CHARACTERIZATION OF SURFACE WATER FOR MANAGED AQUIFER RECHARGE IN THE WATER-STRESSED BARIND TRACT OF BANGLADESH

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ABSTRACT

The gradual declining trend of groundwater level caused by its over-extraction, inadequate rainfall, and little or no natural recharge due to the top clay layer urges managed aquifer recharge (MAR) in the water-stressed Barind tract. The primary source of replenishing groundwater in this area is the surface water that accumulates as rainfall surface runoff in the khari (canal) and beel (vast water body).The physico-chemical and microbial characteristics of the potential source water for recharging are important to explore for the design of a sustainable MAR unit. Furthermore, a safe recharge must be ensured to avoid unwanted groundwater contamination through the managed aquifer recharge. Therefore, the study aimed to characterize the available surface water and evaluate the suitability of source water for groundwater recharge. In order to conduct this study, surface water samples were collected from Sharmangla khari, Rasulpur khari, and Kharoil beel for seven years during the winter and monsoon seasons. The collected samples were examined in the laboratory for pH, EC, turbidity, TDS, TSS, colour, DO, BOD, COD, TC, FC, Ca, Mg, Cl, hardness, Na, Fe, NO_3, PO_4, total-N, and SAR. The test results reveal that the surface water is unsuitable for managed aquifer recharge because it contains high levels of turbidity, color, pathogenic agents, and suspended particles that could quickly clog the recharge unit and shorten the lifespan of the MAR structure. Therefore, a suitable surface water treatment unit should be developed and introduced with a MAR structure for its successful operation.

Keywords: *Surface water, characteristics, treatment, managed aquifer recharge, sustainability*

1. INTRODUCTION

Water is an invaluable resource that is essential for life, and the WEF (2019) considers the scarcity of freshwater as one of the world's top concerns. Ever increasing population with continuous urbanization has made more challenging the sustainable management of water (Elshall et al., 2020). This issue is particularly important for the most groundwater-dependent nations including Iran, Saudi Arabia, Mexico, China, Bangladesh, and India – which collectively make up two-thirds of the world's groundwater-irrigated area (Shah, 2023). The groundwater, a vital natural asset, is losing both quality and quantity due to large withdrawals in Bangladesh (Rahman et al., 2022). The Barind tract area, a grain production hub in Bangladesh's northwestern region, is fully dependent on groundwater irrigation because of flood free high land area, inadequate rainfall, and limited surface water sources (Hossain et al., 2020a,b, 2021a,b,c, 2022a,b; Bari et al, 2021). The annual average rainfall in the Barind tract is 1410 mm, which is lower than the national average of 2550 mm (Jahan et al., 2020), and 80% of it falls between June and October (Faisal et al., 2018). In addition to hydrological drought, the region also endured moderate to severe agricultural drought (Rahman et al., 2017). Groundwater provides about 90% of irrigation in the Rajshahi, Naogaon, and Nawabganj regions of the Barind tract (BADC, 2020). The enormous extraction of groundwater caused by scarce surface water, insufficient rainfall, and pour infiltration (2-3 mm/day) due to deep top clay is declining groundwater continuously, making some parts unsustainable for further extraction (Rahman et al., 2017; Hossain et al., 2019a,b; Ali et al., 2023). Consequently, the present situation in the Barind region can be improved with Managed Aquifer Recharge (MAR), which can be applied to restore groundwater levels and enhance the sustainability of groundwater development (Wendt, et al., 2021). The concept of employing MAR to address water quality challenges in the twenty-first century has been suggested (Zheng et al., 2023).

However the preparation of high-quality water is necessary for groundwater recharge and before that, the water from current sources needs to be clarified through proper arrangement. The accumulated surface water in the *Khari* (canal) and *Beel* (vast water body larger than a pond) are the existing sources that can be utilized for recharging of groundwater need to be characterized. That is why this study has been undertaken with the aim of determining the physical, chemical, and biological characteristics of the *Kharies* and *Beel* water, and groundwater quality also needs to be examined.

2. METHODOLOGY

The appropriate choice of study technique and approach determines the validity of the study's findings. The method includes the selection of the study area, collection of water samples, and testing in the laboratory and evaluation.

2.1 Study Area

Godagari and Mohanpur Upazila under Rajshahi district and Niamatpur Upazila under Naogaon district in the northwest Barind Tract of Bangladesh have been selected as the study area. The study sites are Sharmangla *Khari*, Rasulpul *Khari*, and Kharoil *Beel* under Godagari, Niamatpur, and Mohonpur Upzila, respectively. Figure 1 represents the location map of the study area, and Figure 2 shows the Agro-Ecological Zoning (AEZ) map of the Barind tract area. The agro-ecological zoning map (Figure 2) shows that most of the part of Godagari upazila falls in the ‘high Barind tract zone’ and a minor part is in the ‘high Gange river floodplain zone’ while the major area of Mohonpur upazila covers the ‘high Gange river floodplain zone’ and a minor is in the ‘level Barind zone. On the other hand, the major area of Niamatpur upazila covers the ‘high Barind tract zone', whereas the minor segment falls in the ‘level Barind tract zone’.

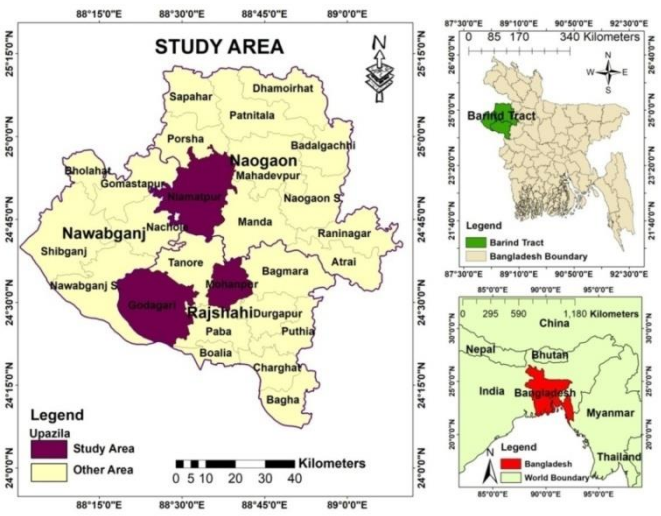


Figure 1: Location map of the study area

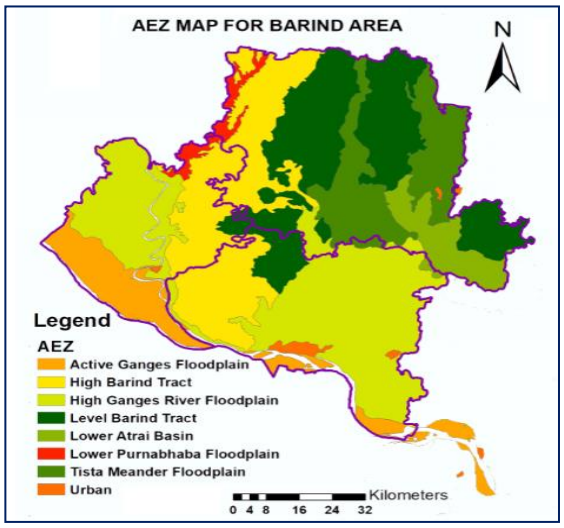


Figure 2: AEZ map of the Barind tract

2.2 Characterization of water

2.2.1 Sample Collection

Ensuring the safety of groundwater is an important consideration, and monitoring the quality of recharged water is an essential part of the MAR application. The surface water samples from the sources and groundwater from each site were collected in July during the monsoon and in December during the winter for seven consecutive years from 2016 to 2022. The samples were collected following standard procedure for each specific test of parameters in sampling bottles and transported in the ice box to the laboratory. The sampling bottles have been carefully cleaned, rinsed with distilled water and sterilized. Extreme care was exercised to avoid contaminating parts of the bottle coming in contact with the water and represents average conditions. In all cases where samples were collected from standing surface water by removing the stopper aseptically and plunged the bottle beneath the surface, mouth down, to a depth of 3 inch or more. The sampling bottles were moved forward away from the hand so that water, which came in contact with the hand, cannot enter the bottles.

2.2.2 Laboratory Analysis

Electric conductivity (EC), pH and dissolved oxygen (DO) were measured in the field at the source. The BOD test was set on the spot to avoid any change in the initial DO. Other tests (Turbidity, colour, TDS, TSS, BOD, COD, TC, FC, Ca, Mg, Cl, hardness, Na, Fe, NO_3, PO_4, total-N) were performed in the Environmental Engineering Laboratory of Rajshahi University of Engineering & Technology (RUET) following the standard methods of testing. The tests for TC and FC were performed immediately after arriving at the laboratory.

Determination of Electric Conductivity (EC) and Dissolved Oxygen (DO)

A digital electric conductivity (EC) meter and dissolved oxygen (DO) meter were used to measure EC and DO directly in the field by inserting respective probe into the source water. The EC meter was switched on and allowed some time to be stabilized. Reading was taken when the meter reading became stable. To get rid of any remaining material from the sample, the EC probe was rinsed with clean water and wiped with a paper towel. The DO meter was calibrated before using for test according to the

manufacturer's instructions. The DO probe was then kept into the water and the reading was noted from the DO meter as milligrams per liter.

Determination of Turbidity and Colour

The method is based upon a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension. Sample was taken in a clear glass cell and put into the cell holder and covered with lid. The turbidity was measured in NTU with respect to distilled water as standard (EPA, 2012). Colour of water was measure with digital colour meter following same procedure as turbidity in term of Pt-Co unit.

Determination of TDS and TSS

A measurement of the amount of dissolved inorganic and organic compounds in water is called total dissolved solids (TDS). It is a crucial factor considered when evaluating the efficacy of wastewater, industrial water, and drinking water. The procedure is applied for the determination of the TDS is same as the standard given in section (2540C) by the American Public Health Association (APHA, 2018). The procedure to find the TSS is described in the section (2540D) of American Public Health Association (APHA, 2018). Before use, the evaporating dish was desiccated after being heated to 180 °C in an oven for an hour. Right before use, it was weighed. A 100 ml of water sample was taken in an evaporating dish by using a measuring cylinder. A dry filter paper was weighted and the sample was passed through the filter paper. The filtered water was evaporated at 103 ^{o}C and the filter paper was dried in an oven. The weights of dried evaporating dish and filter paper were taken after cooling in desiccators. The TDS and TSS were calculated based on the difference between the weights in percentage.

Determination of BOD

The BOD values of water samples were measured following polarographic method (EPA, 2012). The sample was taken into a BOD bottle and the first day DO was measured immediately with DO meter. The starch was added to the sample kept in the laboratory incubation chamber under a temperature of 20 ^{o}C for 5 days. After 5 days incubation the measurement of DO was taken using the same process. The value was noted from the DO meter. Using these two values of DO, the value of BOD was calculated as the difference between the first day DO and after five days DO in mg/l.

Determination of COD

The COD was determined according to Wang and Wang (2022). Instead of potassium dichromate, excessive potassium permanganate is utilized in this alternate COD test. Initially, a 100-ml sample was taken into the Erlenmeyer flask (250 ml). Next, 10 ml of dilute sulfuric acid was mixed with the sample, and 10 ml of standard potassium permanganate was added. Subsequently, the water sample was oxidized under heat (100°C) in a strong acid solution with a known excess of potassium permanganate (KMnO4). After boiling for a fixed time (approximately 30 minutes), the color turned sallowish. The sample was then taken out, cooled, and 10 ml of standard ammonium oxalate was added. Following that, back-titration was performed by adding standard potassium permanganate dropwise using a burette until the color turned into pink. The volume of standard potassium permanganate was utilized for the calculation of the COD value of the waste sample (Equation 1).

Formula: COD (mg/L)= $\frac{V_{KMNO_4} \times C_{KMNO_4} \times 8000}{V_S}$ …… (1)

Where, V_{KMNO_4} =Volume of $KMNO_4$ used for titration of solution (ml), C_{KMNO_4} =Concentration of $KMNO_4$ solution (N) and V_S = Volume of sample (ml)

Determination of Total Coliform (TC) and Fecal Coliform (FC)

In order to identify total coliforms in water samples, the laboratory test implemented Section-9222B from APHA (2006).This method involves a known volume of water being filtered using a membrane filter before being applied to a selective and differentiating agar medium (m-Endo Broth) for coliform growth. Colonies are counted and identified after incubation (35°C ± 0.5°C). This method is known as a membrane filtration method (APHA, 2006). For the purpose of finding fecal coliforms in water samples, the laboratory test utilized the method described in Section-9222D. This method involves a known volume of water being filtered using a membrane filter before being applied to a selective and differentiating agar medium (m-FC Broth) for coliform growth. Colonies are counted and identified after incubation at (44°C ± 0.5°C) (APHA, 2006).

Determination of Hardness

Hardness of waters varies from place to place. In general, surface waters are softer than ground waters. Hardness is caused by polyvalent metallic cations, though the divalent cations, such as calcium and magnesium cations are usually the predominant cause of hardness. In addition, hardness is also caused by Fe^{2+} and Mg^{2+} ions. This method uses ethylenediaminetetracetic acid (EDTA), chelating agents, which forms complex ions with Ca^{2+} and Mg^{2+} and other divalent ions causing hardness. A buffer solution of 2 ml and 2-3 drops of Black T were added in a 100 ml of the sample. Then it was titrated with standard EDTA solution (with continuous stirring) until the last reddish colour disappears. At the end point the solution turns blue. The volume used was noted. The hardness as calculated as follows:

Hardness (in mg/l as $CaCO_3$) = (V×N×50×1000) / (SV), where: V = volume of titrant (ml); N = normality of EDTA; 50 = equivalent weight of $CaCO_3$; SV = sample volume (ml)

Determination of Phosphate

Spectrophotometric technique is used to determine phosphate. A sample was transferred into a 25 ml Pyrex tube. 5 ml of the molybdate solution, and 3 ml of 10% sulphuric acid were added and warmed on a boiling water bath for 15 min, then 2.0 ml of hydrazinium sulphate solution was added. The mixture in the tube was mixed well and immersed in a boiling water bath for another 10 min, then removed and 0.5 ml Brilliant Blue solution were added and heating continued for another 5 min. The mixture was cooled rapidly to room temperature and extracted with chloroform three times (each time 5 ml) and the organic extract collected in a 25 ml volumetric flask and the volume adjusted. The absorbance was measured at 840 nm against a reagent blank within 2 hours. The concentration can be obtained from a calibration curve previously prepared in the range of 5.6 to 28.1 μg $P0_4$ per 25 ml.

Determination of Total-N

The Shimadzu TOC-L with TN module converts all nitrogen compounds to NO at 720 ºC. The instrument automatically calibrates from a single 10 mg/l N solution to establish a multiple point calibration curve from 0.2 – 10 mg/l N. The instrument automatically dilutes (or injects less sample aliquot) off-scale peaks, enabling quantitation up to 500 mg/l. Total analysis time, per injection, is 2-5 minutes. The Method Detection Limit (MDL) is 0.05 mg/l N (ASTM D8083-16).

Determination of Chloride

The Mohr method uses silver nitrate for titration (normality: 0.0141) (method applicability: 0.15 to 10 mg/l chloride ions). The silver nitrate solution is standardized against standard chloride solution, prepared from sodium chloride (NaCl). During the titration, chloride ion is precipitated as white silver chloride: $Ag^+ + Cl^- <=> AgCl$. The indicator (potassium chromate) is added to visualize the endpoint, demonstrating presence of excess silver ions. In the presence of excess silver ions, solubility product of silver chromate exceeded and it forms a reddish-brown precipitate. This stage is taken as evidence that all chloride ions have been consumed and only excess silver ions have reacted with chromate ions: $2Ag^+ + CrO_4^{2-} <=> Ag_2CrO_4$.

Determination of Nitrate

NO_3 in contact with H_2SO_4 produces HNO_3 which in dry condition brings about nitration of phenol disulphonic acid. This nitrophenolic product gives intense yellow colour in alkaline medium which is measured though spectrophotometer. A 25 ml of sample was evaporated in a porcelain dish to dryness. 3 ml of phenol disulphonic acid was added to the residue and dissolve the residue. After 10 minutes 15 ml of distilled water was added and stirred with a glass rod. After cooling, contents of dish was transferred into 100 ml volumetric flask. 12 N KOH/NaOH was added with mixing till the solution is alkaline as indicated by the development of yellow colour due to the presence of NO_3. Then 2 ml of KOH/NaOH was added and made the volume 100 ml with distilled water. Intensity of yellow colour was read on the spectrophotometer at 420 nm wavelength or using blue filter.

Determination of Calcium and Magnesium

Disodium EDTA of 3.6 gm was dehydrated in one liter of deionized water slowly. $MgCl_2$ of 0.1 gm was added to the EDTA solution. Dried $CaCO_3$ of 0.5 gm dissolved with 25 ml of distilled H_2O, then 5 ml of conc. HCl was added to the 250 ml beaker. Then boil the solution gently for 2-5 minutes, keeping the watch glass on the beaker, to expel carbon dioxide. Analytically transfer the solution to a 500.00 ml volumetric flask and QS with DI water. Pipette 25 ml of standard Ca_2^+ solution into a 250-ml Erlenmeyer flask. 20 mL of deionized water and 2-3 drops of EBT indicator were added. The Ca^{2+} standard solution was titrated with the EDTA solution until the color changes from wine red, through purple, to a pure rich blue color. A 100.00 ml of sample were placed in a 150 ml beaker, 15 ml TRIS / Acetylacetone buffer solution were added. Then it was titrated with Na_2EDTA 0.05 or 0.1 mol / l to 2 equivalence points. The first equivalence point corresponds to the Ca_2^+ content, the second to the Mg_2^+ content of the sample. The consumption should be about 5 - 15 ml.

Determination of Sodium

Atomic absorption spectrophotometer was used to determine the sodium concentration in water. The low-temperature flame (about 1700 ^oC as compared to oxygen/acetylene at 3100 ^oC) generates strong emission only from the most easily excited elements. Wavelength isolation is by use of a simple narrow-bandpass interference filter that is designed to transmit only the intense, characteristic sodium-doublet lines at about 589.0 and 589.6 nm.

Determination of Iron

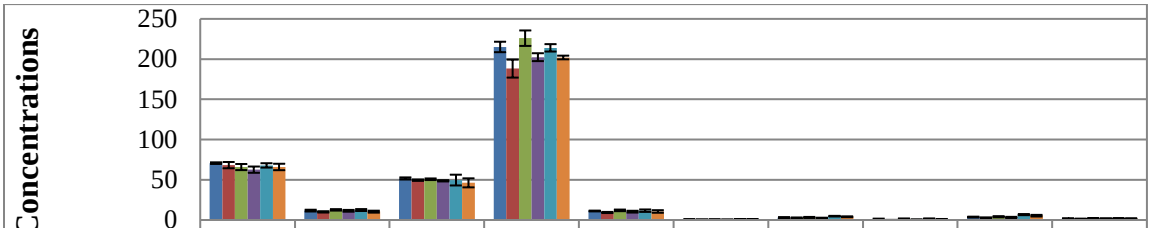
Iron may be present in two forms namely the reduced from (ferrous Fe^{2+}) and the fully oxidized form (ferric, Fe^{3+}). Ferric iron is determined by producing a red-colored iron compound, ferric thiocyanate, by the addition of potassium thiocyanate. 100 ml of the water sample placed in a Nessler. 5 ml of dilute hydrochloric acid was added. Two drops of potassium permanganate solution was added. 5 ml of potassium thiocyanate solution was added. The solution was turned brown as iron was present. The brown color formed was compared of distilled water titrated with the standard iron solution.

3. RESULTS AND DISCUSSIONS

The people are more concern about the safety of groundwater which is the main source of drinking. It is general perception of people is that the recharged water might contaminate the groundwater. Considering these aspects, it is essential to know the source water quality as well as the groundwater quality before and after recharge to determine any deterioration. Furthermore, clogging of MAR structure is the major critical issue that is influenced by many parameters among them EC, turbidity, TDS, TSS, etc. are predominant.

3.1 Surface Water Quality

After analyzing the test results, the chemical, physical, and biological characteristics of surface water are shown in Figure 3 and 4. The quality of surface water mainly depends on natural processes and anthropogenic influences, viz., agricultural, municipal, and industrial activities (Biglin and Konanc, 2016). Thus, it is necessary to monitor and control the quality of surface water to maintain the desired quality for its specific uses. The quantity of surface water is not only a matter of consideration for the recharge of groundwater; quality is also an important parameter.



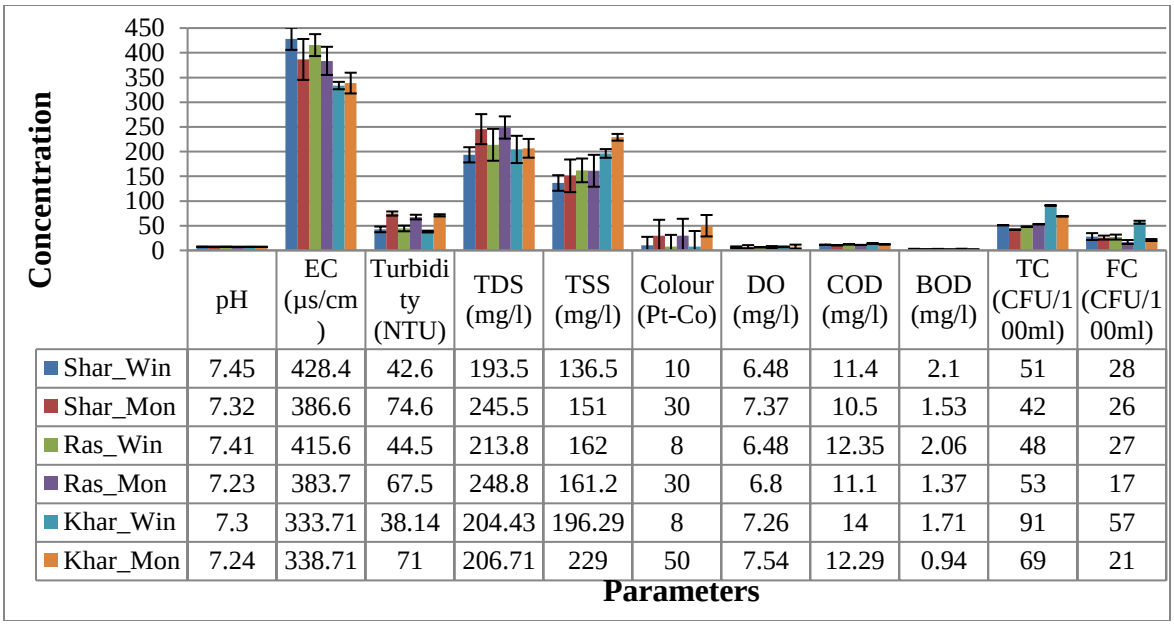
	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	Hardness (mg/l)	Na (mg/l)	Fe (mg/l)	NO3 (mg/l)	PO4 (mg/l)	Total N (mg/l)	SAR
Shar_Win	70.67	11.655	51.62	215.1	11.15	0.578	3.04	0.861	3.645	1.719
Shar_Mon	68.2	10.09	49.52	188.2	9.33	0.427	2.33	0.064	2.85	1.463
Ras_Win	65.82	12.59	50.635	226	11.96	0.531	3.16	1.22	4.06	1.912
Ras_Mon	62.57	11.42	48.73	202.4	10.35	0.382	2.33	0.362	3.2	1.71
Khar_Win	67.87	12.3571	49.6286	214	11.5771	0.83857	4.72714	1.35714	6.7	1.83
Khar_Mon	65.9071	10.3543	46.18	202	10.5929	0.79571	4.02143	0.63857	5.35	1.71857

Figure 3: Chemical characteristics of surface water in the study area

It is observed in general that the chemical parameters for all three study sites are within the acceptable limit for drinking purposes according to ECR 97, both in the monsoon (wet) season and the winter (dry) season. However, the concentration of each parameter is slightly higher in the dry season than in the wet season. It might be due to the dilution of minerals by runoff water in the wet season. The quality of surface water may vary in monsoon and dry seasons due to the dilution of concentration (Ishimaru et al., 1990).

The results on the physical characteristics of surface water show that all parameters are within acceptable limits except turbidity and color both in wet and dry seasons. Total suspended solids (TSS) varies from 136.5±17.49 to 229±21.70 mg/l which needs to be considered for sustainable operation of MAR because TSS is the main cause of clogging of infiltration surface that reduces the infiltration rate (Jeong et al., 2018; Dillon et al., 2016).

According to the water quality standard turbidity of drinking water must be less than 10 NTU while the test results show the turbidity for Sharmangla *khari*, Rasulpur *khari*, and Kharoil *beel* are 74.6±4.17 NTU, 67.5±4.69 NTU and 71±2.23 NTU in wet season and 42.6±5.70 NTU, 44.5±5.78 NTU and 38.14±1.77 NTU in dry season, respectively. It is observed that the turbidity for all sites is higher in the wet season compared to the dry season which is due to the carrying of soil particles during the surface runoff. Similarly, the color of surface water is higher in all study sites in the wet season compared to the dry season due to the settlement of suspended particles as well as the reduction of turbidity.



	pH	EC (µs/cm)	Turbidity (NTU)	TDS (mg/l)	TSS (mg/l)	Colour (Pt-Co)	DO (mg/l)	COD (mg/l)	BOD (mg/l)	TC (CFU/100ml)	FC (CFU/100ml)
Shar_Win	7.45	428.4	42.6	193.5	136.5	10	6.48	11.4	2.1	51	28
Shar_Mon	7.32	386.6	74.6	245.5	151	30	7.37	10.5	1.53	42	26
Ras_Win	7.41	415.6	44.5	213.8	162	8	6.48	12.35	2.06	48	27
Ras_Mon	7.23	383.7	67.5	248.8	161.2	30	6.8	11.1	1.37	53	17
Khar_Win	7.3	333.71	38.14	204.43	196.29	8	7.26	14	1.71	91	57
Khar_Mon	7.24	338.71	71	206.71	229	50	7.54	12.29	0.94	69	21

Figure 4: Physical and Biological characteristics of surface water in the study area

Furthermore, the presence of Ca, Mg, Cl, and NO_3 which cause the hardness of surface water as well as the presence of iron might significantly affect the MAR operation by forming scale and encrustation. As a result of this effect, the recharge unit could be clogged. The clogging of the MAR unit might also happen due to the suspended solids that cause the turbidity as well as the color of the water. Therefore, removal or reduction of these elements from source water for groundwater recharge is essential before use in the MAR system.

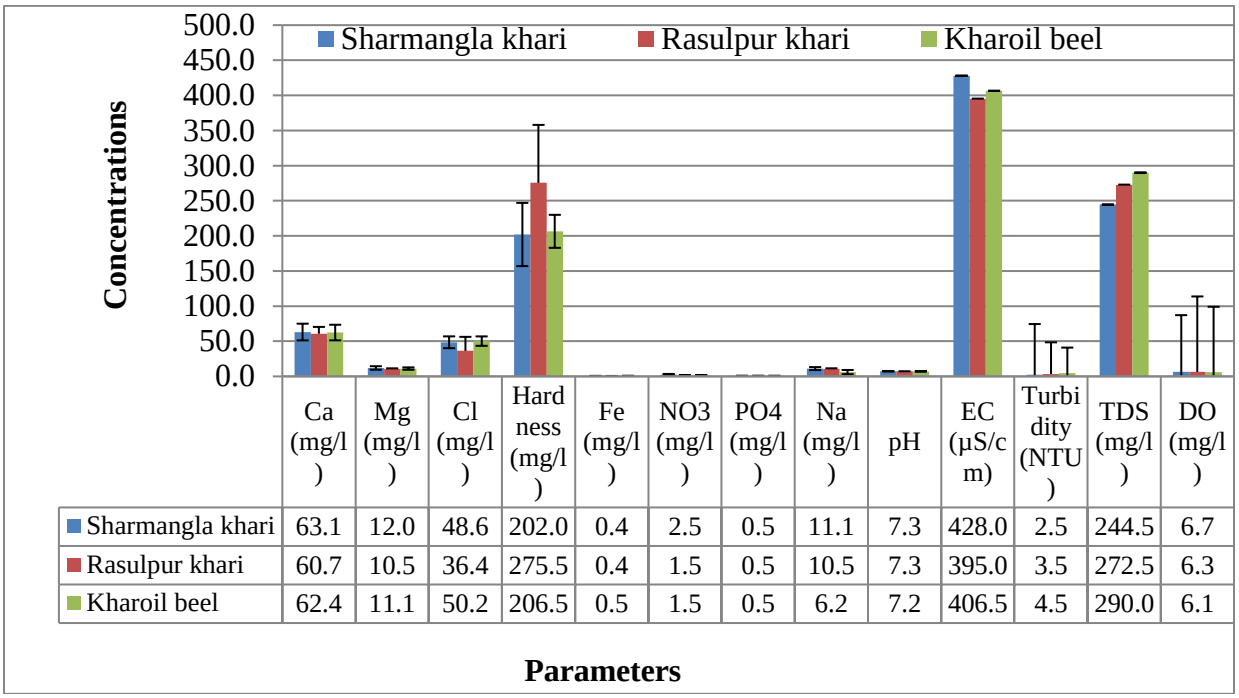
Surface water runoff contains a wide range of pollutants such as organic substances, sediment, heavy metals, nutrients, pathogenic microorganisms, and pathogen indicators. The available research on surface water characterization shows that the pH varies from 7.79 to 8.43, DO varies from 6.16 to 10.61 mg/l, and TSS varies from 19.60 to 342.18 mg/l (He et al., 2010). Salehi et al., (2020) investigated the surface water quality and found pH 7.8±1.1, Fe 6.8±10.8 mg/l, Mg 8.8±20.3 mg/l, total N 2.1±10.5 mg/l, COD 208.8±332.2 mg/l, BOD_5 23.2±34.1 mg/l and TSS 428.2±969.2 mg/l. Cheema, et al. (2017) studied the surface water quality for five sites and found mean concentration pH 7.52 to 7.88, TSS 133 to 225 mg/l, BOD_5 96 to 115 mg/l, COD 231 to 315 mg/l, total N 10.20 to 12.35 mg/l, total P 1.42 to 2.85 mg/l, Fe 0.97 to 1.59 mg/l. Salam et al. (2012) found that pH ranges 7.72 to 8.6, chloride from 81.79 to 13.78 mg/l, and No_3 from 2.10 to 5.20 mg/l for surface water of Mohonpur upazila. Therefore, the results obtained in the present study are in usual concentrations.

The reason for the higher color in the wet season could be due to the presence of turbidity for suspended solids, organic substances, and gaseous elements (Kumar, 2016). The presence of total coliform varies from 42±4 to 69±2 CFU/100 ml in the wet season and 48±5 to 91±3 CFU/100 ml in the dry season while fecal coliform varies from 17±21 to 26±1 CFU/100 ml in wet season and 27±1 to 57±2 CFU/100 ml in dry season. It can be noticed that coliform concentration in the wet season is lower than dry season due to the huge volume of surface water. The presence of coliforms in surface water depends on the characteristics of the catchment (Cheema et al., 2017). He et al. (2008) found fecal coliform 1 to 160 CFU/100 ml in surface water. Faecal coliform (FC) is always found to be higher during low-flow seasons than during high-flow seasons (Mohammad et al., 2011).

From the above discussion, it is clear that the available surface water is not suitable for using managed aquifer recharge due to the presence of a high concentration of turbidity, color, and pathogenic agents, as well as suspended particles that may cause quick clogging of the recharge unit and a reduction in the service life of the MAR structure.

3.2 Groundwater quality

The groundwater quality was determined to know the present concentration of the selected parameters and to evaluate any deterioration of quality by the recharge of surface water to the aquifer. The initial condition of groundwater quality was presented in Figure 5.



	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	Hardness (mg/l)	Fe (mg/l)	NO3 (mg/l)	PO4 (mg/l)	Na (mg/l)	pH	EC (µS/cm)	Turbidity (NTU)	TDS (mg/l)	DO (mg/l)
Sharmangla khari	63.1	12.0	48.6	202.0	0.4	2.5	0.5	11.1	7.3	428.0	2.5	244.5	6.7
Rasulpur khari	60.7	10.5	36.4	275.5	0.4	1.5	0.5	10.5	7.3	395.0	3.5	272.5	6.3
Kharoil beel	62.4	11.1	50.2	206.5	0.5	1.5	0.5	6.2	7.2	406.5	4.5	290.0	6.1

Figure 5: Characteristics of groundwater in the study area

The results show that the quality of groundwater considering all the tested parameters is acceptable as per drinking water quality standard guidelines.

4. CONCLUSIONS

The application of MAR has now become a prime need for the drought-prone water-stressed Barind area. The available surface water in the Sharmangla *khari*, Rasulpur *khari*, and Kharoil *beel* was characterized through laboratory analysis. According to the test results, chemical parameters at each of the three locations are within the allowable range of drinking water standards as established by the Environment Conservation Rules (ECR, 2023), in both the monsoon (wet) season and winter (dry) season. The findings regarding the physical properties of surface water reveal that, in both wet and dry seasons, all parameters are within acceptable ranges with the exception of turbidity and color. Total suspended solids (TSS) vary from 136.5±17.49 to229±21.70 mg/l which must be taken into account for long-term MAR operation. Turbidity values for Sharmangla *khari*, Rasulpur *khari*, and Kharoil *beel* in the rainy season are 74.6±4.17 NTU, 67.5±4.69 NTU and 71±2.23 NTU, respectively, and 42.6±5.70 NTU, 44.5±5.78 and 38.14±1.77 NTU in the dry season. Total coliform concentrations range from 42±4 to 69±2 CFU/100 ml in the wet season and 48±5 to 91±3 CFU/100 ml in the dry season, while fecal coliform concentrations vary from

17±21 to 26±1 CFU/100 ml in the wet season and 27±1 to 57±2 CFU/100 ml in the dry season. As a result of the high concentrations of turbidity, color, pathogenic agents, and TSS, surface water is not suitable for MAR use without treatment. The existing groundwater quality remains within the acceptable limits of drinking water standards as ECR, 2023 mentioned. Existing surface water needs to be treated to bring it to an acceptable limit before being used for MAR and groundwater quality should be monitored at a regular interval due to recharge to avoid any deterioration of groundwater quality. The findings of this study would be significant for policymakers and practitioners in water resource management in water stressed area like Barind tract.

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