Pollution, 2(2): 183-197 , Spring 2016
DOI: 10.7508/pj.2016.02.007
Print ISSN 2383-451X Online ISSN: 2383-4501
Web Page: https://jpoll.ut.ac.ir Email: jpoll@ut.ac.ir

Assessment of Salinity Hazard of Irrigation Water Quality in Monsoon Season of Batiaghata Upazila, Khulna District, Bangladesh and Adaptation Strategies

Shammi, M.[1,2*], Karmakar, B.[1], Rahman, M.M.[1,3], Islam, M.S.[1,4], Rahman, R.[1] and Uddin, M.K.[1]

1. Department of Environmental Sciences, Jahangirnagar University, Dhaka, Bangladesh
2. Department of Environmental Pollution and Process Control, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi-830011, Xinjiang, PR China
3. Faculty of Environmental Earth Science, Graduate School of Environmental Science, Hokkaido University, Sapporo, Japan
4. Department of Environmental Biology and Chemistry, Graduate School of Science and Engineering for Research, University of Toyama, Gofuku 3190, Toyama 930-8555, Japan

Received: 24 Oct. 2015 Accepted: 21 Nov. 2015

ABSTRACT: Batiaghata Upazila, Khulna District in south-west coastal region of Bangladesh is the mostly saline affected area, where agriculture activities are mainly dependent on rainfall. 23 water samples from surface water and shallow tube well (STW) were collected in the monsoon season and analyzed for physico-chemical properties to classify them according to salinity hazard. Electrical Conductivity (EC) of both surface and groundwater samples were slightly higher than that of acceptable limit (<700 µS/cm). The cations were in permissible limit with the trend of $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ in both surface and groundwater while the anions trend in both surface and groundwater of the study area were $Cl^- > SO_4^{2-} > PO_4^{3-}$. EC and TDS showed high positive correlation with Na^+, K^+ and Ca^{2+} with Cl^- as confirmed from Correlation Matrix and Principal Component Analysis (PCA). Most of the STW water samples compared to the surface water had higher Soluble Sodium Percentage (SSP) values while Sodium Adsorption Ratio (SAR) indicated the surface water and ground water with low sodium hazard. The Kelly's ratio of STW water is more subjected to sodium hazard compared to surface water in the study area.

Keywords: Electric conductivity (EC), groundwater, irrigation, salinity hazard, Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), surface water, water quality.

INTRODUCTION

Water, the vital element in all aspects of life on Earth, plays an extremely important role for human being, socio-economic development and the existence of ecosystems (An *et al.*, 2014). The quality and quantity of any water supply planning is highly important, especially when considering for irrigation purposes. Irrigation is one of the major need and contributing factor of any economy in the

*Corresponding Author: Email: mashura926@gmail.com, Tel: +8615292895424

world (Vyas and Jethoo, 2015). Bangladesh is an irrigated-agriculture based country and is dependent on adequate water supply of usable quality (Shahid *et al*., 2006). For the safeguard of a healthy growth and sustainable yield of crops, the water used for the irrigation has to be of intended quality (Vyas and Jethoo, 2015). The total area under irrigation in Bangladesh is 5,049,785 ha and 78.9% of this area is covered by groundwater sources including 3,197,184 ha with 1,304,973 shallow tubewells and 785,680 ha with 31,302 deep tubewells (DPHE and JICA, 2010). However, most ricelands in the coastal region of Bangladesh remain fallow in the dry season because surface water resources are saline and unsuitable for rice irrigation, while groundwater (GW) is not intensively utilized because of the fear of salt-water intrusion into coastal aquifers (Mondal *et al*., 2008). Salinity becomes a major problem in south-west coastal region of Bangladesh, where irrigation water quality is highly affected by high levels of salinity, which is a source of irrigation salinity and it mainly results from rises in the groundwater table due to excessive irrigation and the lack of adequate drainage for leaching and removal of salts (Corwin *et al*., 2007). Besides that, the freshly deposited alluviums from upstream in the coastal areas of Bangladesh become saline as it comes in contact with the sea water and continues to be inundated during high tides and ingress of sea water through creeks. The factors which contribute significantly to the development of saline soils are tidal flooding during wet season (June-October), direct inundation by saline or brackish water, and upward or lateral movement of saline ground water during dry season (November-May; Haque, 2006).

A very few studies were conducted in the coastal districts of Bangladesh particularly in Khulna regarding the quality of surface and ground water for irrigation purposes. Brackish nature in most of the groundwater is due to the seawater influence and hydrogeochemical processes (Bahar and Reza, 2010). The groundwater is dominantly of Na–Cl type brackish water (Halim *et al*., 2010). Most groundwater is slightly alkaline and largely varies in chemical composition. Salinity, total hardness, and sodium percentage (Na%) indicate that most of the groundwater samples are not suitable for irrigation (Bahar and Reza, 2010). The shallow groundwater quality of Khulna City Corporation of Bangladesh was highly associated with high levels of salinity and iron problem, and the problem aggravates especially in dry season (Adhikary *et al*., 2012). By comparing the deep aquifer for irrigation water quality in southwestern zone of Bangladesh, it was found that the Northern deep groundwater had the highest salinity, and other chemical concentrations showed a decreasing trend towards the south. Low chemical concentrations in the southern region indicated the best quality groundwater for irrigation (Rahman *et al*., 2012).

Batiaghata Upazila, in Khulna district is in the southwest coastal region of Bangladesh where saline water intrusion is the most severe (Karim *et al*., 1990), where farmers mostly cultivate a single rice crop in the wet season under rainfall conditions (Mondal *et al*., 2008). The use of groundwater as sole source of irrigation remains a risky venture, owing to the possible intrusion of saline water from the river into the coastal aquifers if the water level of the aquifers is lowered because of excessive withdrawal of water for irrigation (Mondal *et al*., 2006). However, even in monsoon season, there are times when prolonged drought condition persists and farmers are at stake in choosing which sources of water to use as irrigation water. Therefore, a detailed investigation regarding the irrigation water quality and their salinity hazard classification has to be done for the monsoon season in the area, particularly for the available water resources including surface water, and shallow ground water. As most of people of these districts are dependent on agriculture and fisheries, keeping these in mind, the objectives of the research were to assess the hydrochemistry of surface water and groundwater of the area in the monsoon season, to evaluate the suitability of irrigation water quality of different sources of Batiaghata Upazila of Khulna districts in Bangladesh, and choosing the best source of water that has the potential for irrigation water quality.

MATERIALS AND METHODS

Study Area

Batiaghata Upazila is situated in Khulna District located between 22°34´ and 22°46´ North latitudes and between 89°24´ and 89°37´ East longitudes (Fig. 1). 16 surface water samples (7 River water samples and 9 pond water samples) and 7 shallow Tube well (STW) (depths from 100-150 feet) water samples were collected in August (monsoon season) which are often used as irrigation sources in the study area.

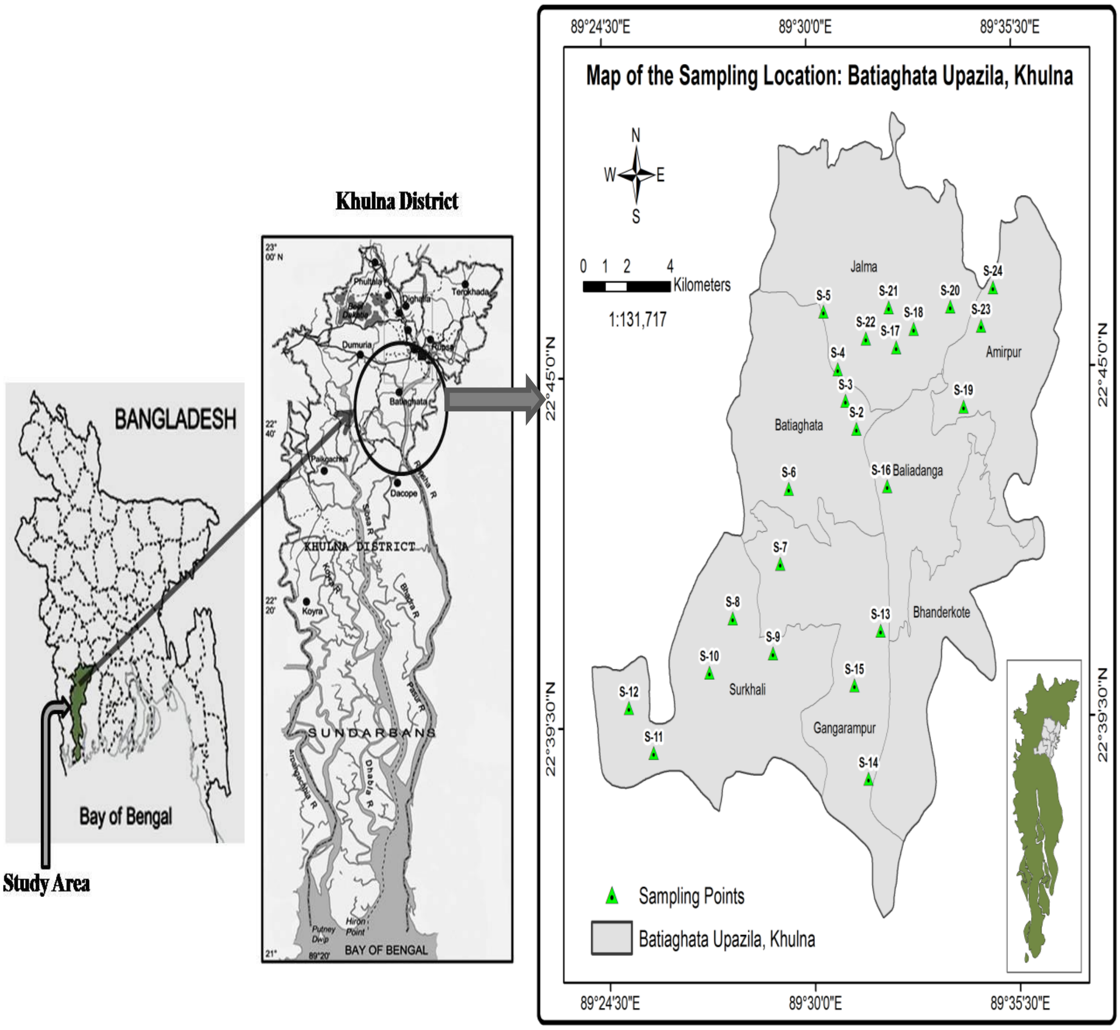

Fig. 1. Sampling Points of Batiaghata Upazila, Khulna

The samples were collected following standard method (APHA, 1998). The water samples were preserved in 500 ml Polyethylene bottles. Each of the bottles were acid washed followed by rinsing with distill water, and sample water washing. Two sets of same samples were collected from each location. One set of sample was kept under non-acidified condition and another kept under acidified condition by adding

0.01 M nitric acid. The samples were preserved in refrigerator at 4ºC until analysis. Sampling locations were recorded by GPS (Model- Explorist 200, Megellan), water pH and DO by Multi- meter Ion 6 (HACH 51910, USA), EC by Conductivity Meter (HANNA HI 8033), TDS by HANNA HI 8734 each three times. Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg) were determined by Atomic Absorption Spectrophotometry (AA-7000 SHIMADJU) Spectrophotometer; Phosphorus (P) and Sulphur (S) by UV Spectrophotometry SPECORD 210 PLUS and chloride by titrimetric method as described by Huq and Alam, (2005). MilliQ water was used for all types of sample processing and analysis.

Secondary data Collection

To investigate the occurrences of salinity, different environmental parameters were investigated and secondary information were collected mostly for soil, river and some hand tube-well data of Batiaghata Upazila from local Soil Research Development Institute (SRDI) from 2004 to 2011.

Data analysis

In most irrigation situations, the primary water quality concern is salinity levels, since salts can affect both the soil structure and crop yield. The build-up of salinity in the root zone increases the osmotic pressure of the soil solution and causes a reduction in both the rate of water absorption by the plants and the soil water availability (Vyas and Jethoo, 2015).

Irrigation sources high in sodium (Na) may lead to the deterioration of soil structure. High soil Na causes soil clays and organic matter to disperse or deflocculated. The clays and organic matter clog soil pores, reducing water infiltration and soil aeration. These problems are greater on fine textured soils such as clays and loams than on sandy soils. Calcium (Ca) and magnesium (Mg) cause the soil to flocculate, and therefore counteract the negative effects of Na (Vyas and Jethoo, 2015).

The Sodium Adsorption Ratio (SAR) describes the relationship between soluble Na^+ and soluble divalent cations (Ca^{2+} and Mg^{2+}) (Alrajhi *et al*., 2015). The higher the Na in relation to Ca and Mg, the higher the SAR (Vyas and Jethoo, 2015).

SAR was calculated by the following equation (Richards, 1954) as:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \tag{1}$$

where, all the ions are expressed in meq/L.

SAR values are plotted against EC values (in µS/cm) on the U.S. Salinity diagram to categorize analyzed water samples according to their irrigational suitability quotient. This has long been the standard measure of potential sodium hazard for irrigation water (U.S. Salinity Laboratory Staff, 1954). The potential for irrigation water to have poor infiltration properties is assessed by determining the sodium adsorption ratio (SAR) and the electrical conductivity (EC) of the water (Vyas and Jethoo, 2015).

Soluble Sodium Percentage (SSP) is also used to evaluate sodium hazard. Water with a SSP greater than 60% may result in sodium accumulations causes a breakdown in the soil's physical properties (Khodapanah *et al*., 2009). SSP was calculated by the following equation (Todd, 1980):

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

where, all the ions are expressed in meq/L.

The SSP values and the EC values have been plotted on the Wilcox diagram (Wilcox, 1955) which implies the quality of irrigation water into six classes.

Total Hardness (TH) was calculated by the equation proposed by Raghunath, (1987):

$$TH = Ca^{2+} \times Mg^{2+} \times 50 \tag{3}$$

where TH is expressed in mg/L.

Magnesium Adsorption Ratio (MAR) was calculated by the equation proposed by Raghunath (1987).

$$MAR = \frac{Mg^{2+} \times 100}{Mg^{2+} + Ca^{2+}} \quad (4)$$

where, all the ionic concentrations are expressed in meq/L.

Kelly's ratio is also an important parameter for irrigation water quality, which is measured considering sodium ion concentration against calcium and magnesium ion concentrations. Kelly's ratio of more than 1 indicates an excess level of Na^+ in water. Water with a value of KR< 1 is considered suitable for irrigation, while those with a ratio more than 3 is considered as unsuitable for irrigation. The Kelly's Ratio was calculated using the equation (Kelly, 1963) as:

$$Kelly's\ Ratio = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}} \quad (5)$$

where all the ionic concentrations are expressed in meq/L.

Statistical Analysis

Data were input by Microsoft office Excel 2007, processed into graphs by Sigmaplot 10.0 (Systat Software, USA). Standard error of the samples was calculated. To quantitatively investigate the relationships among the dataset, Correlation Coefficient Matrix and multivariate statistics Principal Component Analysis (PCA) was performed in origin 9.0 (OriginLab, USA).

RESULTS AND DISCUSSION

Analysis of secondary Electrical Conductivity (EC) data of Kazibaccha River and Rupsa River collected from SRDI from 2004 to 2011 with each month interval, indicated that the temporal variation of salinity was increasing from the month of December (pre-monsoon season) and reaches its highest peak in May followed by a declining trend in June (Fig. 2). The reason for the salinity increased from January to May is because of low flow in the upstream river and low rainfall that the local runoff cannot contribute to the river discharge while inflow of saline water from the Bay of Bengal. May is regarded as the most salinity affected months from the data as Kazibaccha River with EC of 26.30±3.35 dS/m and Rupsa River 24.47±2.41 dS/m. With the setting of hydrological season in June, enough rainfall-runoff and upstream river discharge, the salinity level was lowered. Although the present study did not consider salinity differences in ebb tide and flood tides, previous reports mentioned the presence of significant differences in salinity levels of the river water during ebb and flood tides. The average salinity at flood tides reached 4 dS/m in mid-February, but remained below 4 dS/m during ebb tides until the beginning of March (Mondal *et al.*, 2006).

The soil electrical conductivity data collected for 6 different soil series from SRDI from the year 2004 to 2011 also shows a similar trend of salinity occurrences (Fig. 3) for that river water. The reason for the salinity increased in the soil from March to June is because of low flow in the upstream river and low rainfall occurrences that the local runoff cannot contribute to soil flushing of build-up salts. Besides, the intrusion of saline water from the Bay of Bengal by the contribution of tidal flood in river also increases the salt concentration in the soil. Starting from July, adequate rainfall and run-off flushes out excess salinity and keep the salinity level low in the soil until October. However, as the starting of post monsoon season, from November, due to low rainfall, the soil salinity starts building up. Among the 6 soil series data, sites 14A and 14B, collected from Baoza and Dumuria, respectively from Krishnanagar, Batiaghata is less affected by salinity in the peak dry season. On the other hand, soil series 16A, 16B and 17A and 17B collected from Fultala, Batiaghata is mostly affected by salinity occurrences.

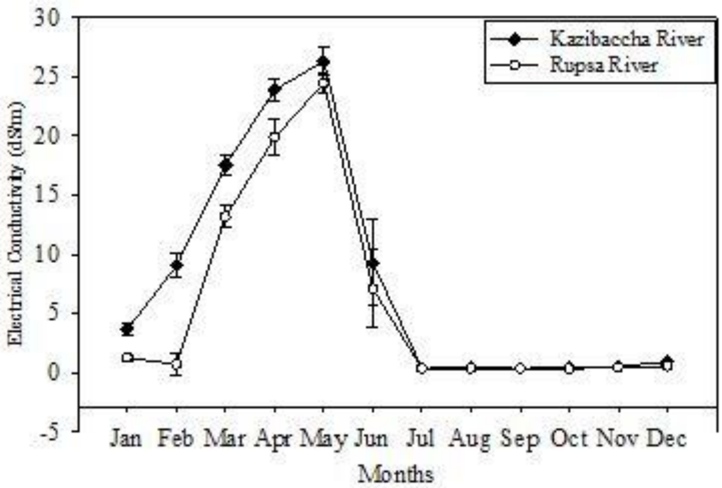

Fig. 2. Electric Conductivity EC (dS/m) of Kazibaccha River and Rupsa River Batiaghata Upazila Khulna (from 2004 to 2011) collected from SRDI. Vertical and capped bars indicate standard error of the means.

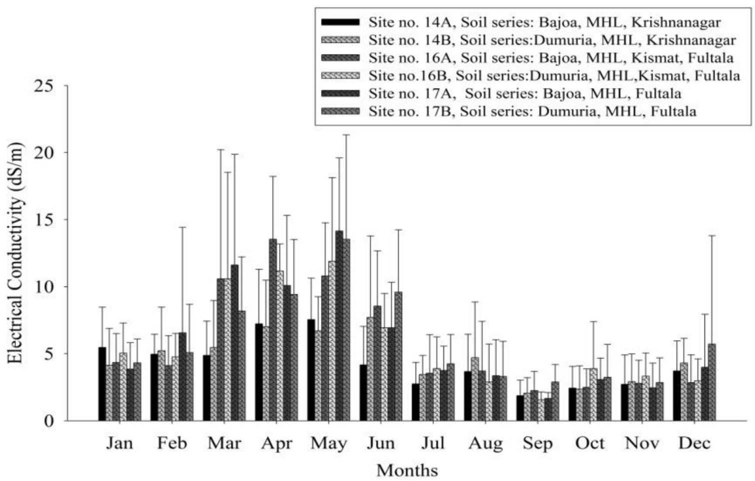

Fig. 3. Six different soil series from Batiaghata from 2004 to 2011collected from SRDI (MHL= medium high land). Vertical and capped bars indicate standard error of the means.

The dynamics of groundwater Electrical Conductivity data of hand tube well were collected from SRDI from 2004-2011, of four locations of Batiaghata Upazila, which are presented in Figure 4. Salinity trend of hand tube well indicates the level of salinity was also being affected in the water. The level of salinity in sites 14 and 17 ranged on an average from 1.48±0.12 dS/m and 1.40±0.12 dS/m, respectively. On the contrary, hand tube well of site 15 and 16 were 1.79±0.14 dS/m and 1.76±0.10 dS/m. This implies that groundwater salinity could vary greatly with the seasonal variations as the aquifer is also affected by saline water recharge. Although the level of Electrical Conductivity Dynamics is not as acute as surface water, the level of electrical conductivity in ground water reached as much as 2 dS/m in the dry season. Therefore, from the above secondary data analysis it is observed that, salinity dynamics in river water, shallow groundwater as well as in soil is varied significantly in both monsoon and dry seasons.

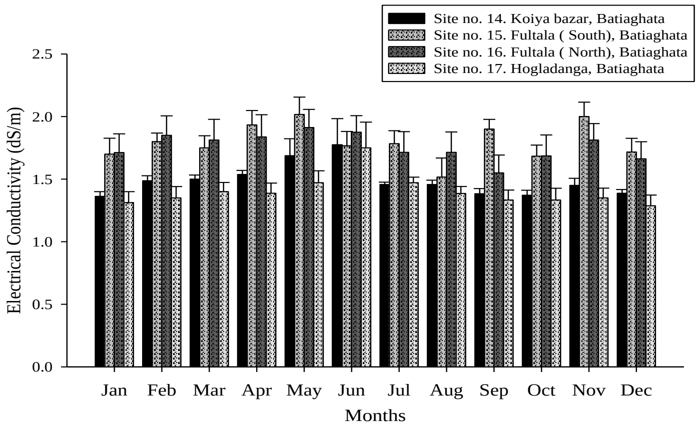

Fig. 4. Electric Conductivity (dS/m) for hand tube well of four sites from the years 2004 to 2011. Vertical and capped bars indicate standard error of the means.

However, in the monsoon season (which water sources can significantly serve as irrigation water sources without possessing much hazard of salinity and alkali hazard) 23 samples from river water, pond water, and STW were collected. Some of their important hydro-chemical characteristics were analyzed. The range of the pH value of the surface water in the study area were 7.35 to 8.70 with the average value of 7.82 and pH value of ground water 7.45 to 8.36. All the values of pH were within the permissible limit of pH 6.5-8.5 for irrigation water quality set by MOEF/DoE/GOB (1997). The Electrical conductivity (EC) value of water samples of the study area varied from 400 µS/cm to 3800 µS/cm with an average value of 1456.52 µS/cm. The average Electrical Conductivity (EC) value of surface water was 1531.25 µS/cm ranged from 400 µS/cm to 3800 µS/cm. According to irrigation water quality classification (Wilcox, 1995) average water sample including STW and surface water of study area was “Slight to Moderate” for irrigation. The EC values ranged from 1000 µS/cm to 1600 µS/cm with average value of 1285.71 µS/cm for STW which are within acceptable range of 2250 µS/cm set by MOEF/DoE/GOB (1997).

Although chloride is essential to plants in very low amount, it can cause toxicity to sensitive crops at high concentrations. According to Mass (1990) the Cl^{-} concentration Below 70 mg/L is generally safe for all plants. The Cl^{-} content of the River water sample ranged from 29.99 mg/L to 629.80 mg/L with an average value of 264.91 mg/L. For pond water Cl^{-} content ranged from 69.97 mg/L to 927.11 mg/L with an average value of 305.79 mg/L. The STW water samples of the study area had 79.98 mg/L to 289.91 mg/L with an average value 175.66 mg/L. The sensitive plants may show injury to the average Cl^{-} concentration of all the samples water of Batiaghata Upazila and potential in degree of restriction fell in the severity of “slight to moderate” (Ayers and Westcot, 1985). The SO_4^{2-} content of the surface sample ranged from 18.48 mg/L to 134.64 with an average concentration of 70.11 mg/L. On the contrary, in the pond water SO_4^{2-} concentration varied from 14.99 mg/L to 97.43 mg/L with an average value of 58.33 mg/L. For the STW water samples of the study area, SO_4^{2-} concentration varied from 34.52 mg/L to 79.50 mg/L with an average value of 52.43 mg/L. PO_4^{3-} content of the surface water sample ranged from Bellow Detectable

Limit (BDL) to 2.04 mg/L with an average value of 1.14 mg/L. For the pond water samples PO_4^{3-} concentration varied from BDL to 1.58 mg/L with an average concentration of 1.31 mg/L. STW water samples of the study area had PO_4^{3-} concentration of 0.34 mg/L to 2.28 mg/L with an average value of 1.35 mg/L. It is observed that the cations trend in both surface and groundwater of the study area were following the trends of $Cl^- > SO_4^{2-} > PO_4^{3-}$ (Fig. 5). All the anion contents of sample values were under permissible limit according to (MOEF/DOE/GOB 1997).

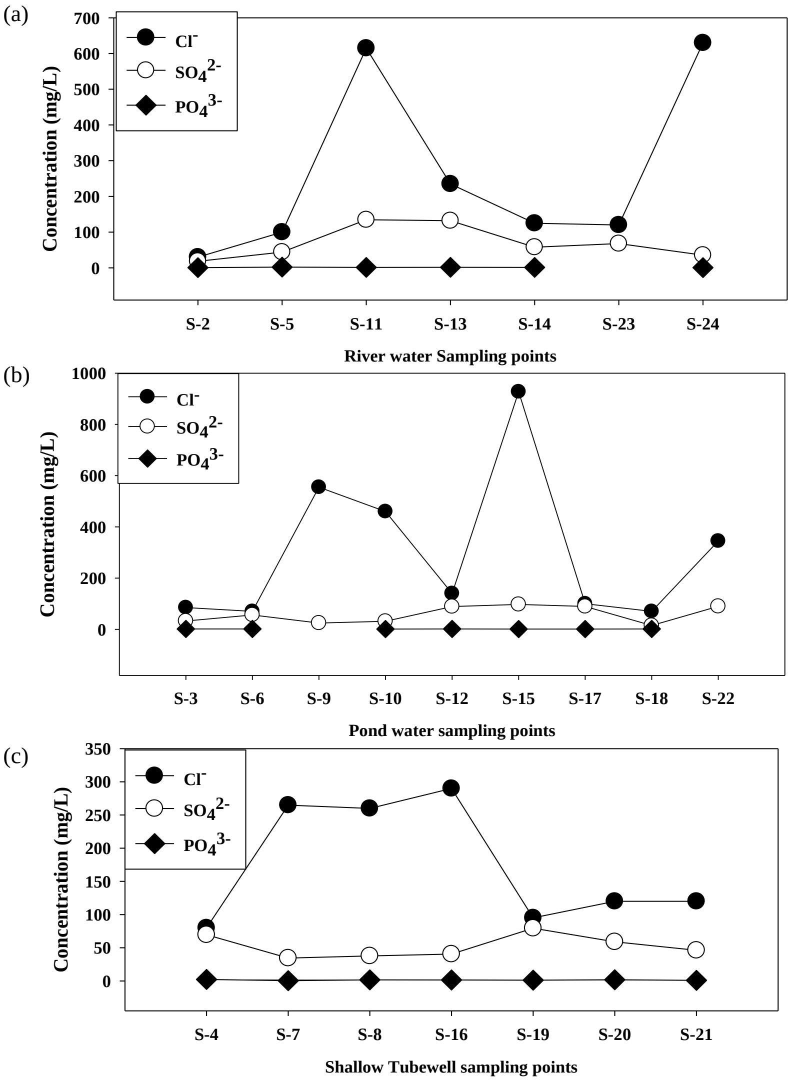

Fig. 5. Selected anions Cl^-, SO_4^{2-} and PO_4^{3-} concentration (mg/L) of the sampling locations of Batiaghata Upazila indicating (a) River water sampling points of Kazibaccha River and Rupsa River, (b) Different pond water sampling points, and (c) Shallow tube well locations. No data point indicate bellow detection limit (BDL).

It is evident that the cations trend in both surface and groundwater of the study area were $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$. Irrigation water that has high sodium (Na^+) content can bring about a displacement of exchangeable cation Ca^{2+} and Mg^{2+} from the clay minerals of the soil, followed by the replacement of the cations by sodium. Correlation coefficient is a commonly used measure to establish the relationship between two variables. It is simply a measure to exhibit how well one variable predicts the other. The correlation matrices for EC, TDS and major ions were prepared and illustrate in (Table 1) that EC and TDS show high positive correlation with Na^+ , $K^+$and Ca^{2+} with Cl^- had shown a positive and strong correlation with EC and TDS indicating the ions originated from the same sources of water.

Principal Component Analysis (PCA) which is a method complementary to classical approaches of hydrogeochemical research (Morell, Gimhez, and Esteller, 1996) provides quick visualization and shows correlation among different water quality variables. PCA on the combined datasets provided two factors with Eigenvalue >1 that can explains approximately 70% of the variability of the data (PC 1 variance of 54.29% and PC 2 variance of 15.97%) (Table 2). When the two variables are far from the center and close to each other, they are significantly positively correlated (r ≈ 1). Therefore PC1 may represent the anions and cations (K^+, Na^+, Cl^- and Ca^{2+}) in relation with representing salinity (EC and TDS) of the water samples. PO_4^{3-} is negatively correlated with the anions, cations, and EC, while Mg^{2+} and SO_4^{2-} are weakly correlated with EC and TDS (Fig. 6).

Table 1. Pearson Correlation matrix for water samples (n= 23)

	EC	**Na^+**	**K^+**	**Mg^{2+}**	**Ca^{2+}**	**Cl^-**	**SO_4^{2-}**	**PO_4^{3-}**	**TDS**
EC	1								
Na^+	0.88*	1							
K^+	0.52*	0.55*	1						
Mg^{2+}	0.31	0.1	0.42*	1					
Ca^{2+}	0.78*	0.60*	0.48*	0.3	1				
Cl^-	0.92*	0.93*	0.65*	0.26	0.67*	1			
SO_4^{2-}	0.34	0.28	-0.02	0.38	0E+00	0.23	1		
PO_4^{3-}	-0.3	-0.26	-0.11	0.13	-0.25	-0.31	0.07	1	
TDS	0.81*	0.79*	0.57*	0.19	0.65*	0.80*	0.09	-0.46	1

2-tailed test of significance is used

*Correlation is significant at the 0.05% level

Table 2. Extracted Eigen vectors for Coefficients of Principal Component Analysis (PCA)

	Coefficients of PC1	**Coefficients of PC 2**
EC	0.43	0.04
Na^+	0.40	-0.05
K^+	0.31	0.08
Mg^{2+}	0.16	0.61
Ca^{2+}	0.35	-0.06
Cl^-	0.43	-0.01
SO_4^{2-}	0.11	0.56
PO_4^{3-}	-0.16	0.50
TDS	0.40	-0.17
Eigenvalue	4.88	1.43
Percentage of variance	54.29%	15.97%
Total variance	70% (approx.)	

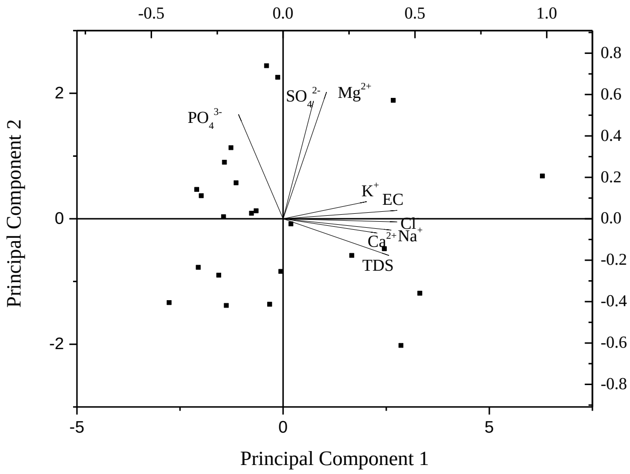

Fig. 6. PCA of the anions and cations of irrigation water samples of Batiaghata Upazila

The soluble sodium percentage (SSP) is also widely utilized for evaluating the suitability of water quality for irrigation (Wilcox, 1948). The $\%Na^+$ is computed with respect to relative proportions of cations present in water, where the concentrations of ions are expressed in meq/L which is plotted in Wilcox diagram (Fig. 7). Excess Na^+, combining with carbonate, leads to formation of alkaline soil, whereas with Cl^- saline soil is formed. Neither of soils will support plant growth. Among the 7 River water samples, only one fell under good class (14%), three fell under "Fair class" (43%), one fell under "Poor class" (14%) and two fell under "very poor class" (28%). Among the nine pond water samples three fell under "Good" class (33.33%), two fell under "fair class" (22.22%), two fell under "Poor class" (22.22%) and two fell under "Very Poor Class" (22.22%). On the other hand, among the seven STW samples one fell under Fair class (14.28%), five fell under Poor class (33.33%) and one fell under Very Poor class. As the sampling time was August during the monsoon season, some of the river water and pond water could be suitable sources of irrigation. Other times could be dependent on the rain water. Some of the pond water also fell under "poor" to "very poor" classification in Wilcox diagram due to the soil flushing by rainfall run-off or excess irrigation water runoff from the near-by agricultural fields.

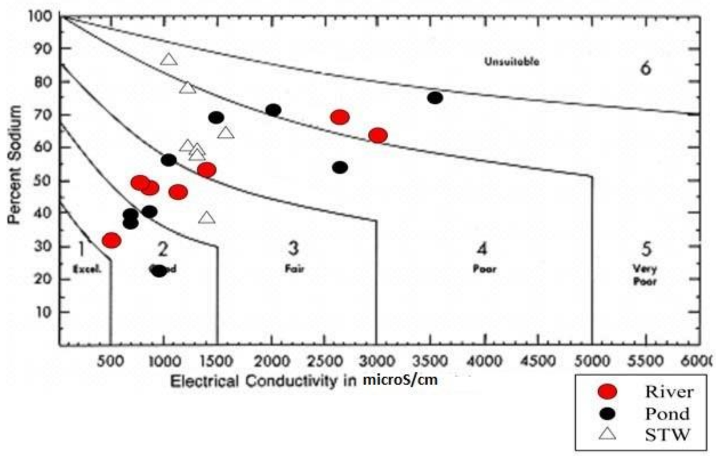

Fig. 7. Wilcox's diagram for irrigation water classification of collected samples from Batiaghata Upazila

In terms of salinity hazard, after plotting Electrical Conductivity (EC) and SAR value on the US Salinity Laboratory's diagram, Salinity hazard classification for Batiaghata Upazila was drawn (Fig. 7). Four River water samples (57.14%) and four pond water samples (44.44%) and one STW sample (14.28%) fell under C1-S1 group which implies low alkali and low salinity hazard. Five STW sample (71.42%) one pond water sample (11.11%) and one river water sample (14.28%) fell under medium alkali hazard and medium salinity hazard group C2-S2. One STW fell in C1-S3 group which implies low salinity hazard but high alkali hazard. Only one pond water sample (11.11%) fell in C3-S2 group of high salinity and medium alkali hazard. One pond water sample (11.11%) fell in C2-S3 group of medium salinity hazard but high alkali hazard. Two River water sample (28.57%) fell under high salinity and high alkai hazard, i.e., in the C3-S3 group. Only one pond water sample (11.11%) fell under C3-S4 group which is high salinity hazard but very high alkali hazard.

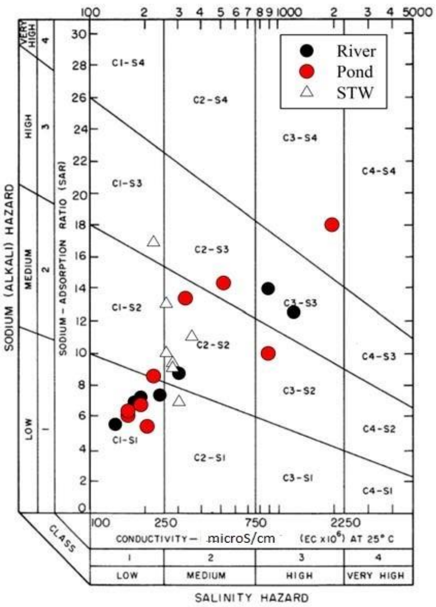

Fig. 8. US Salinity Laboratory's diagram for salinity hazard classification of Batiaghata Upazila

Although the Total Hardness (TH) is the criteria for evaluating drinking water quality, TH values of surface water of the study area ranged from 118 mg/L to 624 mg/L with an average value of 287.63 mg/L. 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). The average values of TH in STW water were 198 mg/L with range of 64 mg/L to 400 mg/L but fulfill the requirement of irrigation water quality in case of total hardness by MOEF/DoE/GOB (1997). It has been suggested that KR for irrigation water should not exceed 1.0 (Kelly, 1963). Except 34.78% samples which includes eight surface water sample (four river and four pond water samples) along with one STW samples, the rest of 65.21% samples exceeded KR. As Na^+ concentration is higher in the sample water compared to Ca^{2+} and Mg^{2+} the ratio has increased. So, it can be concluded that, most of the water resources especially river and the STW water is more subjected to Sodium hazard in the study area. MAR causes a harmful effect when exceeds a value of 50 (Gupta and Gupta, 1987). Except one STW (S-21) all other STW samples in the study area exceeded MAR value of 50. Compared to the shallow tube well and pond water samples, river water samples (71.42%) had shown lower MAR values within 50 (Table 3).

At the same level of salinity and SAR, adsorption of Na^+ by soils and clay minerals was greater at higher Mg:Ca ratios. This is because the bonding energy of Mg^{2+} is less than that Ca^{2+}, allowing more Na^+ adsorption and it happens when the ratio exceed 4.0 (Michael, 1992). Besides, soil containing high levels of exchangeable Mg^{2+} causes an infiltration problem (Ayers and Westcot, 1985). In the study area, the ratio of Mg^{2+} and Ca^{2+} for surface water ranged from 0.133 to 0.557 with the average value of 0.314. The STW water samples had the Mg:Ca ratio ranged from 0.098 to 0.592 with an average value of 0.259. From Table 3, it is evident that in the study area, the ratio of Mg^{2+} and Ca^{2+} for all the surface and ground water was less than 1.0. Thus, it indicates a good proportion of Ca^{2+} and Mg^{2+}, which maintain a good structure and tight condition with no permeability problem of the soil of the area.

The presence of excessive Na^+ in irrigation water promotes soil dispersion and structural break down when Na^+ and Ca^{2+} ratio exceeds 3:1. Such a high Na:Ca ratio (>3:1) results in severe water infiltration problem, mainly due to lack of sufficient Ca^{2+} to counter the dispersing effect of Na^+ (Table 3). Excessive Na^+ also creates problem in crop water uptake, poor seedling emergence, lack of aeration, plant and root decreases, etc. (Ayers and Westcot, 1985). However, considering Na:Ca ratio, some of the pond water samples had shown high suitability as irrigation water. Only water samples of STW (S-19) of the study area had the ratio more than 3:1. River water and STW of the area had high Na:Ca values compared to the pond water of the area. Results suggest that the brackish nature of STW and surface water is mostly due to the seawater influence and hydrogeochemical processes (Bahar and Reza, 2010). The elevated EC, Cl^- and high content of Na^+ relative to Ca^{2+}, Mg^{2+} and K^+ samples suggest their saline origin which agrees with the previous study (Halim *et al*., 2009). Salinity, total hardness, and sodium percentage (Na%) indicate that most of the River water and STW samples are not suitable for irrigation while few pond water samples of the area can be suitable for irrigation in the monsoon season.

Table 3. Irrigation water quality parameters found in water sample of study area

Sample ID	Source	SSP (%)	MAR (meq/L)	Kelly (meq/L)	SAR (meq/L)	Na:Ca	Mg:Ca	TH (mg /L)
S-2	(River)	31.002	41.627	0.428	1.437	0.619	0.507	118
S-3	(Pond)	38.662	70.076	0.574	2.056	0.494	0.154	124
S-4	(STW)	59.108	70.853	1.429	6.421	1.215	0.149	144
S-5	(River)	46.748	48.064	0.855	3.339	1.071	0.391	154
S-6	(Pond)	36.152	55.985	0.547	2.377	0.589	0.284	176
S-7	(STW)	58.004	62.932	1.350	5.719	1.293	0.213	234
S-8	(STW)	56.309	52.011	1.262	5.376	1.461	0.334	250
S-9	(pond)	70.222	72.041	2.307	11.287	1.929	0.140	338
S-10	(Pond)	67.925	60.270	2.075	10.226	2.074	0.238	264
S-11	(River)	68.048	54.504	2.097	10.895	2.318	0.302	378
S-12	(Pond)	55.136	45.657	1.208	4.811	1.594	0.430	194
S-13	(River)	52.179	39.938	1.067	5.006	1.609	0.544	168
S-14	(River)	48.270	40.910	0.856	2.995	1.261	0.522	148
S-15	(Pond)	73.899	61.154	2.782	15.366	2.740	0.230	456
S-16	(STW)	62.969	58.193	1.668	7.565	1.727	0.260	200
S-17	(Pond)	39.577	39.359	0.630	2.802	0.964	0.557	244
S-18	(Pond)	21.846	62.627	0.242	1.298	0.233	0.216	456
S-19	(STW)	85.134	78.699	5.676	14.118	4.345	0.098	64
S-20	(STW)	37.414	37.903	0.563	3.000	0.894	0.592	400
S-21	(STW)	76.593	67.908	3.235	9.836	2.869	0.171	94
S-22	(Pond)	52.902	70.288	1.108	6.396	0.950	0.153	624
S-23	(River)	45.460	49.757	0.806	3.482	0.976	0.365	192
S-24	(River)	62.568	73.071	1.651	9.267	1.361	0.133	568

Adaptation strategies

The following adaptation strategies are recommended based on the field work and data analysis

1. Storing of excess rainwater in ponds: Excavation of ponds and store rainwater is a good way to mitigate irrigation water scarcity in the affected area. It was observed from data analysis that some of the pond water could be the best source for irrigation in the study area. So during the monsoon, this pond water can be utilized for irrigation practices. Part of the excess pond water can be used in the dry periods for growing vegetables.

2. Covering land in dry season to reduce evaporation: It was observed from the data analysis that groundwater was in shallow depth and presents a salinity threat. Keeping lands uncovered during summer and winter, therefore, might lead to excess salinity build up on soil due to evaporation. Covering land with plastic sheet can be one way of preventing soil evaporation.

3. Application of ashes and Biochar: It is necessary to bring down the salinity from soil by leaching salts from land. During the field work, it was observed that many farmers had dug a small pit in the corners of their land which was covered with ashes. The objective of this strategy was to sorb salt from water during soil flushing in the rain or excess irrigation. In this regard, a more scientifically recommend adaptation strategy can be application of biochar to amend salt affected land. Biochar can ameliorate salt stress effects on plants through salt sorption, suggesting novel applications of biochar to mitigate effects of salinization in agriculture (Thomas *et al*., 2013). Biochar addition reduced plant sodium uptake by transient Na^+ binding due to its high adsorption capacity, decreasing osmotic stress by enhancing soil moisture content, and by releasing mineral nutrients (particularly K^+, Ca^{2+}, Mg^{2+}) into the soil solution (Akhtar, Andersen, & Liu, 2015). Taking this into account, further research can be taken in the saline tolerant areas of the country to ameliorate salt stress in agricultural production

4. Agriculture with saline tolerant species: Salinity tolerant paddy species BRRI-dhan 47 (Boro dhan), BRRI-dhan 40, BRRI dhan-41, (T. Aman varieties) may be the solution to overcome salinity impact in the coastal areas (Abedin & Shaw, 2013) as well as affected study areas. Besides, salt tolerant crops like BARI tomato and vegetables can be grown in the dry period. This would also lower the salinity from soil.

CONCLUSION

Batiaghata Upazila of Khulna district is the mostly saline affected area, where the sources of irrigation water even in monsoon is a crisis for the farmers, during low rainfall and drought conditions. Although many salt-tolerant rice-varieties and many vegetable varieties are recommended for coastal agriculture, but a plan must be assessed carefully during the low-rainfall and drought condition, which sources of water to be used for irrigation to avoid risk of accumulation of excess salinity in the agricultural crop-fields and to avoid crop-failures. Besides, presence of high salinity and sodicity in alternative sources of irrigation water other than rain-water can deteriorate the soil properties of valuable agricultural land as well as damage the crop production in such a critical area where sources of saline free land is a high need. It is palpable that large production in agricultural sector is highly dependent on good quality of irrigation water. So, it is very important to assess the irrigation water quality of the existing water resources of Batighata Upazila to maximize agricultural yield. Therefore, considering the results and discussion, it can be concluded that, all the sources of surface water and ground water has the risk of salinity hazard for irrigation even in monsoon. Surface water especially river water and STW contains high risk of alkali hazard. Some of the pond water which accumulates salt from soil flushing of nearby agricultural land during monsoon season by rain-fall run-off also contains high risk. Therefore proper adaptation strategies must be taken in order to ameliorate salt stress.

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