International Research Journal of Environmental Sciences ISSN 2319–1414
Vol. **7(6),** 25-33, June **(2018)** *Int. Res. J. Environmental Sci.*

Studies on the seasonal variations of ground water quality in Lefunga block of West Tripura District, Tripura, India

M.K. Singh, R. Paul* and B. Karmakar
Department of Chemistry, Tripura University, Suryamaninagar, Tripura West-799022, India
rajib251987@gmail.com

Available online at: www.isca.in, www.isca.me
Received 19th February 2018, revised 25th April 2018, accepted 1st May 2018

Abstract

Our present work is to find out the suitability of groundwater for drinking and irrigational purposes within the Lefunga block of west Tripura district, Tripura and also to evaluate their seasonal variation. Water samples have been collected from ten different spots of Lefunga block. Collected groundwater samples from the study area have been analysed for the determination of some physical parameters like pH, EC, TDS along with vital cations and anions like Ca, Mg, Na, K, Fe, Cl, HCO_3, SO_4 and F etc. The obtained analytical data of water samples in Lefunga block suggest that the quality of water is within the standard limits of WQI categorization and acceptable for drinking purposes both in pre and post-monsoon seasons except one location having high level of iron content. Based on the analytical data, different water quality indices like sodium percentage (Na %), Sodium Absorption Ratio (SAR), Magnesium Hazard (MH), Permeability Index (PI) and Kelly's ratio (KR) have been measured for the suitability irrigational purposes. The calculated water quality indices reveal that the groundwater of Lefunga block is suitable for agricultural purpose for both the seasons.

Keywords: Groundwater, water quality index, drinking and irrigation, sodium absorption ratio (SAR), Lefunga block, Tripura.

Introduction

Water is a basic ingredient of all form of life support system and economic development that covers about 70% of the earth surface. Water resource plays major role in drinking, agricultural, industrial, domestic and other environmental activities[1-4]. Among all freshwater resources groundwater is essential for the survival of all living composition on planet for its better hygienic concern. It is about 20% of the world resources where majority of the world population dependent on ground water mainly for drinking reason. Ground water is the cheapest, more convenient and less impurity content compared to surface water because of effective filtering[5-8]. Groundwater is one of the prime water supply sources mainly for drinking and agricultural purposes found in most part of India. It is also found that about 90% population of this country uses groundwater for drinking and other various exercises. Groundwater quality is very much related with the local environmental and geological conditions and mostly affected by both natural and anthropogenic activities.

The level of groundwater changes by the regular withdrawal and hence the quality of groundwater also changes. The quality of groundwater is also associated with various geological and chemical influences that include recharged water quality, communication between water soil and gases, ion exchange reaction between the aquifer etc[9]. Due to these natural geochemical practices the quality of groundwater is affected to a greater extent and varied in different places. Addition to this, intensive use of groundwater due to rapid population expansion, unprocessed waste water from industry and municipality, application of various types of fertilizers in agricultural areas are imposing greater threat to the groundwater resources. Therefore special attention should be given to observe the water quality and to locate the sources of contamination responsible for the groundwater pollution.

When groundwater is contaminated, its quality can't be restored back easily. Several water borne diseases are spreading slowly in the rural areas. People belonging to below poverty line are consuming the contaminated poor quality groundwater due to lack of awareness. In developing countries like India, major portion of transmissible diseases are activated due to consumption of unhealthy water[5,6]. So water quality monitoring is the most important need now a days and it has been taken at highest priorities by the various environmental protection agencies[2].

Our main objective of the work is to analyze the physiochemical parameters of ground water samples collected from different locations in rural tribal populated Lefunga block of West Tripura district, India and also study their seasonal variation in relation to drinking and irrigational water quality standards. It has been found from the survey of literature that no systematic research work has been undertaken in this area except our paper[10]. So the outcome of this work will help the government to maintain the water quality for betterment of standard of tribal people of the Lefunga block by formulating efficient management plans.

Study area: Our study area shown in Figure-1 is geographically bounded between 23º56´22´´ N to 23º56´55´´ N and 91º18´10´´ E to 91º25´49´´E. Total area of the block is 13,076 sq. Km which consists of ten village council. Total population of the block is 25146 where majority of the people belongs to tribal category. For drinking and irrigation, groundwater is the prime source of this block.

Materials and methods

Groundwater samples were collected from ten tube wells in different locations across the Lefunga block during pre-monsoon (March to May, 2016) and post- monsoon (September to November, 2016) period. Analysis of the collected water samples were carried out according to the standard methods specified in APHA[11]. Samples were collected in plastic bottles rinsed with dilute nitric and deionised water. The G.P.S coordinate in this connection for each sampling site were attained using a hand held Garmin GPS. Some physical parameters like pH, electrical conductivity (EC), total dissolved solids (TDS) were measured on the spot using the potable HI 98130 Combo pH/ EC/ TDS/ Temperature meter by Hanna Instruments. Flame photometric method was applied for the determination of Sodium (Na) and Potassium (K) concentration. Values of Calcium (Ca) and Magnesium (Mg) were identified by complexometric method whereas Chloride (Cl^-) concentrations were determined by argentometric analysis. Sulphate ($SO4^{2-}$) and Iron (Fe) concentrations were calculated spectophotometrically and bicarbonate (HCO_3^-) was measured by titrimetric analysis. The value of fluoride (F^-) was identified by the Ion selective colorimetric method. The analytical results of ten collected samples are shown in Table-1-2. All the concentrations have been calculated in mg/L except pH and Electrical conductivity.

Results and discussion

The following parameters have been used to analyze water quality viz., pH, electrical conductivity, TDS, Chloride, Sulphate, Bicarbonate, Fluoride, Sodium, Potassium, Calcium, Magnesium, and Iron. The data obtained after analysis of the collected groundwater samples are discussed below.

Concentration of Hydrogen ion (pH): Hydrogen ion concentration designated as pH is a very important characteristic that predicts about the acidic or basic property of water. All the physico-chemical and biochemical action within the water are pH dependent[12-15]. pH value of the study area varied between 4.36 to 5.28 during pre-monsoon and 4.26 to 5.21 during post-monsoon season. So the pH of collected water samples is acidic and below to the acceptable limit of drinking according to WHO (World Health Organisation)[16]. The lower value of pH may be due to the developing of CO_2 from both atmosphere as well as plant resources and gets into water solution[17]. This may affect the mucous membrane in living beings, bitter taste to water, corrosion and the aquatic life.

Electrical Conductivity (E.C): The value of Electrical conductivity of water indicates the salt or ion concentration within the water. Pure water has lower value of electrical conductivity[17]. The values of EC of collected water samples were recorded in the range 35.9 to 157.0 µS/cm during pre-monsoon and 49.0 to 205.6 µS/cm during post-monsoon period. All the water samples come under WHO standards for electrical conductivity.

Total dissolved solids (TDS): TDS is the combination of all kinds of inorganic and organic substances within the water as molecule, ions or micro granular suspended form. Water having higher value of TDS reduces the solubility of gases in it and causes increase in density of water[18,19]. TDS values were varied from 24.0 to 104.0 mg/L and 32.66 to 136.0 mg/L during pre and post monsoon period respectively. Seasonal variations were found and comparatively higher values were noticed in post-monsoon season which may be due to movement and leakage of poor class of water in this area.

Calcium and Magnesium (Ca^{+2} and Mg^{+2}): According to the WHO and BIS, the maximum allowable limit for Calcium in water is 75mg/L and that of Magnesium is 30mg/L[16, 20]. Calcium values of the collected water samples ranges from 7.85 to 11.78mg/L during pre-monsoon and 8.73 and 11.78mg/L during post-monsoon season. The Magnesium concentration varied from 3.57 to 7.14mg/L in pre-monsoon and 3.02 to 7.14mg/L in post-monsoon season. The obtained Calcium and Magnesium values for the collected water samples were found within the safe standard limit.

Chloride: Chloride mainly comes from various kinds of inorganic chloride salts of alkali and alkaline earth metal. The prime sources of chlorides are natural chloride layered soil, industrial, municipal, domestic sewage water and wastes of animals etc[19]. In the study area the values of Chloride were found in the range 16.5 to 23.57mg/L during pre-monsoon and 12.57 to 18.86mg/L during post-monsoon season having average value of 19.40mg/L and 14.61mg/L respectively. All the Chloride values are within the desirable limits specified by WHO for both the seasons.

Sulphate (SO_4^{-2}): According to the WHO the acceptable range for Sulphate in drinking water is 250 mg/L. The analytical value of Sulphate in collected water samples are varied from 2.17 to 15.39mg/L in pre-monsoon and 1.98 to 14.97mg/L in post-monsoon season which are well within the standard limit.

Bicarbonate (HCO_3^{-1}): The water samples have Bicarbonate values in the ranges of 19.13 to 52.62mg/L and 19.13 to 58.8 mg/L for both the seasons respectively.

Fluoride (F^-): The observed Fluoride value in collected water samples ranges from 0.1 to 0.43mg/L and 0.09 to 0.29mg/L for both pre and post-monsoon period respectively which are within the prescribed limit by BIS[20].

Sodium and Potassium (Na and K): WHO and BIS together specified the maximum acceptable limit for sodium in drinking water is 200 mg/L. The higher sodium concentration level leads to various physiological disorders like high blood pressure, kidney diseases and higher osmotic pressure in mucus cells[21]. Analysis of water samples of the study area showed that the concentration of sodium varied from 0.49 to 1.02 and 0.44 to 0.98 mg/L in pre-monsoon and post-monsoon respectively. The content of potassium in water samples ranges from 0.06 to 0.35 and 0.04 to 0.26 mg/L for both the season.

Iron: Iron concentration is not a worried issue regarding the health risk but extreme quantities may leads irritation. Higher iron concentration cause changes the water taste, discoloration of clothes and other utensils. It is also not suitable for processing of food and beverages. The permissible values of iron in drinking water must remain in between 0.3 to 1.0 mg/L[22]. After analysis, the iron content in the study area varied from 0.08 to 3.05mg/L and 0.08 to 2.25mg/L in pre- and post-monsoon respectively. In pre-monsoon, iron concentrations were found higher than the post-monsoon period. Due to recharge of underground water during the rainy season, lower concentration of iron was observed in post-monsoon period.

Water quality index: According to Ramakrishna, 2009 the Water Quality Index can be calculated using the following steps[23].

First step: Allocating different weights (wi) to the analysed parameters based on their significance on drinking water quality.

Second step: A relative weight (W_i) is measured by the following formula,

$$Wi = wi/\Sigma wi \quad (1)$$

Third step: Quality rating (qi) is calculated by the following way:

$$qi = (Ci / Si)*100 \quad (2)$$

Where, Ci signifies the concentration of each parameter for each water sample expressed in mg/L and Si stands for the drinking water quality criterion in terms of WHO standards for each chemical parameter.

Fourth step: Determination of water quality Index (WQI) by the following method,

$$SIi = Wi * qi \quad (3)$$

$$WQI = \Sigma SIi \quad (4)$$

Weights for each chemical parameter, relative weights have been presented in Table-3. Categorization of water quality based on WQI value is given in Table-4 and water quality evaluation of study area is presented in Table-5. Since potassium has no particular WHO standard, this parameter is not included for WQI measurement. The results of Water Quality Index reflect the water quality at Abhicharan bazaar is not suitable for drinking purpose for both the seasons due to high iron concentration.

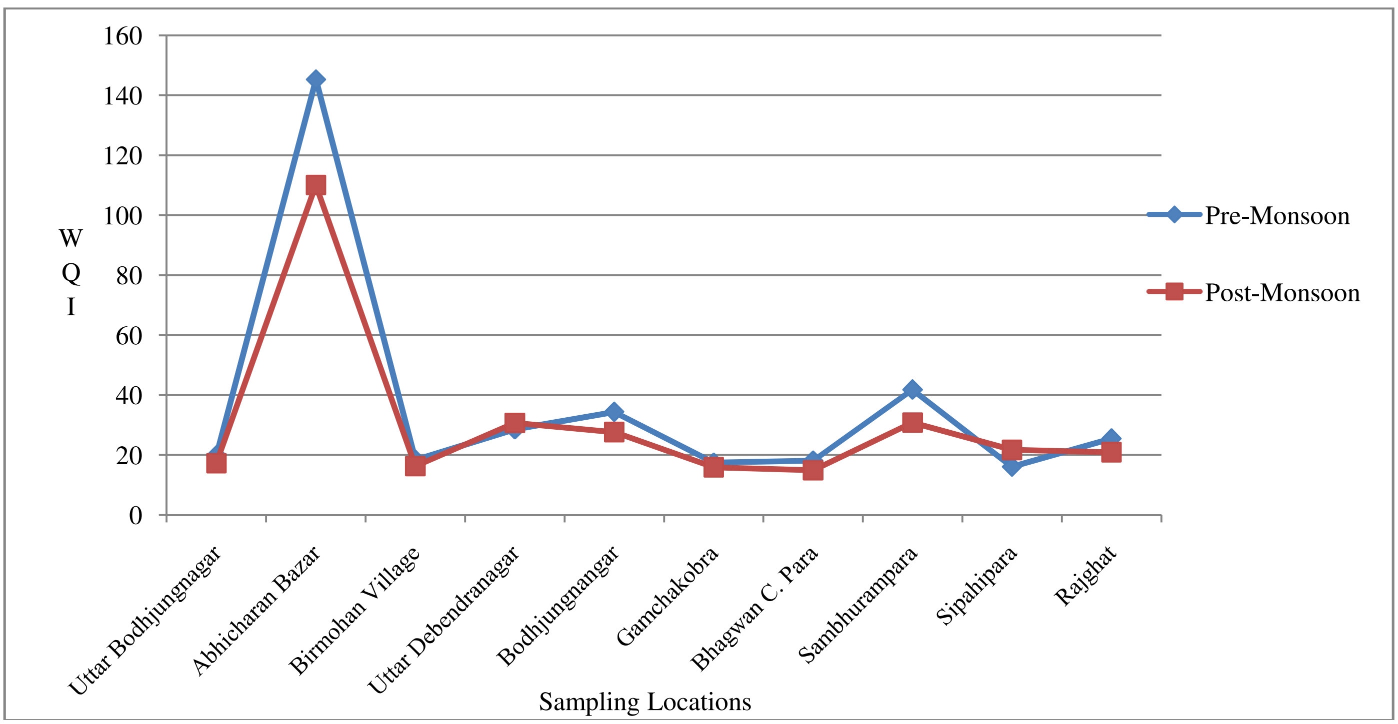

Figure-1: Variation of ground water quality during pre and post monsoon based on WQI.

Table-1: Data analysis of Lefunga block during pre-monsoon season.

Study area	pH	EC	TDS	Ca	Mg	Cl^-	SO_4^{-2}	HCO_3^-	F^-	Na^+	K^+	Fe
Uttar Bodhjung Nagar	4.79	59.43	39	11.78	3.57	18.85	3.01	19.13	0.11	0.84	0.10	0.19
Abhicharan Bazar	5.28	121.19	81	9.81	5.95	16.5	15.39	45.44	0.43	0.85	0.28	3.05
Birmohan Village	5.09	147.29	96.6	7.85	3.96	18.85	2.17	23.92	0.11	0.52	0.06	0.12
Uttar Debendra Nagar	4.36	157.01	104	10.47	3.96	18.85	2.99	32.67	0.31	1.02	0.35	0.53
Bodhjung Nagar	4.66	66.86	44	9.16	6.34	23.57	2.36	22.32	0.18	0.66	0.15	0.51
Gamcha kobra	5.01	36.51	24.6	10.47	5.55	18.85	2.61	52.62	0.17	0.78	0.18	0.10
B.C. Para	4.59	35.9	24	7.85	3.96	18.85	2.74	20.72	0.11	0.49	0.11	0.16
Sambhu Rampara	4.84	124.41	82	9.16	3.96	18.85	3.02	20.72	0.11	0.98	0.24	0.68
Sipahipara	4.93	51.34	33.3	10.47	6.34	22	2.86	35.08	0.14	0.68	0.11	0.08
Rajghat	5.21	117.5	78	11.78	7.14	18.85	11.57	19.13	0.1	0.53	0.18	0.28

Table-2: Data analysis of Lefunga block during post-monsoon season.

Study area	pH	EC	TDS	Ca	Mg	Cl^-	SO_4^{-2}	HCO_3^-	F^-	Na^+	K^+	Fe
Uttar Bodhjung Nagar	4.44	71.1	49	9.36	3.405	14.14	2.6	27.72	0.09	0.72	0.08	0.14
Abhicharan Bazar	4.8	148.75	101	11.23	5.67	14.14	14.97	52.92	0.29	0.62	0.15	2.25
Birmohan Village	4.89	164.8	108.6	8.73	3.78	14.14	2.01	31.92	0.1	0.44	0.04	0.08
Uttar Debendra Nagar	4.26	205.6	136	10.16	3.78	18.84	2.86	45.36	0.15	0.9	0.26	0.42
Bodhjung Nagar	4.81	87.3	58	10.16	4.54	15.71	1.98	28.56	0.1	0.58	0.04	0.38
Gamcha kobra	4.88	49	32.66	10.35	3.78	12.57	2.39	58.8	0.13	0.70	0.15	0.08
B.C. Para	4.38	53.53	36	8.73	3.02	12.57	2.60	38.64	0.07	0.49	0.11	0.1
Sambhu Rampara	4.64	142.53	94.66	8.92	3.02	12.57	2.76	40.32	0.15	0.98	0.24	0.42
Sipahipara	4.78	62.33	42	11.59	5.29	17.28	2.55	50.4	0.14	0.68	0.11	0.21
Rajghat	5.02	124.8	82	7.49	4.54	14.14	3.98	30.24	0.1	0.43	0.09	0.19

Analysis of water used for Irrigation: For the determination of suitability of water for irrigational purpose, following five geochemical indices were calculated for each water sample.

Percent Sodium (Na%): Sodium Percent is very significant indices for water used for irrigation purpose because soil properties and permeability is seriously affected by higher amount of sodium in water [24]. According to Tood, Sodium percentage in groundwater is calculated by using the following equation[25],

$$Na\% = \{(Na^+ + K^+)/ (Ca^{2+} + Mg^{2+} + Na^+ + K^+)\} *100$$

Where the quantity all ions are expressed in milliequivalents per litre (meq/L).

Obtained values of Na% for water samples collected from ten different sampling sites of Lefunga block suggest that the water quality falls under excellent category and suitable for irrigation purpose in terms of sodium percentage during pre and post monsoon season.

Sodium absorption ratio (SAR): Sodium absorption ratio measures the sodium exposure to soil which is a vital factor for irrigation. Reaction of sodium with soil decreases its permeability that makes the cultivation tough due to dispersion of clay particles[26].The following formula is used for the calculation of SAR,

$$SAR = [Na^+] / \{([Ca^{2+}] + [Mg^{2+}])/ 2\}^{1/2}$$

Where: values of the ions are calculated in meq/L.

SAR values (<10) for ten collected water samples of Lefunga block suggest excellent water quality and are suitable for irrigation in all agricultural fields of Lefunga block.

Magnesium hazard (MH): Mg Hazard in water can be predicted by Szabolcs and Darab[27]. The formula for the determination of MH is presented below:

$$MH= Mg^{2+} / (Ca^{2+} +Mg^{2+}) * 100$$

All the ionic concentrations are expressed in meq/L.

The water with MH value < 50 is suitable for irrigation while MH value >50 is not suitable for irrigation. The value of MH of analysed groundwater indicate that about 70% of collected water samples are fitted for irrigational use during pre-monsoon season while 30% water samples were unsuitable. Post-monsoonal MH value reveals that about 90% of the water samples are suitable and the remaining 10% is not suitable for agriculture purpose.

Table-3: Relative weight of measured parameters.

Parameter	WHO Standard	Weight (wi)	Relative Weight (Wi)
pH	6.5	5	0.128205128
EC	2250	2	0.051282051
TDS	1000	4	0.102564103
Ca^{+2}	200	2	0.051282051
Mg^{+2}	100	2	0.051282051
Cl^-	1000	3	0.076923077
SO_4^{-2}	400	5	0.128205128
HCO_3^-	772	3	0.076923077
F^-	1.5	5	0.128205128
Na^+	200	3	0.076923077
Fe	0.3	5	0.128205128
		Σw_i=39	

Table-4: Water quality categorisation on the basis of WQI.

WQI	Water class
50 and below	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
300 and above	Unsuitable for drinking

Table-5: WQI value during pre-and post-monsoon season in Lefunga block:

Sampling station	Source of drinking water	Season	WQI	Results
Uttar Bodhjungnagar	Tube well	Pre	19.9722	Excellent
		Post	17.298	Excellent
Abhicharan Bazar	Tube well	Pre	145.252	Poor
		Post	110.125	Poor
Birmohan Village	Tube well	Pre	18.424	Excellent
		Post	16.335	Excellent
Uttar Debendranagar	Tube well	Pre	28.654	Excellent
		Post	30.725	Excellent
Bodhjungnagar	Tube well	Pre	34.449	Excellent
		Post	27.705	Excellent
Gamchakobra	Tube well	Pre	17.537	Excellent
		Post	15.975	Excellent
Bhagawan Chowdhury Para	Tube well	Pre	18.163	Excellent
		Post	14.977	Excellent
Sambhurampara	Tube well	Pre	41.877	Excellent
		Post	30.828	Excellent
Sipahipara	Tube well	Pre	16.169	Excellent
		Post	21.752	Excellent
Rajghat	Tube well	Pre	25.559	Excellent
		Post	20.980	Excellent

Kelly's ratio (KR): Kelly's ratio is another important indices that predicts the irrigational suitability of ground water. If the ratio appears bellow one, the water can be used for irrigation otherwise not. When there is higher value of sodium in water, higher Kelly's ratio is then obtain.[25]The formula used for evaluating the Kelly's ratio is,

$KR = Na^{+}/ (Ca^{+2} + Mg^{+2})$

All the ionic concentrations are expressed in meq/L

The Kelly's ratio calculated for water samples from ten different sites of Lefunga block lie below 1 for both the seasons and is fitted for irrigation.

Permeability index (P.I.): Extensive utilisation of water for irrigation influence the soil permeability as it is associated with sodium, magnesium and bicarbonate ions[28]. The formula used for calculation of permeability index is given bellow:

$PI = Na^{+} + [\{(HCO_3^{-})^{½} / (Ca^{+2}+Mg^{+2}+Na^{+})\}*100]$

According to Doneen groundwater has been classified as class I, class II and class III category in connection with its Permeability index values for irrigational acceptibility[29]. The ground water classified as class I (PI>75%), class II (PI in between 25–75%) categorized as good and used for irrigation purpose while class III (PI<25%) are not suitable for irrigation. The PI values for all groundwater samples in Lefunga block are classified as Class-I and Class-II categories and good for irrigation purposes in both the seasons.

The calculated geochemical indices of groundwater samples are expressed in Table-6.

The classification of groundwater samples collected from ten various locations of Lefunga block based on measured parameters is listed in Table-7.

Conclusion

The quality of groundwater in Lefunga Block of West Tripura District, Tripura has been studied for drinking and irrigational purposes using some important water quality parameters. The analytical data suggest that the electrical conductivity values of water of Lefunga Block are well within the WHO standards while pH values are below the WHO standards indicating its acidic nature. The iron content in water sample is within the maximum allowable limit except in one site in pre-monsoon and value decreases in post-monsoon which may be due to recharge of water resources during monsoon. Overall, the quality of water of Lefunga Block is suitable for domestic consumption except a few locations. The geochemical water quality indices reveal that the groundwater samples from ten different locations from Lefunga block have excellent water quality Index values except Abhicharan Bazar location. The significant influencing water quality parameters for irrigation such as EC, Na%, SAR, MH, PI and KR were determined and compared with standard limits. The analytical data suggest that the groundwater quality of Lefunga Block is suitable for irrigational uses as they pose neither salinity hazards nor loss of soil properties.

Table-6: Seasonal data of geochemical indices in Lefunga block.

Sampling station	Season	% Na	SAR	MH	KR	PI
Uttar Bodhjungnagar	Pre	4.22	0.05	33.55	0.35	64.62
	Post	4.25	0.05	37.70	0.35	90.13
Abhicharan Bazar	Pre	4.28	0.05	50.26	0.57	87.96
	Post	2.89	0.03	45.68	0.52	90.33
Birmohan Village	Pre	3.23	0.03	45.66	0.38	87.08
	Post	2.61	0.03	41.90	0.35	96.35
Uttar Debendranagar	Pre	5.87	0.06	38.65	0.41	91.29
	Post	5.27	0.06	38.26	0.39	104.56
Bodhjungnagar	Pre	3.19	0.04	53.55	0.59	62.42
	Post	2.87	0.03	42.67	0.42	77.83
Gamchakobra	Pre	3.76	0.04	46.89	0.52	94.39
	Post	3.95	0.04	37.82	0.37	117.30
Bhagawan Chowdhury Para	Pre	3.23	0.03	45.66	0.38	81.22
	Post	3.38	0.03	36.56	0.30	115.18
Sambhurampara	Pre	5.82	0.06	41.86	0.42	75.29
	Post	6.53	0.07	36.06	0.34	115.58
Sipahipara	Pre	2.98	0.04	50.21	0.58	72.86
	Post	3.07	0.04	43.19	0.49	89.39
Rajghat	Pre	2.28	0.02	50.24	0.63	48.30
	Post	2.71	0.03	50.24	0.42	93.68

Table-7: Groundwater Classification in terms of Electrical Conductivity, Sodium percentage, Sodium Absorption Ratio, Magnesium Hazard, Permeability Index and Kelly's ratio.

Parameters	Range	Class	Percentage of water samples within the limit (Pre-monsoon)	Percentage of water samples within the limit (Post-monsoon)
EC	<250	Excellent	100%	100%
	250-750	Good	0%	0%
	750-2000	Permissible	0%	0%
	2000-3000	Doubtful	0%	0%
	>3000	Unsuitable	0%	0%
Na%	< 20	Excellent	100%	100%
	20-40	Good	0%	0%
	40-60	Permissible	0%	0%
	60 -80	Doubtful	0%	0%
	>80	Unsuitable	0%	0%
SAR	< 10	Excellent	100%	100%
	10-18	Good	0%	0%
	18-26	Permissible	0%	0%
	> 26	Unsuitable	0%	0%
MH	<50	Suitable	70%	90%
	>50	Unsuitable	30%	10%
KR	< 1	Suitable	100%	100%
	>1	Unsuitable	0%	0%
PI	Class-I & Class- II (25- 75% or >)	Suitable	100%	100%
	Class- III (25% or <)	Unsuitable	0%	0%

Acknowledgements

Authors would like to acknowledge the Chairman, Tripura State Pollution Control Board for his kind support to pursue the research work. Laboratory support provided by the Head of Department of Chemistry, Tripura University, Suryamaninagar to carry out the water analysis is also duly acknowledged.

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