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Assessment of Temporal Variability of Soil and Water Salinity in the Saline Prone Vicinity of Bangladesh

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Abstract Salinity intrusion is a concerning issue in the coastal vicinity of Bangladesh. This study was conducted to investigate the variability of soil and water salinity at Paikgachha upazila of Khulna district in Bangladesh. Soil samples were collected from inside and outside polder of Bhodra river of Paikgachha upazila and some selected crop fields. Water samples (Deep tube-well water and pond water) were collected periodically from different locations and sites of Paikgachha upazila. The soil and water samples were analyzed for pH and electrical conductivity (EC). Soil pH was determined by using a glass electrode pH meter. Soil EC was measured in soil-water suspension (1:2 and 1:5) using EC meter. The pH of water samples was determined by using pH meter. The EC of collected water samples was determined by inserting the probe of EC meter to the saline water. The findings of the study reveal that polder had a remarkable effect on soil pH, showing that inside polder soil pH value ranged from 5.09-6.58 and outside polder, the pH varied from 7.61-8.14. The EC value recorded at 1:5 soil-water suspension was always lower than that noted at 1:2 soil-water suspension, which was, although not proportional, as due to the dilution effect. Soil pH value of some crop field soil ranged from 4.98 to 7.39. The EC (1:2 soil-water ratio) value varied within a wide range from 2.02 to 14.65 dS/m and these values from 0.49-5.74 dS/m when EC was measured on 1:5 soil-water ratio. The pH value of pond water ranged from 7.07 to 7.90. The EC value varied within a wide range from 0.91 to 33.55 dS/m. The pH value of deep tube-well water ranged from 7.20 to 7.44. The EC value varied within a wide range from 3.38 to 8.87 dS/m. Therefore, this study will provide a better understanding of the temporal variability of soil and water salinity in the saline prone vicinity of Bangladesh.

Keywords: *soil salinity, water salinity, variability, Bangladesh*

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1. Introduction

Salinity intrusion is a rising problem in the coastal areas around the globe, especially in the low-lying developing countries [1]. Bangladesh is facing a great threat due to salinity intrusion in the coastal vicinity. The problem becomes worsened predominantly in the dry season when rainfall is deficient and incapable of lowering the concentration of salinity on surface water and leaching out salt from soil [2]. Soil and water salinity are major constrictions for higher crop productivity in the southern region of Bangladesh [3]. The effect of climate change both magnitude and extent of soil salinity in this region are increasing with time, with the record of 0.83 mha in 1973, 1.02 mha in 2002 and 1.06 mha in 2009 [4]. These changes negatively impact on soil fertility and crop productivity which underpins the rural economy of coastal Bangladesh. The causes for salinity rise can be attributed to decrease in upstream freshwater flow, sea level rise and also due to the alteration from rice to shrimp cultivation using tidal water [5]. Salinity is a major threat to crop production in coastal areas all over the world [6], half of the watered surface is seriously affected by salinity [7], however, and other probable affects concern not only crop yield but also salinization of lands, degradation of ground and surface water and the underground migration of salts from salt-laden geological strata to rivers. Use of poor quality groundwater has become inevitable for irrigation to compensate rapidly growing water demands due to increasing water requirements for irrigation and the competition between human and industrial water use, especially in arid and semi-arid regions [8,9]. The cultivable areas in coastal districts are affected with varying degrees of soil salinity. The coastal and offshore area of Bangladesh includes tidal, estuaries and river floodplains in the south along the Bay of Bengal. Agricultural land use in these areas is very poor, which is roughly 50% of the country's average [10]. Soil salinity arises primarily due to land inundation by saline tidal waters in the wet season (June to October) and the capillary rise of saline water from shallow saline groundwater

tables in the dry season (November to May) [5]. As a result, agricultural practice in Bangladesh is very much seasonal and climate dependent with variations in crop production and yield occurring between wet and dry seasons, and resulting from the large-scale inter-annual variability. Both the hydrological and geological differences in the coastal zone vary the soil salinity concentrations between EC 2 ds/m^{-1} to 18 ds/m^{-1} [11]. Thus highly saline regions are unproductive in terms of crop yield due to the toxicity of the salts, an, as a result, many farmers rely on the wet season monsoons/flooding and/or irrigation to dilute the salts. This can be counterproductive in that monsoonal rains and flooding can cause migration of salts producing high salinity concentrations in certain localities, whilst, irrigation especially in the dry season, can promote saline intrusion of groundwater sources [12]. Soil salinity is one of the world's most serious environmental problems. About 7% of the world's total land area is affected by salt, as in a similar percentage of its arable land; [13]. Excessive soil salinity occurs in much semi-arid to arid regions of the world where it can affect nutrient movement to plants, soil properties, and various soil chemical reactions including pH;, and inhibits the growth and yields of crop plants [14]. Irrigated water demand is highly affected by salinity intrusion in surface water [15] and salt accumulation in the root zone of soil affects plant growth in coastal soil. Besides constraining agricultural production, salinity limits the freshwater availability for drinking purpose and industrial production. The main objective of this study is to investigate the temporal variability of soil and water salinity in the saline prone vicinity of Bangladesh.

2. Materials and Methods

2.1. Study Area with Soil and Water Sample Collection

The research was conducted at Paikgachha upazila of Khulna district in Bangladesh. Paikgachha upazila lies between 21°58´ and 22°89´ North latitude and between 89°33´ and 89°61´ East latitude shown in Figure 1. Soil and water samples were collected periodically from different locations and sites of Paikgachha upazila. Soil samples were collected from inside and outside polder of Bhodra river of Paikgachha upazila and some selected crop fields. The collected soil samples were carried to the laboratory, air dried, ground to pass through a 2-mm sieve to break down large macro aggregates. Composite samples were prepared by mixing the sieved 15 (0-15cm depth) samples and preserved in plastic bottles for subsequent laboratory analysis. Water samples (Deep tube-well water and pond water) were collected periodically from different locations and sites of Paikgachha upazila. Water samples were collected in 250 ml plastic bottles previously washed with distilled water and sealed immediately to avoid exposure to air. Samples were collected at running condition of hand tube well after pumping sufficient quantity of water. All water was colorless, odorless, tasteless and also free from turbidity at the time of sampling. After sampling, the samples were brought to the central laboratory, Patuakhali Science and Technology University, Bangladesh and water kept in a clean, cool and dry place.

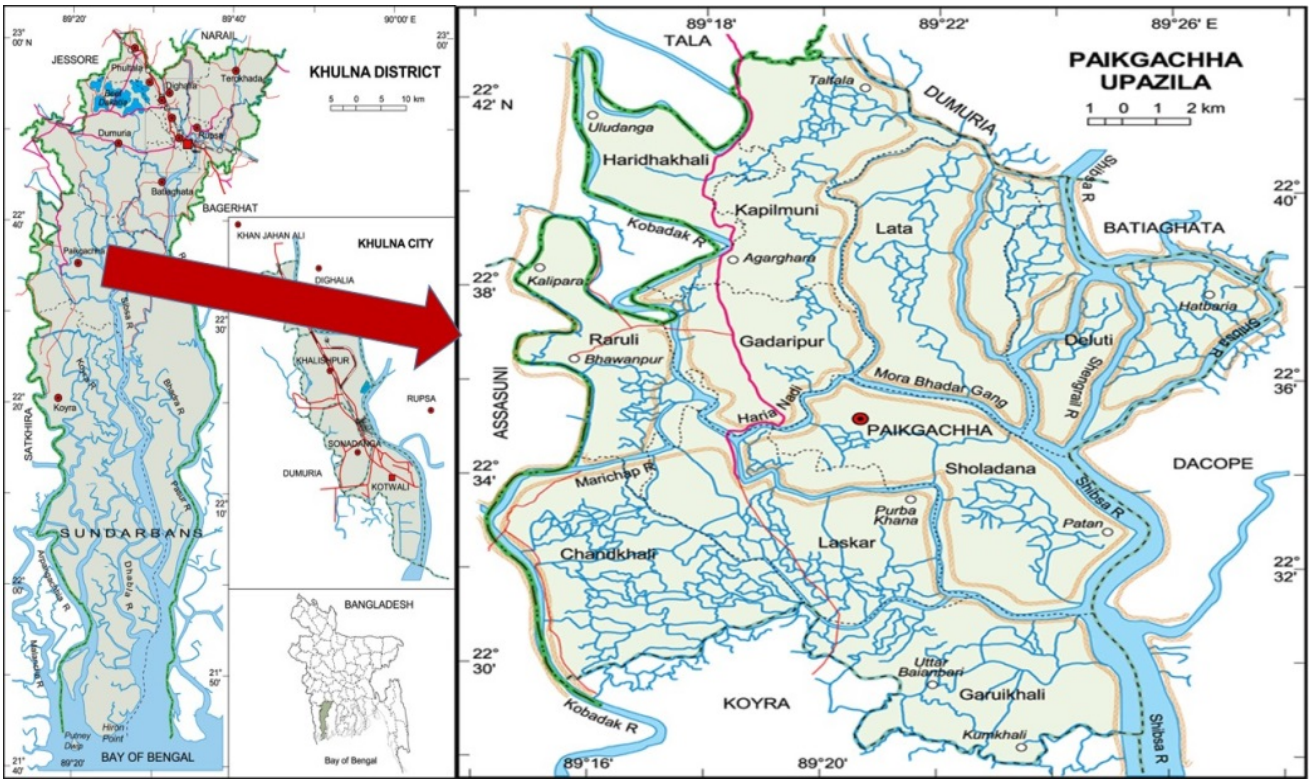

Figure 1. Map showing the study area of Paikgachha upazila of Khulna district, Bangladesh

2.2. Analysis of Different Chemical Properties of Soil

2.2.1. Determination of pH

Soil pH was determined by using a glass electrode pH meter (WTW pH 522; Germany) as described by Jackson (1973). Ten grams of air-dried soil from each sample site was taken in 50 mL beakers separately and 25 mL of distilled water was added to each beaker. The suspension was stirred well for 20 minutes and allowed to stand for about 30 minutes. Then each sample was stirred again for 2 minutes before taking the reading. The position of the electrode was immersed into the partly settled soil suspension and pH was measured. The result was reported as soil pH measured in water (soil: water ratio was 1:2.5).

2.2.2. Determination of Electrical Conductivity (EC)

The electrical conductivity (EC) of collected soil samples were determined electrometrically (soil water ratio was 1:2 and 1:5) by a conductivity meter (WTW LF 521; Germany) as described by Anderson and Ingram (1996). Twenty gram of air-dried soil was taken in a plastic container and 100 mL of distilled water was added to it. The suspension was stirred for 30 minutes intermittently and then allowed to stand for 30 minutes. Then the electrical conductivity was determined by an electrical conductivity meter (Calibrated with 0.01 N KCl solutions). The results of EC were expressed in desi Siemens per meter (dS/m).

2.3. Analysis of Different Chemical Properties of Water

2.3.1. Determination of pH

The pH of water samples was determined electrometrically following the procedure mentioned by using pH meter (HANNA EC 215) [16].

2.3.2. Determination of Electrical Conductivity (EC)

The EC of collected water samples was determined electrometrically using conductivity meter according to the method mentioned by (HANNA EC 214) [17].

3. Results and Discussion

3.1. Effects of Polder on Soil Properties at Fulbari Village, Paikgachha Upazila, Khulna

3.1.1. Soil pH

In this study, soil samplings have been done periodically from outside and inside the polder of Bhodra river. Soil samples were collected starting from 01 March through 15 June of 2015. Polder had a remarkable effect on soil pH, Table 1 showing that inside polder soil pH value ranged from 5.09 - 6.58 over sampling dates and outside polder the pH varied from 7.61 – 8.14. When mean pH value of all sampling dates was calculated it was found that, inside polder, soil pH was 5.75 which was 7.92 for outside polder. Compared to inside polder, the outside polder soil remains wet due to tidal water inundation having high river water pH, especially during a full moon and no moon time.

3.1.2. Electrical Conductivity (EC)

Electrical conductivity (EC) of soil was measured at 1:2 and 1:5 soil-water suspension and shown in Table 2. At 1:2 soil-water ratio the EC value inside polder ranged from 1.77 – 3.01 dS/m and for outside polder it differed from 4.05 -9.79 dS/m. It was further observed that the EC value over the dates did not follow a definite trend. Table 2 showed that 1:5 soil-water ratio, similar results were recorded, with the results of EC value from 1.02 – 1.85 dS/m and 1.97 – 4.90 dS/m inside and outside polder, respectively. The EC value recorded at 1:5 soil-water suspension was always lower than that noted at 1:2 soil-water suspension, which was, although not proportional, as due to the dilution effect.

Table 1. Effects of polder on pH of Bhodra river flooded soil at Fulbari village, Paikgachha upazila, Khulna in 2015.

Polder effect	Sampling dates						
	01.3.2015	15.3.2015	31.3.2015	15.4.2015	15.5.2015	31.5.2015	15.6.2015
	pH						
Inside polder	5.09 (±0.010)	5.76(±0.175)	5.10 (±0.030)	5.47 (±0.055)	6.05 (±0.100)	6.58 (±0.000)	6.24 (±0.150)
Outside polder	7.82 (±0.005)	7.61(±0.060)	7.84 (±0.040)	8.01 (±0.060)	8.10 (±0.000)	7.95 (±0.060)	8.14 (±0.070)

Figures in the parenthesis indicates standard error (±) of means

Table 2. Effects of polder on the electrical conductivity of Bhodra river flooded soil at Fulbari village, Paikgachha upazila, Khulna in 2015.

Polder effect	Sampling dates						
	01.3.2015	15.3.2015	31.3.2015	15.4.2015	15.5.2015	31.5.2015	15.6.2015
	$EC_{1:2}$						
Inside polder	2.88 (±0.117)	1.77 (±0.014)	2.29 (±0.010)	2.50 (±0.062)	3.01 (±0.144)	3.00 (±0.034)	2.79 (±0.014)
Outside polder	7.10 (±0.115)	5.86 (±0.024)	7.15 (±0.057)	4.99 (±0.646)	5.79 (±0.163)	9.79 (±0.129)	4.05 (±0.019)
	$EC_{1:5}$						
Inside polder	1.85 (±0.086)	1.39 (±0.158)	1.26 (±0.005)	1.42 (±0.019)	1.63 (±0.019)	1.02 (±0.369)	1.55 (±0.005)
Outside polder	4.14 (±0.124)	2.88 (±0.034)	3.48 (±0.038)	2.79 (±0.000)	3.06 (±0.091)	4.90 (±0.053)	1.97 (±0.043)

Figures in the parenthesis indicates standard error (±) of means

3.2. Effect of Chemical Properties of Some Field Soil, Paikgachha Upazila, Khulna

3.2.1. Soil pH

Under this study, soil samples were collected from different crop fields representing less and more salinity affected areas; Hatbari-1, Hatbari-2, Kainmuk, Darunmallik, Noyai, Kalinagar, Korinkhola, Sanerberh, Telekhali-1, Telekhali-2, Shahidkhali, Fulbari-1, Fulbari-2, Bigordana-1, Bigordana-2, Bigordana-3, Gobipagla, Noldanga-1, Noldanga-2 ; to examine the different soil chemical parameters. Data were collected on 20 March 2015. Soil pH values ranged from 4.98 to 7.39 over the 19 samples were shown in Table 3.

3.2.2. Soil Electrical Conductivity (EC)

In Table 4, the EC (1:2 soil-water ratio) value varied within a wide range from 2.02 to 14.65 dS/m, these values from 0.49 – 5.74 dS/m when EC was measured on 1:5 soil-water ratio.

Table 3. Soil pH of some field soil, Paikgachha upazila, Khulna.

Sample description	pH	Sample description	pH
Hatbari-1	5.78 (±0.035)	Shahidkhali	7.31 (±0.135)
Hatbari-2	5.88 (±0.075)	Fulbari-1	6.72 (±0.140)
Kainmuk	5.62 (±0.015)	Fulbari-2	7.36 (±0.285)
Darunmallik	6.05 (±0.150)	Bigordana-1	4.98 (±0.010)
Noyai	6.38 (±0.005)	Bigordana-2	5.30 (±0.035)
Kalinagar	7.12 (±0.060)	Bigordana-3	5.45 (±0.040)
Horinkhola	6.22 (±1.505)	Gobipagla	7.39 (±0.050)
Sanerberh	6.14 (±0.020)	Noldanga-1	6.28 (±0.340)
Telekhali-1	6.21 (±0.005)	Noldanga-2	7.32 (±0.005)
Telekhali-2	6.50 (±0.315)		

Figures in the parenthesis indicates standard error (±) of means.

Table 4. Electrical conductivity of some field soil, Paikgachha upazila, Khulna

Sample description	$EC_{1:2}$ value	$EC_{1:5}$ value	Sample description	$EC_{1:2}$ value	$EC_{1:5}$ value
Hatbari-1	3.13 (±0.072)	1.03 (±0.244)	Shahidkhali	3.66 (±0.168)	0.76 (±0.077)
Hatbari-2	3.70 (±0.378)	1.67 (±0.507)	Fulbari-1	3.83 (±0.407)	2.32 (±0.072)
Kainmuk	14.65(±0.402)	4.60 (±1.905)	Fulbari-2	2.29 (±0.000)	0.96 (±0.570)
Darunmallik	4.47 (±0.024)	1.83 (±0.459)	Bigordana-1	2.45 (±0.038)	1.27 (±0.043)
Noyai	6.96 (±0.115)	2.07 (±0.436)	Bigordana-2	3.74 (±0.010)	1.02 (±0.172)
Kalinagar	4.13 (±0.062)	1.07 (±0.345)	Bigordana-3	3.88 (±0.168)	2.32 (±0.340)
Horinkhola	9.85 (±0.096)	3.29 (±0.727)	Gobipagla	2.86 (±0.091)	0.64 (±0.057)
Sanerberh	2.44 (±0.000)	5.74 (±1.914)	Noldanga-1	3.21 (±0.014)	1.09 (±0.062)
Telekhali-1	4.08 (±0.258)	1.68 (±0.024)	Noldanga-2	2.54 (±0.019)	0.71 (±0.000)
Telekhali-2	2.02 (±0.010)	0.49 (±0.287)			

Figures in the parenthesis indicates standard error (±) of means.

3.3. Effect of Chemical Properties of Water of Some Selected Pond and DTW at Paikgachha Upazila, Khulna

3.3.1. pH and Electrical Conductivity (EC) of Pond Water

In Paikgachha upazila, Khulna, 11 ponds were selected for collecting water to examine the different water chemical parameters. The ponds are situated in Kainmuk, Tangramari, Soladana, Noyai, Kalinagar, Canal (fulbari), Horinkhola, Bigordana, Darunmallik, Telekhali, Fulbari village. Data were collected on 20 March 2015. The pH value of pond water ranged from 7.07 to 7.90 over the 11 samples. The EC value varied within a wide range from 0.91 to 33.55 dS/m showed in Table 5.

Table 5. pH and electrical conductivity of some selected pond collected from different villages of Paikgachha upazila, Khulna, Bangladesh

Pond water		
Pond no.	pH	EC (dS/m)
Kainmuk	7.13 (±0.01)	33.55 (±0.05)
Tangramari	7.35 (±0.02)	26.80 (±0.30)
Soladana	7.55 (±0.01)	14.89 (±0.24)
Noyai	7.07 (±0.01)	10.60 (±0.30)
Kalinagar	7.90 (±0.01)	1.57 (±0.01)
Canal (fulbari)	7.63 (±0.01)	23.35 (±0.35)
Horinkhola	7.74 (±0.01)	6.52 (±0.01)
Bigordana	7.67 (±0.02)	7.04 (±0.02)
Darunmallik	7.37 (±0.01)	0.91 (±0.02)
Telekhali	7.56 (±0.02)	22.45 (±0.05)
Fulbari	7.25 (±0.01)	2.10 (±0.07)

Figures in the parenthesis indicates standard error (±) of means

3.3.2. pH and Electrical Conductivity (EC) of Deep Tube-well Water

In Paikgachha upazila, Khulna, water samples were collected from 11 different deep tube-wells to examine the different water chemical parameters. The deep tube-wells are situated in Fulbari-1, Fulbari-2, Senerberh, Bigordana, Soladana-1, Tangramari, Carbanda-1, Carbanda-2, Soladana-2, Noyai, Gobipagla village. Data were collected on 20 March 2015. Table 6 showed the pH value of deep tube-well water ranged from 7.20 to 7.44 over the 11 samples. The EC value varied within a wide range from 3.38 to 8.87 dS/m.

Table 6. pH and electrical conductivity of some selected deep tube-wells collected from different villages of Paikgachha upazila, Khulna, Bangladesh

Deep tube-well water		
Tube-well no.	pH	EC (dS/m)
Fulbari-1	7.35 (±0.01)	5.75 (±0.06)
Fulbari-2	7.30 (±0.02)	6.63 (±0.16)
Senerberh	7.27 (±0.01)	5.89 (±0.06)
Bigordana	7.35 (±0.01)	5.41 (±0.05)
Soladana-1	7.24 (±0.02)	4.30 (±0.13)
Tangramari	7.44 (±0.04)	3.38 (±0.03)
Carbanda-1	7.21 (±0.01)	7.43 (±0.06)
Carbanda-2	7.28 (±0.01)	3.42 (±0.03)
Soladana-2	7.20 (±0.01)	3.98 (±0.04)
Noyai	7.33 (±0.01)	8.87 (±0.01)
Gobipagla	7.30 (±0.01)	6.88 (±0.01)

Figures in the parenthesis indicates standard error (±) of means

4. Conclusions

Soil and water salinity is a great threat to successful crop production and safe drinking water supply at Paikgachha upazila of Khulna district. The salinity levels both in soil and water in the study area show an increasing trend after monsoon period. When monsoon concludes, that is in dry period salinity starts to increase. The electrical conductivity (EC) value of water varied from pond to pond, and some pond water was found unsafe for irrigation. Deep tube-well water was unsafe for drinking. Polder was found very effective to lessen salinity problem at Paikgachha upazila. It potentially reduced pH and EC toxicity of soil. This study is very little but elementary work which will be supportive in future studies. The future studies should consider this variability's in order to receive more accurate solution for deteriorating the salinity problems in the coastal vicinity of Bangladesh.

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