https://doi.org/10.54989/msd-2022-0016

ASSESSMENT OF PHYSIO-CHEMICAL PROPERTIES OF GROUND WATER IN THE SOUTH WESTERN COASTAL ZONE OF BANGLADESH

KHAN Md. Shohel[1,2]

[1] Department of Environmental Science and Disaster Management, Noakhali Science and Technology University, Noakhali-3814, Bangladesh, sajibicb@gmail.com

[2] Institute of Bangladesh Studies, University of Rajshahi, Rajshahi-6205

ABSTRACT: Groundwater quality is deteriorating due to contamination of various pollutants from different anthropogenic functions and salt water intrusion in the coastal regions of Bangladesh. Three coastal villages denoted as shoreline (Rajoir), interim (Gangarampur) and inland (Ganopatipur) areas of south western coastal zone of Bangladesh were purposively selected to determine the temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), dissolve oxygen (DO), total hardness (TH), chloride (Cl-), potassium (K+) and calcium (Ca++) ions. A total of 40 water samples were collected from 20 sampling sites based on the maximum water use declared by local communities. Temperature, pH, EC, TDS and DO were measured onsite and TSS, TH, Cl-, K+ and Ca++ were measured in the laboratory. Based on the EC values 100% water samples were within the desirable limit (<750 µS/cm) in inland area but in shoreline area, 100% water samples were not permissible limit (>1500 µS/cm). TDS classification showed that 100% sampling station's water were fulfilled the criteria for irrigation purpose in shoreline area and 100% sampling station's water were within desirable category in inland area. The study revealed that the trend of EC, TDS and Cl- concentrations were decreased from shoreline to inland villages, respectively. The study resulted the positive correlation between EC: TDS (r=0.712), TDS: Ca (r=0.585), DO: K (r=0.5041), Cl- : K (r=0.581), K: Ca (r=0.635) showed homogeneous sources of variables and same anthropogenic activities might be responsible for the excess concentrations in the study area. So, the water should not be used for drinking purpose without any proper treatment.

KEYWORDS: Groundwater, Tube well, Shoreline, Interim and Inland

1. INTRODUCTION

Drinking water scarcity existed in the entire coastal zones of Bangladesh and some areas of the coastal zones were fully dependent upon shallow/deep tube well water because of excessive salinity (Ahmed et al., 2020) and cost effectiveness. In global water distribution, only 0.26% of fresh water is available for human being consumption and stored in streams, lakes, soil moisture and ground water (Park, 2001; Rasheed, 2011). Water used in diversified ways for agriculture, industrial, commercial, forestry, fisheries, navigation, ecosystem, etc. and also for community services of domestic consumption including drinking and sanitation (Rasheed, 2011). The countrywide fresh water demand is growing every day which is being intensified by several socio-technical drivers of high demographic changes, quick and unplanned industrialization and urbanization, climate change, etc. Vulnerable ecosystem and the inconsistency of water availability in winter, monsoon and summer seasons complicates this issue more vulnerable.

Bangladesh has restricted contact to both surface and ground freshwater in rural areas because of excessive salinity intrusion in coastal areas (Bernier et al., 2016) and riverine flood plain country in the world (Khan et al., 2021). These areas are composite systems with robust, dynamic interconnections between physical and anthropogenic processes demanding special attention (Welch et al., 2017) and face acute burdens including different land use pattern due to construction of embankments and abstraction of groundwater for agricultural and household consumption (Adnan et al., 2019; Syvitski et al., 2009) as well as transformation of agricultural cultivable lands into shrimp farming. The water is directedly adulterated by nonstop use of different inorganic fertilizers and insecticides for agriculture and fish feed for shrimp farming, especially, tiger prawn cultivation. This country is very much exposed to vulnerable because of negative impacts temperature because of its physiographical location, the influence of seasonal water flow patterns from upstream, rainfall, and fluctuations, natural catastrophic or manmade/natural disasters, etc. that increases the possibility of deterioration of water quality (Hossain et al., 2021; Salam et al., 2019). It may also further be responsible for industrial sewages including geochemical process for surface water and infiltration-percolation-runoff-leaching for ground water from point and non-point sources of polluted sites (Verlicchi and Grillini, 2020). The objective of this scientific study was to determine the selected physiochemical properties of ground water (tube well) and to compare the result among shoreline, interim and inland villages of the study area.

2. METHODOLOGY

2.1. Study Area

The adjacent three districts (tier 2) of south western coastal zones of Bangladesh, Satkhira, Khulna and Bagerhat were purposively selected as the study area. Then, the upazila (tier 3) were categorized into three types, i. e., shoreline (exposed), interim and inland coastal zones based on the distance from the coast, salinity concentrations, mean tidal fluctuations and cyclonic risk (table 1), respectively. Upazila, and villages were also selected purposively depending upon fresh water crisis and unavailability. Three villages named Rajoir (Sarankhola), Gangarampur (Batiaghata) and Ganapatipur (Kalaroa) were determined as shoreline, interim and inland villages, respectively (figure 1). The dominant sources of fresh water in the selected areas were tube well except shoreline village (table 2). The maps were derived from Banglapedia (2021).

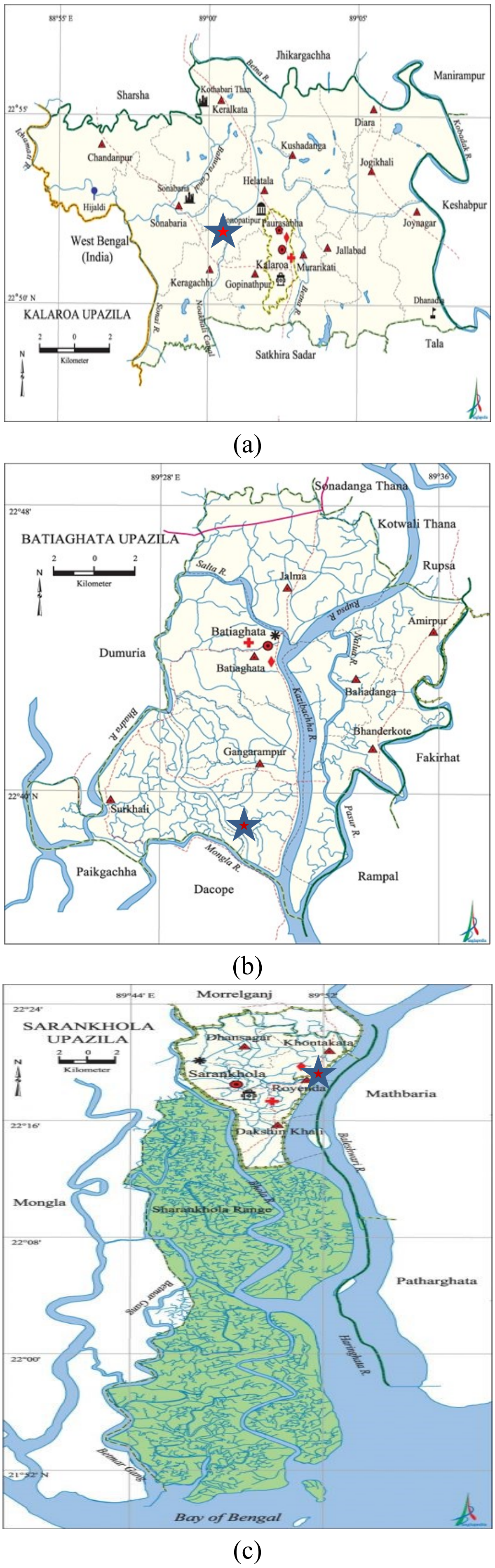

Figure 1. Map of (a) Kalaroa (b) Batiaghat and (c) Sarankhola upazila, ★ denoted the study villages, source: Banglapedia (2021)

2.2. Sampling and analytical procedure

A total of 40 tube well water samples from 20 sampling sites were collected from three selected villages of shoreline, interim and inland coastal areas between 15 March 2022 to 15 April 2022. Tube well was selected based on the maximum water use declared by local communities. Water samples were collected in a plastic bottle which were pre-washed with distilled water. Again, a glass of water was collected for testing some variables on site. Samples were stockpiled in an icebox and transported to Institute of Environmental Science (IES), University of Rajshahi (RU) laboratory. The samples were stored in a refrigerator <4ºC up to complete the experiment.

2.3. Determination of water variables and analysis

A total of 10 different variables (table 3) were tested to accomplish the study. Temperature, pH, TDS and DO were measured in the field directly. The DO reading was converted into ppm through online calculator (https://www.waterontheweb.org/under/waterquality/dosatcalc.html) with considering the temperature. For determination of K and Ca ion samples were prepared in IES laboratory and transferred to Central Science Laboratory (CSL) of University of Rajshahi through Atomic Absorption Spectrophotometer (AAS). The proper methods were tabulated in table 3. Data were analyzed by using MS excel (version 2016) and Statistical Package for the Social Sciences (SPSS, version 22.0).

3. RESULT AND DISCUSSION

3.1. Physio-chemical properties of water

The variables (Temperature, EC, pH, TDS, TSS, DO, TH, Cl-, K+ and Ca++ concentrations were analysed to know the quality of water. The EC and TDS were classified into several types showed in table 4 and identified the percentage of water suitability in the respective area. Based on the EC values 100% water samples were within the desirable limit (<750 µS/cm) in inland area but in shoreline area, 100% water samples were not permissible limit (>1500 µS/cm). TDS were classified by Vetrimurugan, et al., (2017) and Davis and DeWiest (1966) showed that 100% sampling station's water were used for irrigation purpose and exceeded the value set by ECR (1997) in shoreline area and 100% sampling station's water were used for desirable category in inland area (table 4). The mean, range and standard deviation of the selected variables showed different characteristics. The temperature was ranged between 30.5-30.9, 29.5-32.5 and 28.9-32.4 ºC from shoreline, interim and inland villages, respectively. The mean temperature was also ranged between 30.7± 0.28, 30.9 ± 1.13 and 30.2 ± 1.20 for shoreline, interim and inland villages. The study revealed that the temperature of shoreline village and mean temperature of all of the study area exceeded the guideline value (20-30 ºC) set by ECR (1997). The mean pH of all of the study area were within the limit set by both WHO (2017) and ECR (1997).

The total concentration of soluble salt (EC) is one of the vital variables to measure water quality. The EC were ranged between 1856-1982, 1120-1955 and 570-737 µS/cm from shoreline, interim and inland villages, respectively that the study resulted the higher EC was found shoreline and interim villages that exceeded the guideline value of ECR, compare to inland village. The result also claimed that salinity also would be characterized in such a pattern. The mean value of EC was also ranged between 1919± 89.1, 1614 ± 286 and 674 ± 70.7 µS/cm for shoreline, interim and inland villages (table 6a). Similar type of finding was found in Khulna District (interim zone) for EC (100-

6830 μS/cm), for pH (6.4 -7.9), respectively (Mahmud et al., 2020); temperature (27.95ºC), EC (804 μS/cm), pH (7.7) and TDS (522ppm) in cox's bazar district (Deeba et al., 2021).

Table 1. Concentration of the selected indicators of the coastal zone in study districts (PDO-ICZMP, 2003)

District	Upazila	Salinity (dS/m)			Mean tidal fluctuations over the year (m)	Cyclone risk
		Soil	Surface water	Ground water		
Satkhira	Kalaroa	<4	5-10	5-10	1-2	Low
Khulna	Batiaghata	8-15	5-10	1-2	>2	Medium
Bagerhat	Sarankhola	>15	1-5	>10	>2	High

Table 2. District and upazila wise sources of fresh water in the area (source: BBS, 2011a, b, c)

Sources	Bagerhat*	Sarankhola**	Khulna*	Batiaghata**	Satkhira*	Kalaroa**
Tap water (HH)	22528	4230	10810	41	27792	368
Tap water (%)	6.43	16.01	2.0	0.1	5.93	0.62%
Tub well water (HH)	209980	8849	452402	39195	370761	57775
Tub well water (%)	59.90	33.65	83.7	96.4	79.08	97.56
Others (HH)	118029	13222	77292	1423	70300	1079
Others (%)	33.67	50.28	14.30	3.50	14.99	1.82
Total (HH)	350537	26301	540504	40659	468853	59222
Total (%)	100	100	100	100	100	100

*Represents the districts and ** represents the upazila; HH represents households.

Table 3. Determination of variables with instruments/methods

Sl.	Variables	Unit	Instruments/methods
1	Temperature	ºC	pH meter (Adwa AD 12)
2	pH	unitless	pH meter (Adwa AD 12)
3	Electrical conductivity (EC)	μS/cm	EC meter (Adwa AD 31)
4	Total dissolved solids (TDS)	ppm	TDS meter (Adwa AD 201)
5	Dissolved oxygen (DO)	ppm	DO meter (Lutron PDO-519)
6	Total suspended solids (TSS)	ppm	Filtration through Whatman 42 paper
7	Total hardness (TH)	ppm	EDTA* titration method
8	Chloride (Cl^-)	ppm	$AgNO_3$ titration method
9	Potassium (K)	ppm	Flame atomic absorption spectrophotometer (AAS)
10	Calcium (Ca)	ppm	Flame atomic absorption spectrophotometer (AAS)

*EDTA represents ethylenediaminetetraacetic acid

Table 4. Water suitability determination based on EC and TDS

Variables	Classification	Water suitability	Shoreline (%)	Interim (%)	Inland (%)
EC (μS/cm) (Vetrimurugan et al., 2017; WHO, 1993)	<750	Desirable			100
	750–1500	Permissible		40	
	>1500	Not permissible	100	60	
TDS (ppm) (Vetrimurugan et al., 2017; Freeze and Cherry, 1979)	<1000	Fresh			100
	>1000	Brackish	100		
TDS (ppm) (Vetrimurugan, et al., 2017; Davis and DeWiest, 1966)	<500	Desirable for drinking			100
	500–1000	Permissible for drinking		10	
	1000–3000	Useful for irrigation	100	90	

Table 5. Descriptive statistics of selected variables in the study area

Study area		Temp.	EC	pH	TDS	TSS	DO	TH	Cl^-	K^+	Ca^{++}
Shoreline village	Std. dev.	0.28	89.1	0.24	165	222	0.74	2.69	442.034	0.2449	1.4172
	Min.	30.5	1856	7.57	1640	224	4.34	28.7	1953.08	1.178	1.0426
	Max.	30.9	1982	7.91	1873	538	5.39	32.5	2578.21	1.5244	3.0468
	Mean	30.7	1919	7.74	1757	381	4.87	30.6	2265.65	1.3512	2.0447

	Std. dev.	1.13	286	0.49	281	87	0.49	9.56	409.386	0.3585	1.1310
Interim village	Min.	29.5	1120	7.07	984	42	2.83	18.7	142.23	0.4884	0.5114
	Max.	32.5	1955	8.87	1820	340	4.47	44.9	1461.02	1.5132	4.106
	Mean	30.9	1614	8.1	1236	151	4.06	31.2	536.318	0.9903	2.1754
	Std. dev.	1.2	70.7	0.46	30.9	153	0.53	19.7	178.501	0.1532	0.0743
Inland village	Min.	28.9	570	7.09	301	40	2.91	12.9	214.08	0.6248	0.8196
	Max.	32.4	737	8.28	387	416	4.31	67.2	659.79	1.0474	0.9794
	Mean	30.2	674	7.59	359	303	3.78	39.1	429.068	0.7981	0.9157
WHO (2017) limit		-	-	6.5-8.5	600-1000	-	6	250	500	12	75
ECR (1997) limit		20-30	1000	6.5-8.5	1000	10	6	150-600	200-500	12	75

Table 6. Correlation matrix among studied variables of tube well water in the study area (two tailed)

	Temp.	EC	pH	TDS	TSS	DO	TH	CL-	K	Ca
Temp.	1									
EC	0.1654	1								
pH	-0.4106	0.4354	1							
TDS	0.3522	**0.7118**	0.1791	1						
TSS	0.0098	-0.1909	-0.091	-0.2222	1					
DO	0.2149	0.478	-0.1284	0.422	0.1365	1				
TH	-0.1728	-0.2549	-0.2142	-0.2649	-0.079	-0.1347	1			
CL-	0.2068	0.4779	-0.0958	0.4344	0.2556	0.4862	-0.0298	1		
K^+	0.4691	0.3906	-0.0209	0.4525	0.3331	**0.5041**	-0.3989	**0.5813**	1	
Ca^{++}	0.4918	0.3648	0.0726	**0.5854**	0.0732	0.2582	-0.2232	0.1399	**0.6346**	1

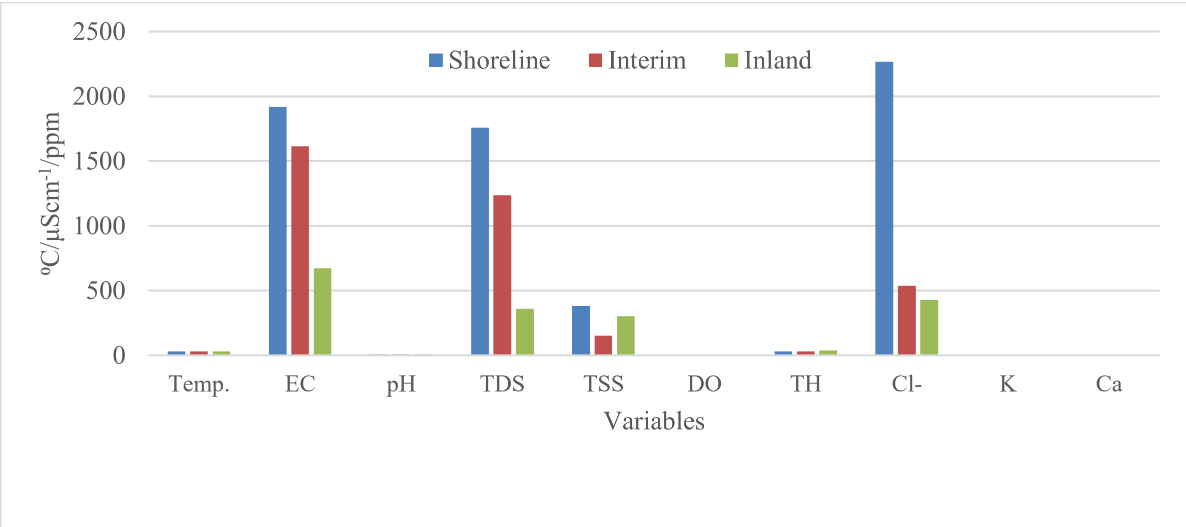

Figure 2. Mean concentrations of different variables in the study area

The TDS, TSS and DO concentration were ranged between 1640-1873 ppm, 224-538 ppm and 4.34-5.39 ppm, respectively for shoreline village, followed by 984-1820 ppm, 42-340 ppm and 2.83-4.47 ppm for interim village; 301-387 ppm, 40-416 ppm and 2.91-4.31 ppm, respectively, for inland village. The study resulted that the lowest deviation of concentration of TDS value were found in the inland village. The mean concentration of these variables for shoreline, interim and inland villages were 1757 ± 165 ppm (TDS), 381 ± 222 ppm (TSS) and 4.87 ± 0.74 ppm (DO); 1236 ± 281 ppm (TDS), 151 ± 87 ppm (TSS) and 4.06 ± 0.49 ppm (DO); 359 ± 30.9 ppm (TDS), 303 ± 153 ppm (TSS) and 3.78 ± 0.53 ppm (DO), respectively. Similar type of finding was found in Khulna District (interim zone), for DO (0.59-4.21 ppm), for EC (100-6830 ppm) and for TDS (7.24-6450 ppm), respectively (Mahmud et al., 2020). The TH, Cl-, K and Ca ion for the shoreline village were ranged between 28.7 - 32.5 ppm, 1953 - 2578 ppm, 1.178 - 1.524 ppm and 1.04 - 3.046 ppm, respectively. Followed by interim village, 18.7 - 44.9 ppm, 142.23 - 1461.02 ppm, 0.4884 - 1.5132 ppm and 0.5114 - 4.106 ppm; inland village, 12.9 - 67.2 ppm, 214.08 - 659.79 ppm, 0.6248 - 1.0474 ppm and 0.8196 - 0.9794 ppm, respectively (table 5). The study findings resulted that the highest mean EC, TDS, TSS and Cl- value were found in the shoreline village, followed by interim and inland villages (figure 2) and TDS and Cl- concentrations of shoreline and interim villages exceeded the limit set by WHO (2017) and ECR (1997).

3.2. Pearson correlation

The correlation result ranged between '-1' to '+1', which '-1' indicates the strongest negative relationship and '+1' indicates strongest positive relationship between two variables. The correlation matrix was produced at 95% significance level to find out the associations and relationship among the variables. The correlation result showed some positive and negative relationship among the determined variables (table 6). The positive correlation represented the variable's homogeneous source of origin and negative correlation represented the heterogeneous source of origin (Deeba et al., 2021; Giri and Singh, 2015). The correlation between EC: TDS (r=0.712), TDS: Ca (r=0.585), DO: K (r=0.5041), Cl-: K (r=0.581), K: Ca (r=0.635) showed a strong positive relationship, that suggested the same sources of origin of variables and same anthropogenic activities or variable movement were responsible in the study area (Deeba et al., 2021; Haloi and Sarma, 2012).

On the other hand, the negative correlation indicated the origin of these variable were different sources. In addition, insignificant positive/negative correlation resulted that these variables were independent and probably the sources were also different. It is concluded that multiple anthropogenic sources (i.e., agricultural fertilizer and pesticides, domestic latrines, industrial effluents, municipal household waste, brick field waste, community sewerage system, etc.) were responsible for contamination and pollution of the ground water in three study shoreline (Rajoir), interim (Gangarampur) and inland (Ganapatipur) villages, respectively.

4. CONCLUSION

The study measured the temperature, EC, pH, TDS, TSS, DO, TH, Cl-, K+, Ca++ concentrations of tube well water collected from shoreline (Sarankhola, Bagerhat), interim (Batiaghata, Khulna) and inland (Kalaroa, Satkhira) villages, respectively. The positive correlation denoted the same sources of pollutants, whereas, negative correlation denoted the different sources of pollutants in the south western coastal zones of Bangladesh. The K+ and Ca++ of all the water samples were within the limit but Cl- ion was exceeded for several sample sites. Finally, based on the study, water of inland areas was better than interim and water of shoreline areas were not suitable for drinking without filtration or treatment.

Acknowledgements

The authors would like to acknowledge the authority of Institute of Bangladesh Studies, Institute of Environmental Science (IES) and Central Science Laboratory (CSL), University of Rajshahi (RU), Rajshahi-6205 for supporting the facilities to complete this research and anonymous reviewers for their valuable comments which increase the quality of the research. Special acknowledgement goes to Professor Dr. Md. Golam Mostafa of IES, RU for giving the opportunity for sample preparation in his water laboratory. Lastly, in depth gratitude to my supervisor Professor Dr. Shitangsu Kumar Paul, Department of Geography and Environmental Studies, University of Rajshahi, Bangladesh.

Funding

This work did not receive any funds but lab facilities were provided by CSL, RU with a minimum cost.

REFERENCES

1. Adnan, M.S.G., Haque, A., Hall, J.W. (2019). Have Coastal Embankments Reduced Flooding in Bangladesh? *Science of The Total Environment*, 682, 405-416. https://doi.org/10.1016/j.scitotenv.2019.05.048.
2. Ahmed, A., Ghosh, P.K., Hasan, M., Rahman, A. (2020). Surface and Groundwater Quality Assessment and Identification of Hydro-Chemical Characteristics of South-Western Coastal Area of Bangladesh, *Environmental Monitoring Assessment,* 192, 258. https://doi.org/10.1007/s10661-020-8227-0
3. Banglapedia. (2021). The National Encyclopedia of Bangladesh, *Asiatic Society of Bangladesh*, Dhaka. https://en.banglapedia.org/index.php/Kalaroa_Upazila; Batiaghata_Upazila; Sarankhola_Upazila
4. BBS (Bangladesh Bureau of Statistics). (2011a). *Population and Housing Census 2011, Community Report, Satkhira Zila*. Statistics and Informatics Division, Ministry of Planning, Bangladesh.
5. BBS (Bangladesh Bureau of Statistics). (2011b). *Population and Housing Census 2011, Community Report, Khulna Zila*. Statistics and Informatics Division, Ministry of Planning, Bangladesh.
6. BBS (Bangladesh Bureau of Statistics). (2011c). *Population and Housing Census 2011, Community Report, Bagerhat Zila.* Statistics and Informatics Division, Ministry of Planning, Bangladesh.
7. Bernier, Q., Sultana, P., Bell, A.R. and Ringler, C. (2016). Water Management and Livelihood Choices in Southwestern Bangladesh. *Journal of Rural Studies*, 45, 134-145. https://doi.org/10.1016/j.jrurstud. 2015.12.017.
8. Davis, S.N., DeWiest, R.J.M. (1966). *Hydrogeology*. Wiley, New York.
9. Deeba, F., Rahman, S.H., Kabir, M.Z., Dina, N.T., Das, S.C., Sultana, S., Ahmed, F.T. (2021). Heavy Metals Distribution and Contamination in Groundwater of the South Eastern Coastal Area of Bangladesh. *Journal of Water and Environment Technology,* 19(5), 267-282. doi: 10.2965/jwet.20-169
10. ECR, *The Environment Conservation Rules* (1997). Department of Environment, Government of the People's Republic of Bangladesh. Poribesh Bhaban E-16, Agargaon, Sher-e- Bangla Nagar, Dhaka-1207, Bangladesh. 179-226 (58 pages).
11. Freeze, R.A., Cherry, J.A. (1979). *Groundwater*. Prentice Hall Inc, New Jersey.
12. Giri S., Singh, A.K. (2015). Human Health Risk Assessment Via Drinking Water Pathway Due to Metal Contamination in the Groundwater of Subarnarekha River Basin, India. *Environmental Monitoring Assessment*, 187(3), 63. doi:10.1007/s10661-015-4265-4
13. Haloi, N., Sarma, H.P. (2012). Heavy Metal Contaminations in The Groundwater of Brahmaputra Flood Plain: An Assessment of Water Quality in Barpeta District, Assam (India). *Environmental Monitoring Assessment,* 184(10), 6229-6237. doi:10.1007/s10661-011-2415-x
14. Hossain, M.R., Khan, M.S., Islam, M.A., Hasan, M. (2021). Pond Sand Filter as An Alternative System for Purifying Drinking Water: Climate Change Perspective in Mongla, Bangladesh. *International Journal of Energy and Water Resources*, https://doi.org/10.1007/s42108-021-00172-y
15. Khan, M.S., Apu, M.R., Begum, S., Billah, M.M. (2021b). Sectoral Impacts of Flash Flood in Tanguar Haor in Sunamganj of Bangladesh, *Asian Journal of Geographical Research*, 4(2), 55-64.
16. Mahmud, A., Shraboni, S. Jagadish C.J. (2020). Assessment of Groundwater Quality in Khulna City of Bangladesh in Terms of Water Quality Index for Drinking Purpose.

Applied Water Science, 10, 226. https://doi.org/10.1007/s13201-020-01314-z
17. Park, C.C. (2001). *The Environment: Principles and Application*. London: Routledge.
18. PDO-ICZMP (Program Development Office for Integrated Coastal Zone Management Plan). (2003). *Delineation of The Coastal Zone, Working Paper*, WP005, Dhaka, Bangladesh.
19. Rasheed, K.B.S. (2011). *Water Resources Management: With Examples from Bangladesh*. Bangladesh, Dhaka: A H Development Publishing House.
20. Salam, M.A., Khan, M.S., Sarker, M.A.H. (2019). Impacts and Coping Techniques to Flood: A Case Study on Two Adjacent Char Land of Jamuna River in Sirajganj District, Bangladesh. International Research *Journal of Environmental Sciences*, 8(3), 53-61.
21. Syvitski, J.P.M., Kettner, A.J., Overeem, I., Hutton, E.W.H., Hannon, M.T., Brakenridge, G.R., Day, J., Vorosmarty, C., Saito, Y., Giosan, L. and Nicholls, R.J. (2009). Sinking Deltas Due to Human Activities. *Natural Geoscience*, 2, 681-686. https://doi.org/ 10.1038/ngeo629.
22. Verlicchi, P. and Grillini, V. (2020). Surface Water and Groundwater Quality in South Africa and Mozambique-Analysis of the Most Critical Pollutants for Drinking Purposes and Challenges in Water Treatment Selection. *Water,* 12, 305. doi:10.3390/w12010305.
23. Vetrimurugan, E., Brindha, K., Elango, L., Ndwandwe, O.M. (2017). Human Exposure Risk to Heavy Metals Through Groundwater Used for Drinking in An Intensively Irrigated River Delta. *Applied Water Science*, 7, 3267-3280, DOI 10.1007/s13201-016-0472-6
24. Welch, A.C., Nicholls, R.J. and Lázár, A.N. (2017). Evolving Deltas: Coevolution with Engineered Interventions. *Elementa Science of the Anthropocene,* 5, 49. https://doi.org/10.1525/elementa.128.
25. WHO. (World Health Organization, 1993). *Guidelines for Drinking Water Quality,* vol. 1, 2nd edition, Recommendations, WHO, Geneva,130
26. WHO. (World Health Organization, 2017). *Guidelines for Drinking-Water Quality*: Fourth Edition Incorporating the First Addendum. Geneva: World Health Organization. License: CC BY-NC-SA 3.0 IGO.