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Research Article

Ionic status of ground and surface water at Madaripur in Bangladesh for drinking and agricultural uses

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ABSTRACT

Water is essential for livestock consumption, drinking, agriculture, and aquaculture. Pond and river are considered to be self-contained, landlocked ecosystems that are often teeming with rich vegetation and diverse organismal life. Groundwater is also involved with drinking and irrigation. Water contains different organic and inorganic components. The water samples were investigated for Mg, pH, Na, EC, Ca, K, S, and P ion at Rajoir Upazila on Madaripur district in Bangladesh to know the water quality of this Upazila for various uses from November 2020 to October 2022. During the study period, Surface water (pond water) had an average pH higher than that of river and tube-well water. The average pH of Pond water was 7.54 at Bajitpur and Raajoir Union. The present research also showed the Electrical Conductivity (EC) ranged from 280 to 1451.67 µScm-1. For irrigation, the Sodium Absorption Ratio (SAR) is the key feature. River water had the lowest SAR (0.567) and Groundwater had the highest (8.67 MeL-1). Groundwater had the highest SSP value (88.9%), while river water had the lowest (24.8%). Almost all the ground and surface (pond and river) water samples were slightly alkaline and appropriate for drinking, irrigation, livestock farming, and aquaculture.

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INTRODUCTION

Quality water is essential for saving lives, and agricultural production as well as to build up a healthy nation. The earth's surface is covered in water to a degree of about 80%. Merely 33,400 m^3 of the predictable 1,011 million km^3 of entire water on Earth are suitable for home, industrial, agricultural, and drinking purposes [1]. In Bangladesh, there are roughly 1.3 million ponds spread across 147000 hectares. With careful excavation and use, these ponds can be transformed into possible miniature reservoirs for fish farming or irrigation [2]. Rivers, streams, and lakes conveniently contain freshwater, which up to only 0.01% of the earth's total water [3]. The amount of fresh water decreased

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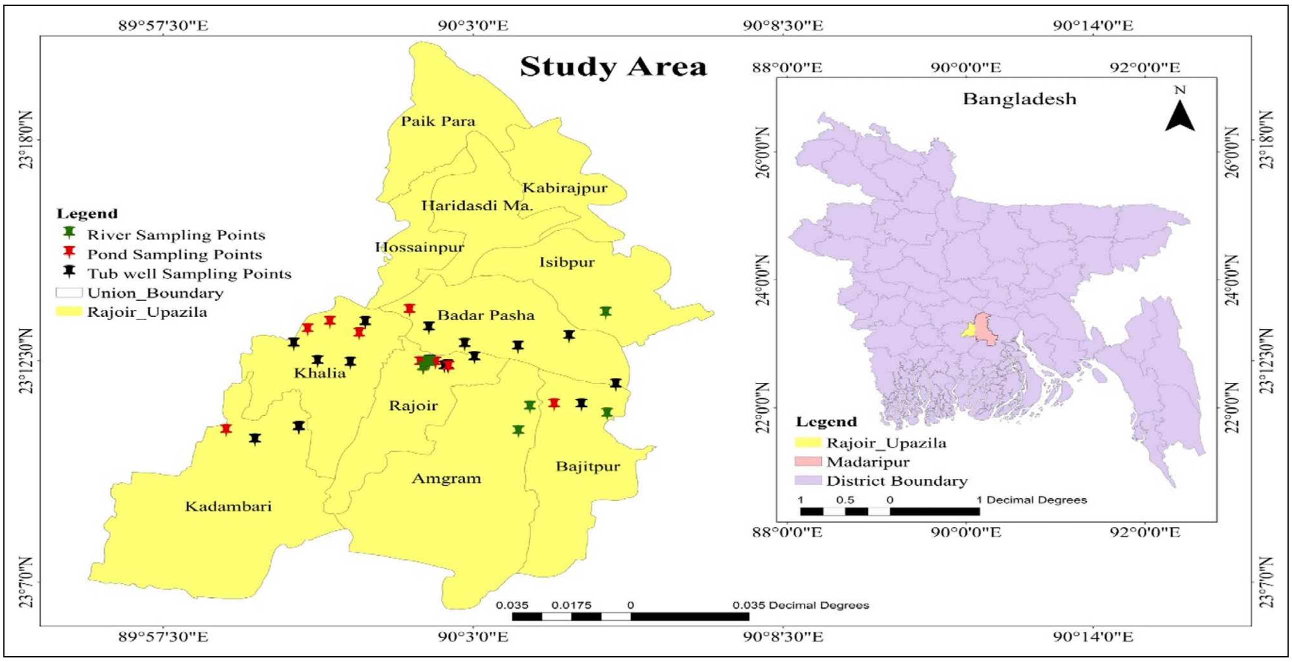

Figure 1. Map of sampling location of Rajoir Upazila.

and the amount of undrinkable water increased due to rising sea levels. Bangladesh is a riverine and plane country with large inland aquatic bodies, containing some of the largest rivers in the world. Due to its peculiar geographic features, Bangladesh is highly vulnerable [2]. Both humans and other animals are harmed by poor quality or contaminated water. Nonetheless, there are trace amounts of organic matter and ions of a few other elements, including Li, B, Ba, Si, Zr, Ti, V, Cr, Mn, Pb, F, Mo, Co, Se Ru, Br, I, Cu, Be, Ni, Ce, As, Bi, P, and Sb [4]. The chemical composition of water is one of the primary factors influencing its quality [5]. Ionic toxicity can arise from using poor quality water for drinking, irrigation, aquatic culture, livestock and poultry consumption, and other uses [6]. In the aforementioned conditions, studies were carried out in Rajoir Upazila of the Madaripur district to evaluate the water quality for agriculture and to compare the ionic status of river, groundwater, and pond water. In addition, to evaluate water sources are suitable for livestock feed, aquaculture, drinking, and irrigation. No comprehensive study was performed in this locality related to the Ionic status of drinking and irrigation water, which is essential for this area.

MATERIALS AND METHODS

According to data from 2016 to 2024, Madaripur district has a maximum temperature of 91°F and a minimum temperature of 80°F with an average rainfall of 65% at summer. On the other hand, the maximum and minimum temperatures during the fall season are 89°F and 63°F, respectively while the average rainfall is 34.5% (source: weather spark).The chemical analyses included Total Dissolved Solids (TDS), Electrical Conductivity (EC), Total Permanent Hardness (TPH), Residual Sodium Carbonate (RSC), pH, Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), calcium (Ca), sodium (Na), potassium (K), phosphorous (P), magnesium (Mg), sulphur (S) etc.

Collection of Water Samples

Twenty one (21) ground water samples, eleven (11) pond water and eight (8) river water samples were taken from various points of Rajoir Upazila at Madaripur district in Bangladesh (Fig. 1) and to know the water quality of this Upazila for various uses during November 2020 to October 2022 following the water sampling methods as defined [7]. Water samples were collected in 500 ml plastic bottles. These bottles were cleaned with dilute hydrochloric acid, and washed with tap water and distilled water. Before sampling, containers were again rinsed 3 to 4 times with the water to be sampled. In the case of the river, water samples were drawn from the mid-stream and a few centimeters below the surface. The collected samples were tightly sealed immediately to avoid exposure to air. After proper marking and labeling, the water samples were carried to the Laboratory of the Department of Agricultural Chemistry, PSTU for testing and kept in a clean, cool, and dry place. Samples were filtered through Whatman No. l filter paper to remove undesirable solid and suspended materials. The analysis was conducted as soon as possible on arrival at the laboratory

Analytical Methods of Water Analyses

The pH value of water samples was evaluated using a pH meter (Brand: WTW pH 522) according to Singh & Parwana [8]. A conductivity meter (Brand: WTW LF 521) was used to measure the EC of a sample of water [9]. TDS was measured using the Chopra and Kanwar [10] method. The samples of pond water were tested for calcium content using the EDTA Titrimetric method. The authors of this analytical method were Singh and Parwana (1999) [8] and

Table 1. Maximum recommended concentrations of various chemical ions for irrigation and drinking water

Name of elements	Drinking		Irrigation
pH	Existing average limits	Recommended maximum limits	Maximum limits
EC	6.50–7.50	6.5–9.0	6.5–8.4
Ca	50–600 µScm-1 (Suitable), more than 600 µScm^{-1}, (Harmful)		50–500 µScm^{-1} (Suitable)
Mg	Less than 2.50 meL^{-1}	Less than 3.75 meL^{-1}	800 mgL^{-1}
Na	Less than 3.50 meL^{-1}	Less than 3.75 meL^{-1}	121.50 mgL^{-1}
K	More than 1.5 meL^{-1}	1.50 - 15.50 meL^{-1}	121.50 mgL^{-1} (4.5 meL^{-1}), suitable
S	Less than 2.50 meL^{-1}	0.30 – 0.80 meL^{-1}	2 mgL^{-1}
P	400 mgL^{-1}	200 mgL^{-1}	20 mgL^{-1}
	1 mgL^{-1}	5 mgL^{-1}	2 mgL^{-1}

Source: WHO, [18] [Dringking Water]; Ayers and Westcott, [17] [Irrigation].

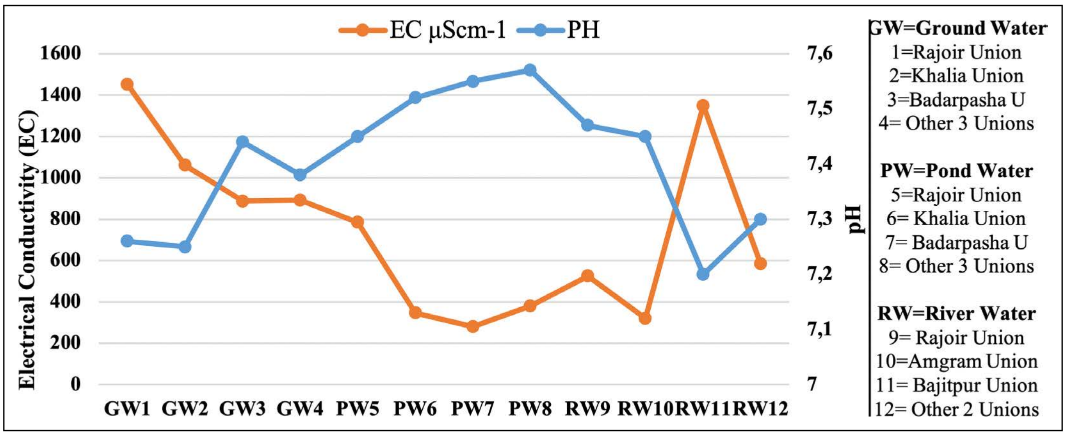

Figure 2. pH and EC profiles during the study period.

Page et al. [11]. Potassium and sodium concentrations were measured from individual water samples, and the percentage of emissions was noted using the procedure defined by Golterman [12] and Ghosh et al. [9]. The concentration of phosphate in water samples were determined by the process of spectrophotometric as per Jackson [13]. Sulphate was determined by Tandon (terbidimetric method) [14]. The Carbonate and bicarbonate content of water samples were examined by acidimetric method of Ghosh et al. [9] and Tandon [14].

Statistical Analysis

The analytical data from the water sample analyses were statistically analyzed (Gomez and Gomez) [15]. Additionally, correlation studies were conducted using MS Excel, a standard computer program.

RESULTS AND DISCUSSION

The major ionic constituent of surface water samples collected from different sources and locations at Rajoir Upazila under Madaripur District were analyzed and the results obtained from chemical analyses have been delineated in this chapter. In the study area, vital ionic constituents such as Ca, SO_4, Mg, Na, K, PO_4, were analyzed and elements were present in variable amounts in the surface water samples.

pH and Electrical Conductivity (EC) Values of Water

The average pH value of surface water (pond water) was comparatively higher than tube wells and river water (Fig. 2). Two pond water samples collected from pond showed pH 7.57 and 7.51 in Bajitpur and Rajoir union. It might be due to the application of liming materials to the pond water to control pH value and fish diseases. These results were partially similar to Zaman et al. [16] where pH ranged from 7.26 to 9.67 in surface water. For agriculture purpose, Ayers and Westcot [17] state that the pH value between 6.5 and 8.4 is acceptable. Permitting to FAO standards, almost all the water samples were appropriate for irrigation. For livestock consumption and drinking purposes, recommended range of pH is 6.5 to 9.2 (Table 1) [18].

According to this recommendation collected water samples from rivers, cannals and ponds (surface water) were acceptable for livestock farming. The average value of EC indicate that the EC of groundwater was comparatively higher than pond and river water (Fig. 2). Based on EC, the agricultural waters were classified into four groups such as low salinity (EC=0–250 µScm^{-1}), moderate salinity (EC=250–750 µScm^{-1}), high salinity (EC=750–2250 µScm^{-1}) and extreme salinity (EC>2250 µScm^{-1}) following Richards [19]. These results are lower than the report on EC 219.0 to 748.0 µScm^{-1}, conducted by Uddin et al. [20] pointed out the EC value of 18 surface water samples of Dumki upazila and have little similarity with the report on EC 348 to 497 µScm^{-1} and 255 to

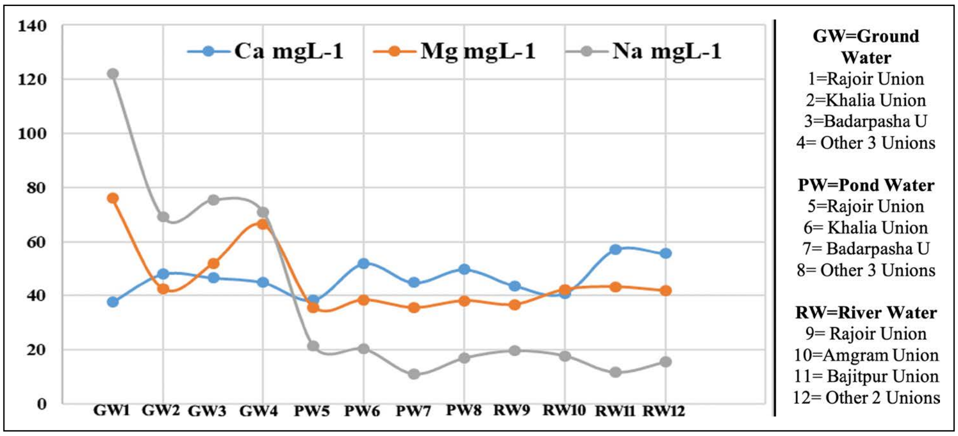

Figure 3. Ca, Mg and Na profiles during the study period (mgL^{-1}).

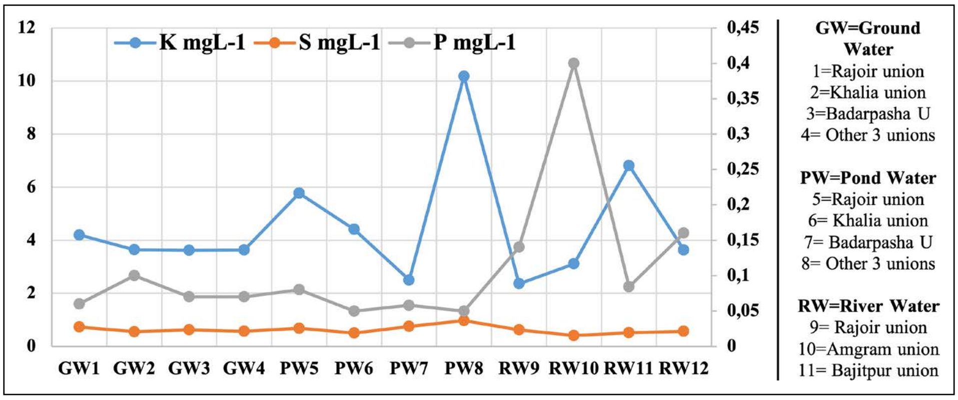

Figure 4. K, S and P profiles during the study period (mgL^{-1}).

387 μScm^{-1} of dry and wet season by Halim [21]. High EC indicated a higher concentration of salt, which has an impact on the salinity hazard and irrigation water quality [22].

Ionic Constituents of Water

The average value of Ca in tube wells, ponds and river water were 44.126, 45.181 and 49.599 mgL^{-1} (Fig. 3). The presence of higher Ca content in some samples might be due to the solubility of $CaCO_3$, $CaSO_4$ and $CaCl_2$. Some of the samples were similar to the findings of Uddin et al. [20] in Dumki different from 16.5 to 34.62 mgL^{-1}. Agricultural water containing less than 20 meL^{-1} (400.8 mgL^{-1}) Ca is appropriate for irrigating crop (Table 1) [17]. According to content of Ca, all water samples could safely be used for irrigation.

Considering fresh water quality for drinking purpose, almost 100% of the samples were found suitable, where the acceptable range of Ca for this aspect is 0.75 to 200 mgL^{-1} as mentioned in (Table 1) WHO, [18].

The results are almost similar to Karim et al. [23] reported that Mg content of 50 surface water were varied from 1.94 to 40.85 mgL^{-1} of 3 Upazilas of Bhola district. For drinking water, the highest suitable limit is 30 mgL^{-1} and maximum acceptable limit is 150 mgL^{-1} [18]. Based on WHO standards, all collected water samples were suitable for drinking purposes. It can be said that all the samples of Mg are appropriate for livestock consumption.

The average value of sodium indicate that Na ion content of groundwater was comparatively higher than pond and river water. The main causes of higher Na ion content in surface water are the presence of evaporated sediments, sewage and wastes, using soaps and detergents etc. Findings in this study showing a little similarity to Karim et al. [23], sodium (Na) content varied from 4.11 to 36.13 mgL^{-1} of 3 Upazila of Bhola. Water generally holding less than 920.00 mgL^{-1} Na is not harmful for long-term irrigation [17]. The acceptable content of Na in water samples for aquaculture is 121.50 mgL^{-1} [24]. All about collected samples of surface water were "suitable" for agricultural uses (Table 1). The average value of potassium indicate that K ion content of pond water was comparatively higher than pond and river water (Fig. 4). The existence of higher level of K in surface water (pond and river) might be due to the surface runoff of irrigation wastes, farm refuses, untreated manure sludge etc. The average value of Sulphur indicates that the S content of pond water was comparatively higher than tube well water and river water. The higher amounts of SO_4 ion in some samples were mainly due to the presence of sulfur reducing bacteria in water, which chemically change natural sulphates in water to hydrogen sulphide.

Similar results were also observed by Zaman et al. [16]. The suitable range of SO_4 ion in agricultural water is less than 20 mgL^{-1}, according to Ayers and Westcot [17]. All the surface water samples (river and pond) being examined were determined to be suitable for irrigation based on this limit. These samples were also healthy for drinking purposes because the expected range of SO_4 ion for these purpose is 200–600 mgL^{-1} according to WHO, 1971 [18] (Table 1). The average value of phosphorus indicates that the P content of tube well water was comparatively higher than pond and river water (Fig. 4). Taslima [25] also studied that this PO_4 content was similar in Gouripur and Muktagacha Upazila (PO_4 ion varied from 0.16 to 2.51 mgL^{-1}). According to Phosphorus content, all the samples were acceptable for aquaculture and irrigation. The expected range of Phosphorus content for livestock consumption is 0–1 mgL^{-1}. Therefore, all the samples were positive for livestock consumption. The Suitable range of phosphorus is 0.00–70 [18]. According to WHO, all taken samples were satisfactory for drinking purposes.

WATER QUALITY DETERMINING INDICES

Sodium Adsorption Ratio (SAR)

Richards [19] stated that water samples with SAR values of less than 10 are suitable for irrigation, 10 to 18 are good, 18 to 26 are fair, and more than 26 are not suitable for agriculture. The calculated SAR obtained from the chemical analyses of 19 surface water samples fluctuated from 0.600 to 2.356 MeL^{-1} in pond water with the average of 1.075 MeL^{-1} and 0.567 to 1.335 MeL^{-1} in river water with an average value of 0.915 MeL^{-1}. The highest SAR (8.674 MeL^{-1}) was found in groundwater and the lowest SAR (0.567) was found in river water. Crops may not be harmed by agricultural water with a SAR of less than 10.00 [26]. Alkalinity hazard was another factor taken into consideration when classifying all of the irrigation water samples. Based on the SAR value, 100% of the samples were classified as excellent for irrigation.

Soluble Sodium Percentage (SSP)

Another important metric that is frequently used to assess the suitability of groundwater for irrigation is the SSP. Furthermore, high sodium contents in relation to Ca and Mg ions decrease soil absorptivity because Na ions are drawn to clay particles and displace Ca and Mg ions, impairing soil permeability and causing deflocculation [27]. The highest SSP value (88.9%) was showed in groundwater and the lowest (24.8%) was observed in river water. In case of ground water, this ranged varied from 24.4% to 88.9% with the mean value of 63.7%. This outcome was slightly similar to Taslima [25] who studied in Gouripur and Muktagacha Upazila where the SSP varied from 9.11 to 31.28% but contradictory to Uddin et al. [20] in Dumki upazila (SSP 0.19 to 0.97%).

Total Permanent Hardness (TPH)

The total hardness (HT) or total permanent hardness (TPH) of groundwater ranged from 216 to 555 mgL^{-1} with an average value of 352 mgL^{-1}. Nine of the twenty-one groundwater samples had TPH values above the mean, while the remaining twelve samples had TPH values below the mean. The highest TPH value (553 mgL^{-1}) was monitored in groundwater and it was tube well water and the lowest value (191 mgL^{-1}) was also observed in pond water. On the other hand, the highest value of 343 mgL^{-1} was found in pond water. In case of surface water (pond and river), the TPH value of river water ranged from 208 to 366 mgL^{-1} and the mean value was 215 MeL^{-1}. Based on hardness, irrigation water was classified as "soft" (0–75 mg L^{-1}), "moderately hard" (75–150 mgL^{-1}), "hard" (150–300 mgL^{-1}) and "very hard" (>300 mgL^{-1}) [28]. According to their classification, out of 19 surface water samples, all the samples were hard to very hard. The higher values of TPH indicated the presence of higher amounts of Mg [27]. Divalent cations, such as Ca and Mg ions were abundant in the water samples, which led to their hardness [26].

CONCLUSION

Although there have been many studies on the ionic content of water in the past, this is significant as updated information for Madaripur district as well as Bangladesh as a whole. According to the World Health Organization, drinking water should contain no more than 70 mgL^{-1} of K, while 19.2 mgL^{-1} of K is acceptable for irrigation. Based on its K content, all of the collected water samples were suitable for drinking and irrigation. Pond and river water were perfect for drinking, agricultural purposes, and livestock use depending on the content found in tube wells. Water from ponds, rivers, and tube wells had acceptable P levels for irrigation, aquaculture, and drinking. All of the water samples were classified as excellent class (SAR<10) for irrigation purposes, with SAR values ranging from 0.567 to 8.377. In case of SSP 12 samples of surface water out of 19 were in "excellent" class, 6 samples were permissible and 1 sample was not permissible in class, whereas 15 groundwater samples were in "not-permissible" class, 4 samples were in "good" class, and the remaining two samples were in "permissible" class for irrigation in the studied area. According to hardness, out of 19 surface water samples, all the samples were hard to very hard in class. Furthermore, regular monitoring of water quality should be needed for the residents of this locality to access safe drinkable water to avoid health-related risks as well as determination of ionic status for irrigation purposes in a seasonal context for successful crop growth according to season which helps rational irrigation scheduling and water budget.

DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

USE OF AI FOR WRITING ASSISTANCE

Not declared.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] S. S. Dara, "A Textbook of Environmental Chemistry and Pollution Control," 7th ed. S. Chand and Company Ltd., Ram Nagar, New Delhi, India, pp. 44–75, 2007. [CrossRef]

[2] M. A. Matin, and R. Kamal, "Impact of climate change on river system," In The International Symposium on Environmental Degradation and Sustainable Development (ISEDSD), Dhaka, Bangladesh (pp. 61–65), 2010.

[3] C. L. Stanitski, P. L. Eubanks, C. H. Middlecamp, and N. J. Pienta, "Chemistry in context: Applying Chemistry in Society", McGraw-Hill, 2003.

[4] A. M. Michael, "Irrigation, Theory and Practices. Vikas Publishing House Private Limited, pp. 448–452, 708–717, 1997.

[5] U. C. Gupta, and S. C. Gupta, "Trace element toxicity relationships to crop production and livestock and human health: implications for management", Communications in Soil Science and Plant Analysis, 29(11-14), pp. 1491–1522, 1998. [CrossRef]

[6] M. W. Zaman, and M. M. Rahman, "Ionic toxicity of Industrial process waters in some selected sites of Sirajgonj in Bangladesh," Bangladesh Journal of Environmental Science, Vol. 2, pp. 27–34 1996.

[7] APHA, (American Public Health Association) "Standard Methods for the Examination of Water and Wastewater," 21th ed., AWWA and WEF, Washington, USA 1-30 40–175, 2005.

[8] K. P. Singh, and H. K. Parwana, "Groundwater pollution due to industrial wastewater in Punjab state and strategies for its control," Indian Journal of Environmental Protection, Vol. 19, pp. 241–244, 1999.

[9] A. B. Ghosh, J. C. Bajaj, R. Hasan, and D. Singh, "Soil and Water Testing Methods. A Laboratory Manual," Division of Soil Science & Agricultural Chemistry IARI, New Delhi, India, pp. 1–48, 1983.

[10] S. L. Chopra, and J. S. Kanwar, "Analytical agricultural chemistry," Kalyani Publication, Ludhiana, 1980.

[11] A. L. Page, R. H. Miller, and D. R. Keeney, "Methods of soil analysis; 2. Chemical and microbiological properties," 2. Aufl. 1184 S., American Soc. of Agronomy (Publ.), Madison, Wisconsin, USA 148(3), 363–364, 1982. [CrossRef]

[12] H. L. Golterman, and R. S. Clymo, "Methods for Chemical Analysis of Fresh Waters", IBP Handbook No. 8. Blackwell Scientific Publications. Oxford and Edinburgh, England. pp. 41–46, 1971.

[13] M. L. Jackson, "Soil Chemical Analysis", (2nd Indian Print) Prentice-Hall of India Pvt. Ltd. New Delhi, 38, p.336, 1973.

[14] H. L. S. Tandon, (ed.), "Methods of analysis of soils, plants, waters, and fertilisers" (Vol. 63, pp. 1–204). Fertiliser Development and Consultation Organisation 1993.

[15] K. A. Gomez, and A. A. Gomez, "Statistical procedures for agricultural research" John Wiley & Sons, 1984.

[16] M. W. Zaman, M. U. Nizam, and M. M. Rahman, "Arsenic and trace element toxicity in groundwater for agricultural, drinking and industrial usage," Bangladesh Journal of Agricultural Research, 26(2), pp.167–177, 2001.

[17] R. S. Ayers, and D. W. Westcot, "Rome: Food and Agriculture Organization of the United Nations", Water Quality for Agriculture (Vol. 29, pp. 174), 1985.

[18] WHO (World Health Organization), "International Standards for Drinking Water. Cited from Ground Water Assessment Development," pp. 248–249, 1971.

[19] L. A. Richards, "Diagnosis and improvement of saline and alkali soils," Agriculture Handbook, 60, pp. 210–220, 1968.

[20] M. N. Uddin, I. M. Shariful, and M. S. Islam, "Quality assessment of surface water resources of Dumki upazila in Bangladesh for irrigation, aquaculture and livestock consumption", Journal of Agroforestry and Environment, 4(2), pp. 81–84, 2010.

[21] M. A. Halim, "Seasonal variation of pond water quality in selected fish farms of Mymensingh area," (Doctoral dissertation, MS Thesis. Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh), 2009.

[22] R. R. Agarwal, J. S. P. Yadav, R. N. Gupta, "Saline and Alkali Soils of India," India.

Council of Agricultural Research, New Delhi-11000, pp. 223–228, 1982.

[23] Z. Karim, B. A. Qureshi, and I. Ghouri, "Spatial analysis of human health risk associated with trihalomethanes in drinking water: a case study of Karachi, Pakistan", Journal of Chemistry, 2013. [CrossRef]

[24] J. W. Meade, "Aquaculture Management", New York. Van Nostrand Reinhold, 1989. [25]. A. Taslima, "Quantitative assessment of ionic status of pond water for irrigation and aquaculture usage in the selected sites of Mymensingh area (Doctoral dissertation, MS Thesis. Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh), 2012.

[25] A. Taslima, "Quantitative assessment of ionic status of pond water for irrigation and aquaculture usage in the selected sites of Mymensingh area (Doctoral dissertation, MS Thesis. Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh), 2012.

[26] D. K. Todd, "Groundwater Hydrology," 2nd ed., Wiley, 1980.

[27] K. R. Karanth, "Ground water assessment, development, and management," McGraw-Hill Pub. Co., 1987.

[28] C. N. Sawyer, and D. L. McCarty, "Chemistry of sanitary engineers," McGraw Hill, pp. 518, 1967.