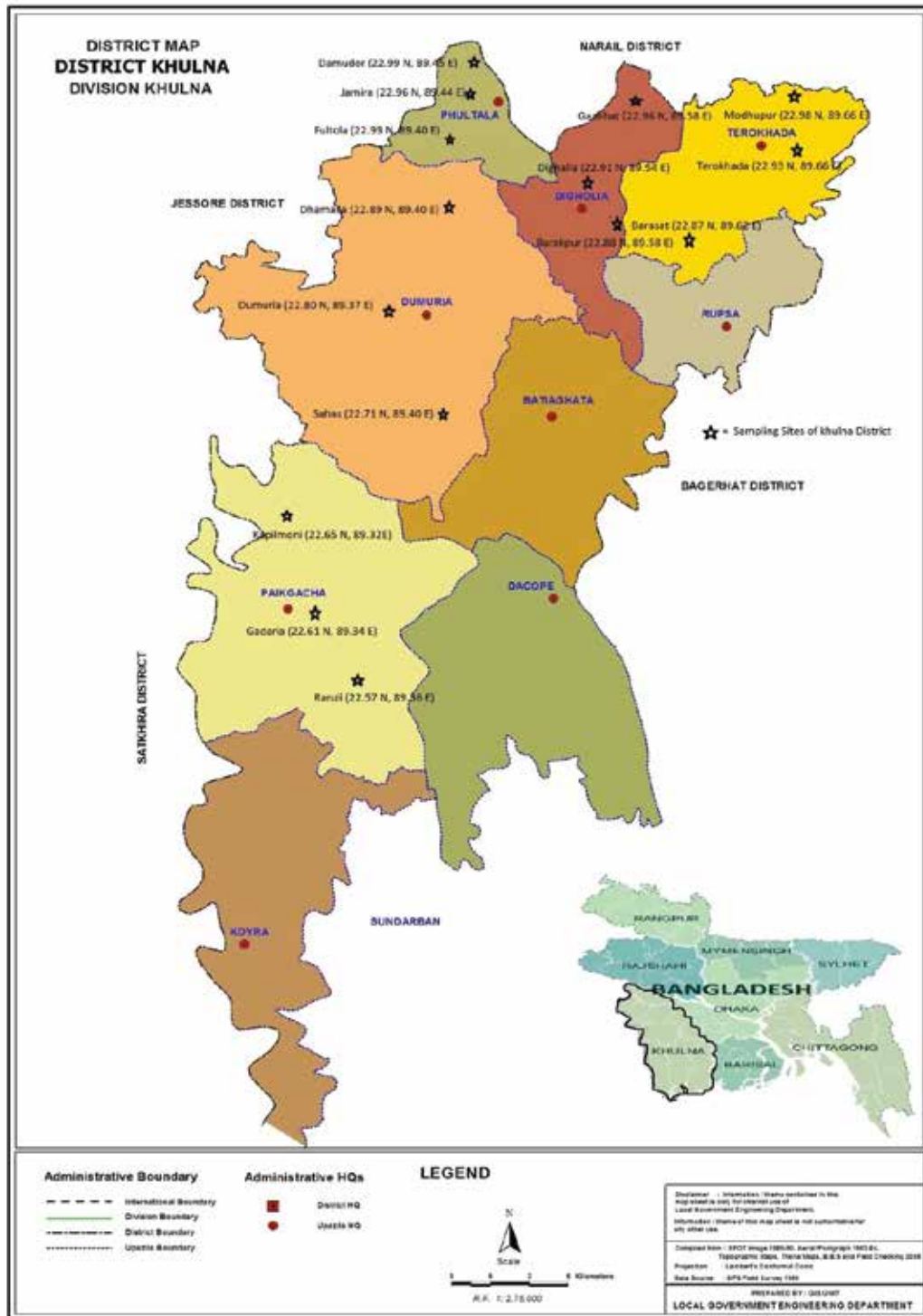

Fig. 1. Map of the sampling sites of Khulna District

Methodology

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 (BPC, 2001a). Khulna district is

collected from shallow tube-wells; because, maximum farmers use shallow tube-well water for irrigation. 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. This

Table I. Description of sampling sites of Khulna District (BPC, 2001b)

Sampling Place	GPS reading	Major Crops	Area (Km^2)
Dumuria	$22^0\,39'$ to $22^0\,56'$ N and $89^0\,15'$ to $89^0\,32'$E	Paddy, Jute, Vegetables etc.	454.23
Paikgacha	$22^0\,28'$ to $22^0\,43'$ N and $89^0\,14'$ to $89^0\,28'$E	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	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	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	Paddy, Coconut, Sugarcane etc.	189.48

under Ganges River Flood Plain and Gopalganj-Khulna Bills Agro-ecological zone. The physiography is Beel centered. The sampling sites of Khulna District are referred in Fig. 1.

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

field sampling method followed the WHO, UCCC and USEPA system of standard laboratory and field sampling principles, rules and regulations (USEPA, 1976; UCCC, 1974).

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. pH was determined electrochemically with the help of glass electrode pH meter as suggested by Jackson (1962). The Electrical Conductivity (EC) of the water samples was

measured directly by the help of EC meter (USDA, 2004). The available Na^+ of water samples were determined by a flame analyzer at 767 nm wavelength (Jackson, 1967). The available K^+ of water was determined by a flame analyzer at 589 nm wavelength (Jackson, 1967). The Ca^{2+} and Mg^{2+} of water samples were determined by titrimetric method (Lanyon and Heald, 1982). Bicarbonate (HCO_3^-)of the water samples were determined by titrimetric method (Jackson, 1962).

Sodium Adsorption Ration (SAR) was determined by the equation using the concentration obtained for Na^+, Ca^{2+} and Mg^{2+} of the water samples (Michael, 1992).

$$SAR = [Na^+] \div (\sqrt{\tfrac{1}{2}} \{[Ca^{2+}] + [Mg^{2+}]\})$$. Where, all the ions were expressed in meq l^{-1}.

Magnesium Adsorption Ratio (MAR) was calculated using the Ca^{2+} and Mg^{2+} content of the water samples by the equation proposed by Raghunath (1987):

$$MAR= \{Mg^{2+}/ (Mg^{2+}+Ca^{2+})\} \times 100$$. Where, all the ions were expressed in meq l^{-1}.

Soluble Sodium Percentage (SSP) was calculated using the Na^+, K^+, Ca^{2+} and Mg^{2+} content of the water samples by the following equation (Todd, 1980):

$$SSP = \{(Na^+ + K^+) / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)\} \times 100.$$

Where, all the ions were expressed in meq l^{-1}.

Sodium to Calcium Activity Ratio (SCAR) was calculated using the Na^+ and Ca^{2+} concentration of the water samples calculated by the following equation (Gupta and Gupta, 1987):

$$SCAR = Na^+/\sqrt{Ca^{2+}}$$. Where, all the ions were expressed in meq l^{-1}.

Sodium Ratio (SR) was calculated using the Na^+ and Ca^{2+} content of the water samples calculated by the following equation (NDLI, n.d.):

$$SR = Na^+ / (Na^+ + Ca^{2+})$$. Where, all the ions were expressed in meq l^{-1}.

Gupta and Gupta (1987) suggested that alkalinity hazard should be determined through the index called Residual Sodium Bicarbonate (RSBC) to be calculated as:

$$RSBC = HCO_3^- - Ca^{2+}$$

Where, RSBC and the concentration of the constituents were expressed in meq l^{-1}.

The Kelly's Ratio was calculated using the Na^+, Mg^{2+} and Ca^{2+} concentration of the samples calculated by the following equation (Kelly, 1963):

$$KR = \{Na^+/ (Mg^{2+}+ Ca^{2+})\} \times 100.$$ Where, all the ionic concentrations were expressed in meq l^{-1}.

Hardness (H_T) is customarily expressed as the equivalent of calcium carbonate (Todd, 1980). Thus:

$$H_T = \{Ca^{2+} (mg\ l^{-1}) \times \text{Molecular Weight of } CaCO_3 / \text{Atomic Weight } Ca\} + \{Mg^{2+} (mg\ l^{-1}) \times \text{Molecular Weight of } CaCO_3 / \text{Atomic Weight } Mg\}.$$

$$= \{Ca^{2+} (mg\ l^{-1}) \times 100.08 / 40.08\} + \{Mg^{2+} (mg\ l^{-1}) \times 100.08 / 24.31\}$$

Where, H_T, Ca^{2+} and Mg^{2+} measured in milligram per litter and the ratios are in equivalent weights. Thus the above equation reduced to:

$$H_T = 2.5\ Ca^{2+} + 4.1\ Mg^{2+}.$$

The effect on permeability has been evaluated by the term permeability index, which is calculated using the Na^+, Mg^{2+}, Ca^{2+} and HCO_3^- concentration of the samples calculated by the following equation (NDLI, n.d.):

$$\text{Permeability index} = \{(Na^+ + \sqrt{HCO_3}) / (Ca^{2+} + Mg^{2+} + Na^+)\} \times 100.$$

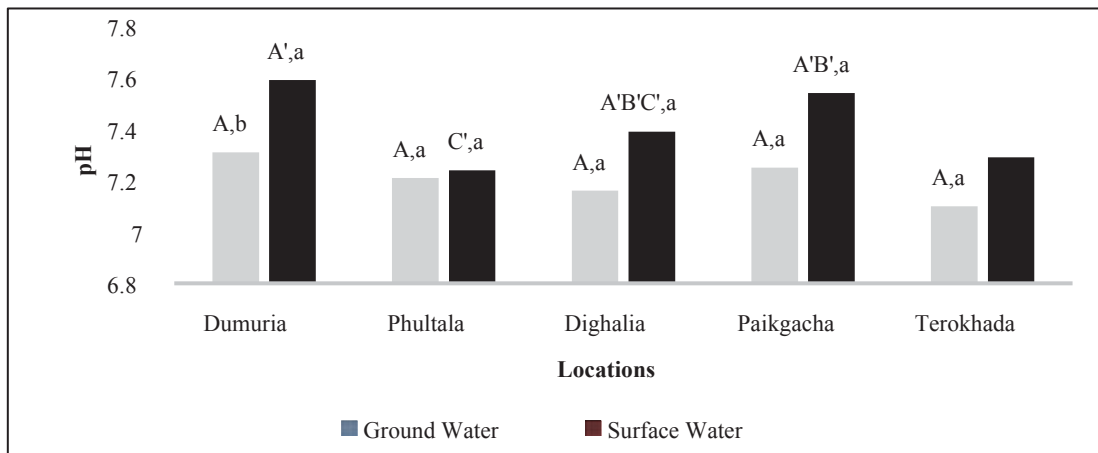Where, ions were expressed as meq l^{-1}.

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). In statistical analysis, the alphabetic letters (A, B, C…) were used to differentiate the content of elements among the ground water, the alphabetic dash (A′, B′, C′…) were used to differentiate the content of elements among the surface water and the small letters (a, b) were used to differentiate the content of elements between the ground and surface water samples.

Results and discussion

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.

Table II. Standard values for irrigation water quality

Parameters	Permissible limit	Reference
pH	6.5 – 8.5	(Bauder*et al.*, 2011; UCCC, 1974).
EC (dS m^{-1})	<0.7 = none, 0.7–3.0 = slight to moderate, >3.0 = Severe	UCCC, 1974
	none = ≤ 0.75, Some = 0.76 - 1.5, Moderate = 1.51 - 3.00, Severe = ≥ 3.00	Bauder *et al.*, 2011
SAR (meq l^{-1})	1-10 = Low; 10 – 18 = Medium; 18 – 26 = High; > 26 = Very High	Fipps, 2013
MAR (%)	< 50	Gupta and Gupta, 1987
SSP (%)	< 60%	Khodapanah *et al.*, 2009
	(40 – 60)%	Wilcox, 1955
SCAR (meq l^{-1})	Non-sodic water < 5, Normal water = 5-10. Low water = 10-20, Medium sodicity water = 20-30, High sodicity water = 30-40, Very high sodicity water >40	Gupta and Gupta, 1987
SR	< 1	NDLI, n.d.
RSBC (meq l^{-1})	Normal water = 0, Low alkalinity water = 2.5, Medium alkalinity water = 2.5-5.0, High alkalinity water = 5.0-10.0, Very high alkalinity water >10	Gupta and Gupta, 1987
KR	< 1	Kelly, 1963
H$_T$ (mg l^{-1})	> 120 mg l^{-1}	Hem, 1970
PI (%)	> 65	NDLI, n.d.

Fig. 2. pH of ground and surface water of different sources in Khulna District

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 Fig.2.

In all cases, the pH of surface water was higher than that of ground water.From statistical point of view, In Dumuria, the pH of ground water was significantly *(p ≤ 0.05)* decreased in respect of surface water. In case of ground water, pH exhibited insignificant difference(at 5% significance level) among the locations and pH of surface water in Terokhada and Phultala was significantly *(p ≤ 0.05)* decreased in respect of Dumuria. 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; UCCC, 1974).

In all cases, the EC of ground water was higher than that of surface water but exhibited insignificant difference(at 5% significance level). EC of ground water exhibited insignificant difference (at 5% significance level) among the locations and the EC of surface water of Dighalia and Terokhada was significantly *(p ≤ 0.05)* decreased in respect of Dumuria.The EC of ground water is moderately limited for irrigated agriculture (Bauder*et al.,* 2011) and slight to moderate (0.7 – 3) restriction for irrigation use (UCCC, 1974). The EC of surface water is limited in some extent for irrigated agriculture and can be used for irrigation purposes with some management practices (Bauder*et al.*, 2011, UCCC, 1974).

Sodium adsorption ratio (SAR)

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
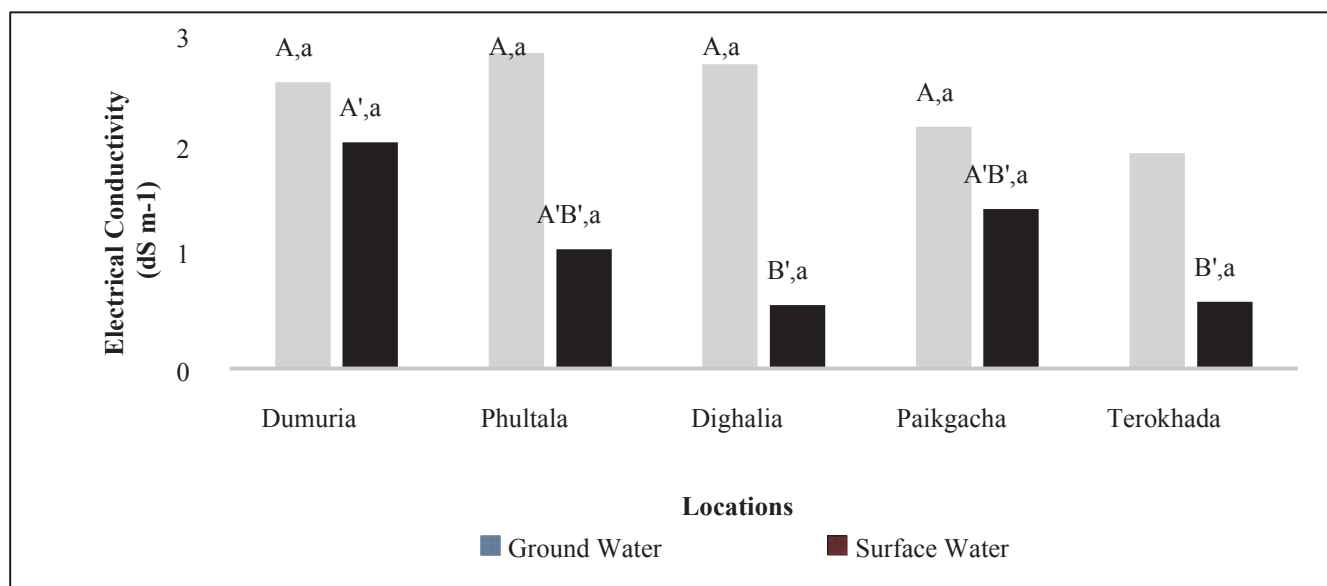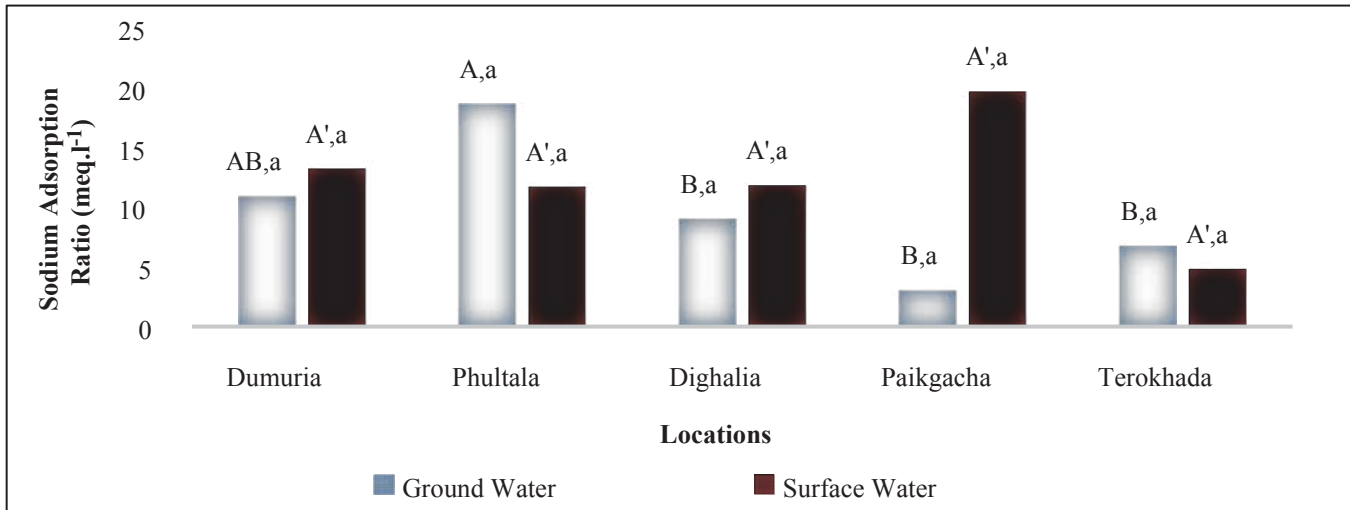

Fig. 3. EC of ground and surface water of different sources of Khulna District

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 Fig. 3.

and 6.72meq l^{-1}respectively. The SAR of surface water of these sources were 13.19, 11.69, 11.82, 19.66and 4.82meq l^{-1} respectively which are presented in Fig. 4.

SAR of surface water was higher than that of ground water in Dumuria, Dighalia and Paikgacha and the reverse condition was in Phultala and Terokhada but statistically exhibited insignificant difference (at 5% significance level) between ground and surface water. SAR of ground water of Phultala was significantly *(p ≤ 0.05)* increased in respect of

Fig. 4. SAR of ground and surface water of different sources in Khulna

Paikgacha, Dighalia and Terokhada but The SAR of surface water showed variable behavior among different locations of Khulna district, but surface water samples exhibited insignificant difference (at 5% significance level) among the locations.The ground water of Dighalia, Paikgacha and Terokhada as well as the surface water of Terokhada had slight to moderate restriction to use as irrigation and rest of all were severe (UCCC, 1974). Based on SAR, ground water of Paikgacha was in 'Fair class', samples of Terokhada were in 'Poor class' and rest of all were in 'Very poor class' (Moss and Kress, 2013). According to Fipps (2013), the ground water of Dighalia, Paikgacha and Terokhada as well as the surface water of Terokhada showed low (1 – 10); ground water of Phultala and surface water of Paikgacha had high (18 – 26) and rest of all had medium (10 - 18) Sodium hazard. The combining effect of average EC and SAR of ground water showed slight to moderate where the surface water showed severe restriction of use for irrigation (UCCC, 1974).

Magnesium adsorption ratio (MAR)

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 MARof surface water of these sources were 45.8%, 29.18%,22.59%, 13.33% and 16.33% respectively which are presented in Fig. 5.

MAR of ground water was higher than that of surface water in Phultala, Paikgacha and Terokhada but the reverse condition was in Dumuria and Dighalia. Statistically, the MAR of ground water exhibited insignificant difference (at 5% significance level) in respect of surface water in all sources of water. MAR of ground water exhibited insignificant difference

(at 5% significance level) with among the locations but in surface water, the MAR of Paikgacha and Terokhada was significantly *(p ≤ 0.05)* decreased in respect of Dumuria. As, both of ground and surface water had the MAR below 50, all the sources are suitable to use in irrigation purposes (Gupta and Gupta, 1987).

Soluble sodium percentage (SSP)

Soluble Sodium Percentage (SSP) of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 67.82%, 80.62%, 60.19%, 41.15% and 62.8%respectively. The SSPof surface water of these sources were 76.57%, 79.07%, 75.25%, 79.46% and 63.38% respectively which are presented in Fig. 6.

The SSP of surface water was higher than that of ground water in all locations except Phultala (Fig. 6). The SSP of ground water of Paikgacha was significantly *(p ≤ 0.05)* decreased in respect of surface water.In case of ground water, SSP of Phultala was significantly *(p ≤ 0.05)* increased and Paikgacha was decreased in respect of Dumuria, Dighalia and Terokhada. But, the SSP of surface water exhibited insignificant difference (at 5% significance level) among the locations.All of the sources of water contain high SSP (> 60%) except the ground water of Paikgacha which may indicate high sodicity that can break down the soil physical structure (Khodapanah *et al.*, 2009). The ground water of Paikgacha fell under 'Fair class' and others under 'Very poor class' (Wilcox, 1955).

Sodium to Calcium activity Ratio (SCAR)

The Sodium to Calcium Activity Ratio (SCAR) of ground water of different sources (Dumuria, Phultala, Dighalia,
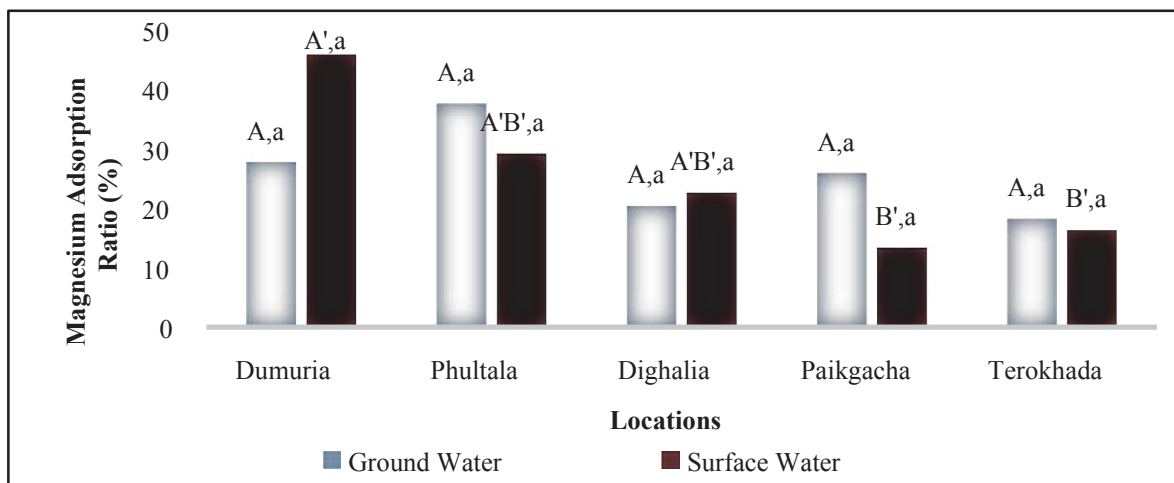
Fig. 5. MAR of ground and surface water of different sources in Khulna
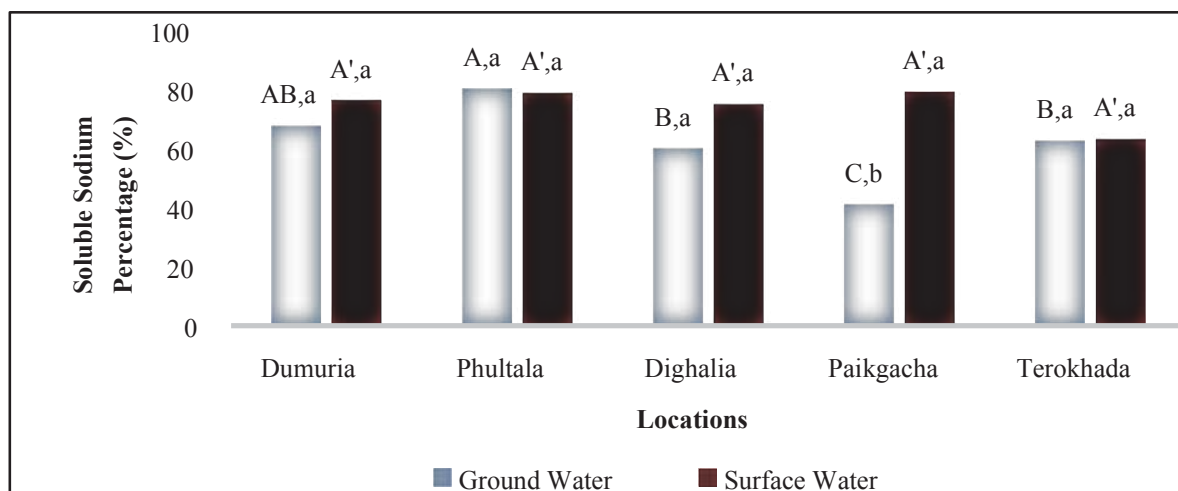

Fig. 6. SSP of ground and surface water of different sources in Khulna

Paikgacha and Terokhada) of Khulna district were 9.39, 16.52, 6.88, 2.52 and 4.3 meq l^{-1} respectively. The SCAR of surface water of these sources were 14.36, 9.86, 4.06, 12.3 and 10.62 meq l^{-1} respectively which are presented in Fig. 7.

The SCAR of surface water was higher than that of ground water in all locations except Phultala and Dighalia. The SCAR of ground water of Phultala was significantly *(p ≤ 0.05)* increased in respect of surface water. SCAR of ground water of Phultala was significantly *(p ≤ 0.05)* increased and Paikgacha was decreased in respect of Dumuria, Dighalia and Terokhada. On the other hand, the SCAR of surface water exhibited insignificant difference (at 5% significance level) among the locations. According to the classification of Gupta and Gupta (1987), the ground water of Paikgacha and Terokhada as well as the surface water of Dighalia are 'Non-sodic' (SCAR ratio < 5); the ground water of Dumuria and Dighalia as well as surface water of Phultala are 'Normal' (SCAR ratio = 5 - 10); the ground water of Phultala as well as the surface water of Dumuria, Paikgacha and Terokhada are 'Low sodic water' (SCAR ratio = 10 - 20).

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 Fig. 8.
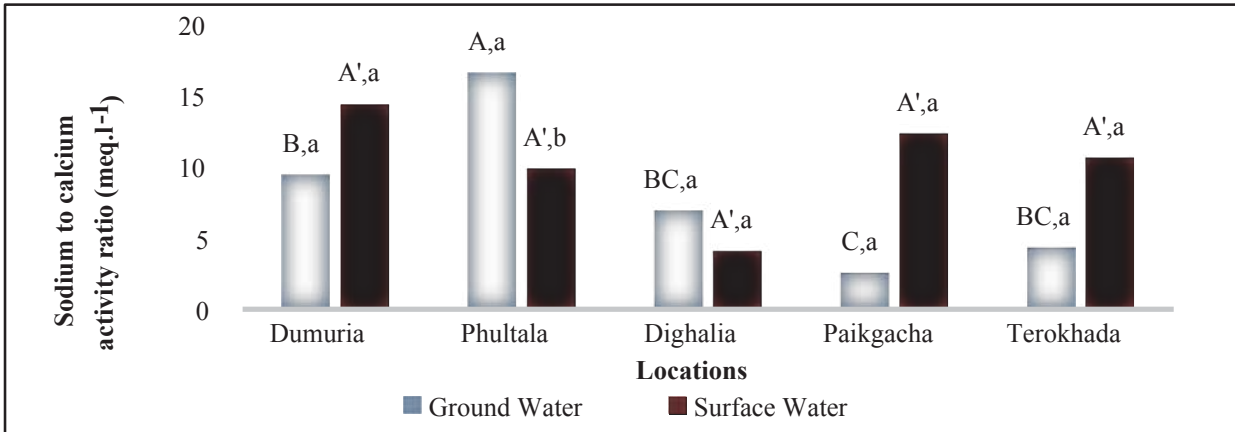
Fig. 7. SCAR of ground and surface waterof different sources in Khulna
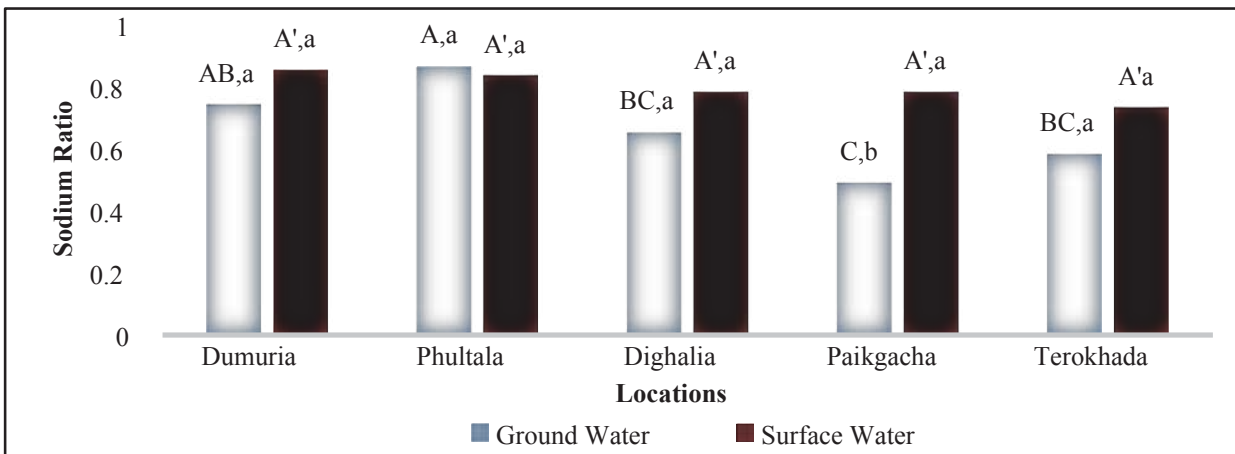

Fig. 8. SR of ground and surface water of different sources in Khulna

The SR of surface water was higher than that of ground water in all the locations except Phultala. The SR of ground water was significantly $(p \leq 0.05)$ decreased in respect of surface water in Paikgacha. Statistically, the SR of ground water of Phultala was significantly $(p \leq 0.05)$ increased and Paikgacha was decreased in respect of Dumuria, Dighalia and Terokhada. But, the SR of surface water exhibited insignificant difference (at 5% significance level) among the locations. All the SR 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.

Residual sodium bicarbonate (RSBC)

The residual sodium Bi-carbonate (RSBC) of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 28.6, 41.2, 29.6, 20.37 and 26.13 meq l^{-1} respectively. The RSBC of surface water of these sources were 15.8, 18.4, 15.47, 22 and 19.87 meq l^{-1} respectively which are presented in Fig. 9.

RSBC of ground water was higher than that of surface water in all the locations except Paikgacha. The RSBC of ground water was significantly $(p \leq 0.05)$ increased in respect of surface water in Phultala and Dighalia. RSBC of ground water of Phultala was significantly $(p \leq 0.05)$ increased in respect of Dumuria, Paikgacha and Terokhada. On the other hand, the RSBC of surface water exhibited insignificant difference (at 5% significance level) among the locations.The RSBC of both of ground and surface water was high due to the high content of HCO$_3^-$ of the sources. All the samples both of ground and surface water are very high alkaline water (> 10 meq l^{-1}) and plants suffer with alkaline hazard by using as irrigation (Gupta and Gupta, 1987).
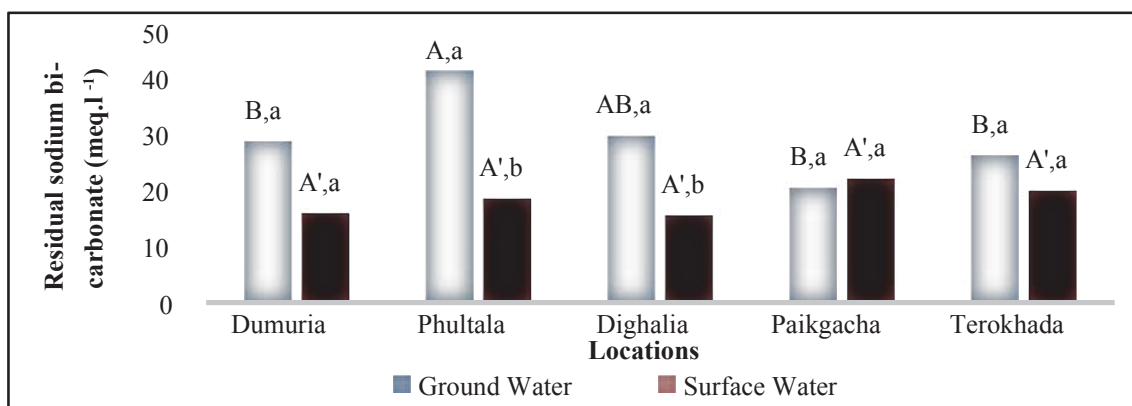
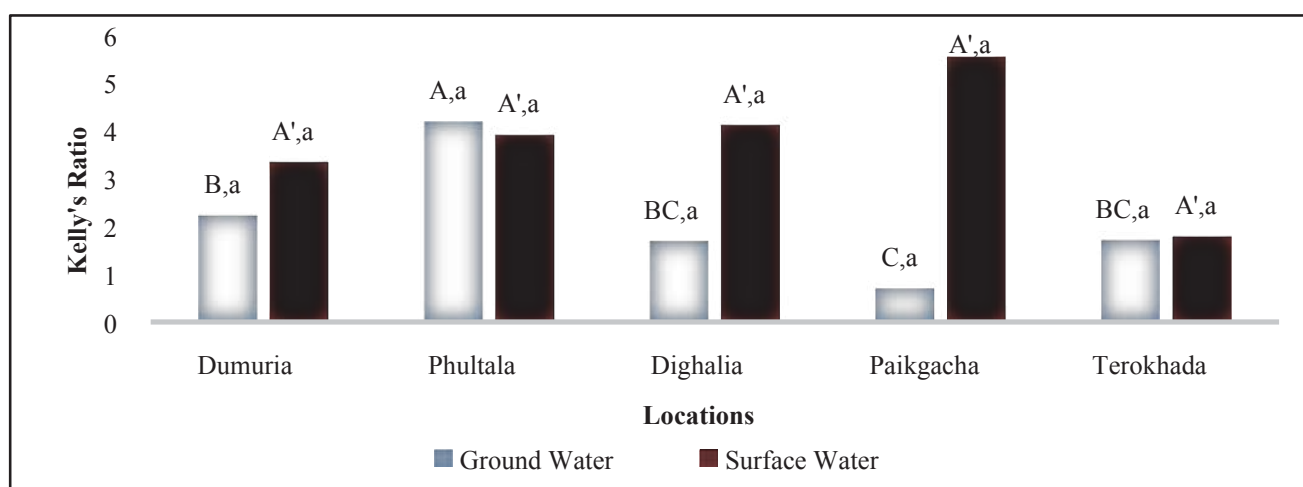**Fig. 9. RSBC of ground and surface water of different sources in Khulna**

Fig. 10. KR of ground and surface water of different sources in Khulna

Kelly's ratio (KR)

The Kelly's Ratio (KR) of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 2.22, 4.184, 1.679, 0.6933 and 1.7 respectively. The KR of surface water of these sources were 3.33, 3.902, 4.1033, 5.53 and 1.776 respectively which are presented in Fig. 10.

The KR of surface water was higher than that of ground water in all the locations except Phultala. The KR of ground water exhibited insignificant difference (at 5% significance level) in respect of surface water of all the locations. Statistically, the KR of ground water of Phultala was significantly *(p ≤ 0.05)* increased and Paikgacha was decreased in respect of Dumuria, Dighalia and Terokhada. On the other hand, the KR of surface water exhibited insignificant difference (at 5% significance level) among the locations. Among the ground water sources, Among the

ground water sources, Paikgacha showed suitability (KR < 1) for irrigation and Phultala showed unsuitability (KR > 3); others were in the between ranges (Kelly, 1963). Among the surface water sources all but Terokhada showed unsuitability (KR > 3) for irrigation (Kelly, 1963). So, it can be concluded that, most of the water resources are more subjected to Sodium hazard in the study area (Shammi *et al.,* 2016).

Total Hardness (H$_P$)

The Total Hardness (H$_T$) of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 600.13, 534, 615.12, 484 and 429 mg l^{-1} respectively. The H$_T$ of surface water of these sources were 403.52, 228.9, 189.25, 316.55 and 208.9 mg l^{-1} respectively which are presented in Fig. 11.

H$_T$ of ground water was higher than that of surface water in all the locations but exhibited insignificant difference (at 5%
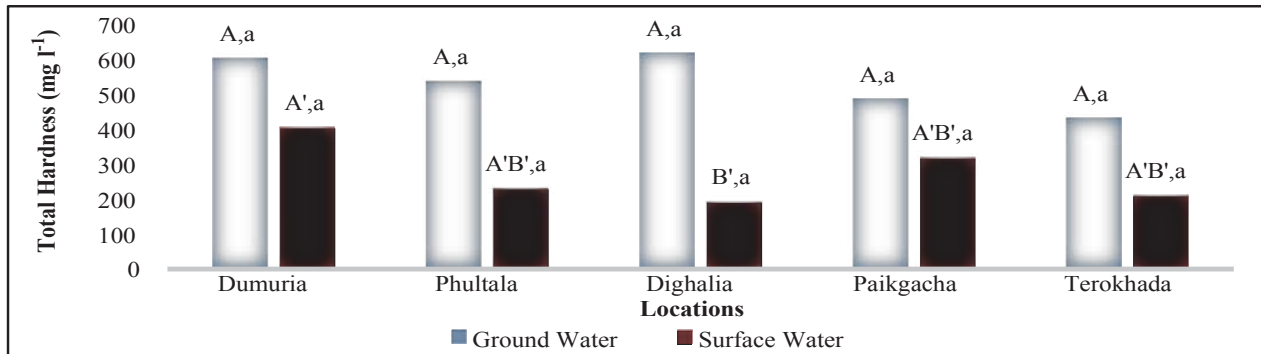
Fig. 11. H$_T$ of ground and surface water of different sources in Khulna

significance level). H$_T$ of ground water exhibited insignificant difference (at 5% significance level) among the locations but, H$_T$ of surface water of Dighalia was significantly *(p ≤ 0.05)* decreased in respect of Dumuria and other sources exhibited insignificant difference.The high value (> 120 mg l^{-1}) of H$_T$ in both of ground and surface water indicates hard water (Hem, 1970). According to the Total Hardness classification (Sawyer and McCarty, 1967), the surface water and the ground water of the study area is very hard (150-300 mg l^{-1}). The ground water quality beyond the permissible limit, however surface water fulfills the requirement of irrigation water quality in case of total hardness by DoE (1997).

Phultala was significantly *(p ≤ 0.05)* increased in respect of Paikgacha and other sources exhibited insignificantly difference but, surface water exhibited insignificant difference (at 5% significance level) among the locations. The PI of both of ground and surface water was high due to the high content of HCO$_3^-$ and Na$^+$ of the sources. All the samples both of ground and surface water are suitable for irrigation as its value exceeds 65 (NDLI, n.d.).

conclusion

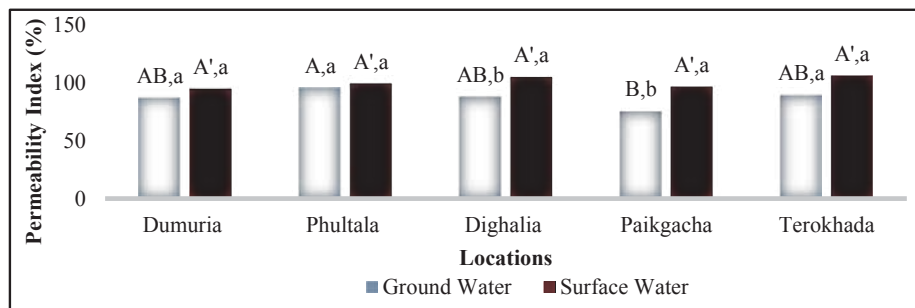EC prevailed in ground water than surface water where pH was within permissible limit to both of ground and surface

Fig. 12. PI of ground and surface water of different sources in Khulna

Permeability Index (PI)

The Permeability Index (PI)of ground water of different sources (Dumuria, Phultala, Dighalia, Paikgacha and Terokhada) of Khulna district were 87.29%, 95.71%, 88.10%, 75.52% and 89.44%respectively. The PIof surface water of these sources were 94.68%, 99.48%, 104.93%, 96.63%and 106.01% respectively which are presented in Fig. 12.

The PI of surface water was higher than that of ground water in all locations and statistically, the PI of ground water was significantly *(p ≤ 0.05)* decreased in respect of surface water in Paikgacha and Dighalia. The PI of ground water of

water. EC and H$_T$ of collected surface water samples was excellent but ground water had slight to moderate restriction to use for irrigation.SAR, SSP, SCAR and KR were high in all sources but surface water contained more than ground. No SR, MAR, and Permeability problem was found to exist in Khulna District. 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. Preferably, ground water is easier to treat as containing lesser problems. But, if possible, the surface water should use for irrigation with proper treatment to lessen the pressure on ground water reservoir.

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