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Evaluation of ground-water quality in Hura Block under Purulia District of West Bengal, India using selected physico-chemical parameters

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Abstract

Groundwater monitoring is crucially important for both developed and developing regions. Water quality mainly depends on its physiochemical as well as microbial characteristics. Present study was directed to evaluate the quality of groundwater as well as its drinking suitability, domestic, and agricultural uses by applying physico-chemical experiments. To achieve this objective, Hura Block of Purulia district under West Bengal was selected as the field of experiment and samples were collected from different positions using global positioning system (GPS) coordinates as reference points. Hura, a community development block within the Purulia Sadar subdivision of Purulia district. Detailed analysis of different physico-chemical parameters like colour, odour, temperature (T), total dissolved solid (TDS) hardness (HA), electrical conductivity (EC), calcium (Ca^{2+}) ion, magnesium (Mg^{2+}) ion, pH level, total alkalinity (TAK), chloride (Cl^-) ion, fluoride (F^-) ion, bicarbonate content (HCO_3^-), free carbon-dioxide (CO_2), and dissolved oxygen (DO) was carried out. A comparative analysis of the experimented results was done with respect to the standard water quality parameters set by WHO (World Health Organization) and BIS (Bureau of Indian Standards).To verify the suitability of water for different purposes, the WAWQI (Weighted Arithmetic water quality index) method was applied by using the experimented values of different parameters. Additionally, to determine the interrelationship between the different parameters, the correlation coefficients were measured by using Pearson's correlation matrix method.

Keywords: Ground-water, Hura block, Global positioning system (GPS), physicochemical parameters, WHO, BIS, Correlation matrix.

Introduction

In scientific literature, it has been observed that "Water Quality" has been narrated in a large extent, may be due to reason that after air, the second most significant component for life is water[1]. So, such an essential constituent must be obtainable for all at a satisfactory level and attempt should be made to get safe, accessible and adequate amount of water[2]. Not only for human beings, water is also vital for the survival of plants, animals along with other living organisms[3]. Based on different sources, water can be divided in two groups, surface water and ground water[4]. Water from both the sources may be polluted through natural and anthropogenic ways, though most of the ways are anthropogenic activities like domestically, agricultural, industry related activities[5]. Biological (e.g. bacteria, algae), chemical (e.g. pH, alkalinity, chloride, hardness, dissolved oxygen, toxic inorganic substances) and physical (e.g. temperature, electrical conductivity, colour, turbidity) parameters are the three parameters which indicate the quality of water[6]. For a particular area or source, quality of water are assessed through these parameters and if the values cross a particular limits then that water area is consider as unsafe or harmful[7]. Presently, many scientists are continuously doing their research work on water quality measurement and a continual deterioration in the water quality is noticeable. Therefore, in order to consider of suitable water source, a single parameter named "Water quality Index (WQI)" has been described as a simplified, logical single value rather than a blank information. In the year 1965, initially WQI was developed by Horton based on some common water quality parameters[8] and after few years, based on individual weights of different parameters, Brown and his co-worker, developed a new WQI which was modified and similar to Horton index[9]. Later on some modifications have been taken into account by several scientists[10,11]. All over the world, many researchers are using these WQI methods to describe quality of water for common uses. *Sunita Shresta et al*. assessed the drinking quality of ground water for Kathmandu valley, Nepal applying Water Quality Index (WQI) method[12]. *Abirami Subramanian* and *Sushmitha Baskar* assessed the water quality of Noyyal river, an important river of Tamil Nadu by using WQI and multivariant statistical tecnique[13].Water quality of Bhilai Steel Plant (BSP) was determined with emphasis on different parameters like pH, total alkalinity (TA), dissolved oxygen (D.O.), sulphate, hardness, magnesium, calcium, nitrate, chloride etc. with the help of Water Quality Index (WQI) method by *Vinod Jena et.al.*[14]. By the use of fourteen different physico-chemical parameters and applying weighted arithmetic WQI (Water Quality Index) method, water quality of Paradeep area of Odisha, India are assessed by *Hementa Meher et al*.[15]. Water suitability of Sagar Dighi, Koch Bihar, and different districts of southern part of West Bengal were examined by water quality researchers with the help of WQI tools [16,17]. The seasonal effect on water quality of some positions of the Hooghly River and some of its nearby locations was assessed with some common physical as well as parameters by using WQI tool by Diptendu Datta and others[18]. Keeping in view the above mentioned precedent, we have decided to measure physical as well as chemical parameters of under-ground water in different areas under Hura block of Purulia district. The experimental findings have been likened with the standard values as suggested by BIS and/or WHO[2,7].

Methodology

Study area: Hura block, a community development block comprised of ten (10) gram panchayats, covers an area of 382.21 Km^2 in the district of Puruliain the state of West Bengal, with a total population of 143575 according to the 2011 census report. This block is bounded by Kasipur, Para Purulia-I, Purulia-II, Puncha blocks of Purulia district and Indpur, Hirbandh blocks of Bankura district. The positions of the ground-water collection points are: Karandih gram under Chatumadar panchayat (G_1); Daldali gram under Daldali panchayat (G_2); Hura Keshabpur gram under Lakhanpur panchayat (G_3); Hura gram under Hura panchayat (G_4); Hatibari gram under Jabarrah panchayat (G_5); Kumardi under Manguria panchayat (G_6); Pakhuria under Bispuria panchyatya (G_7); Devkunda pukur under Ladhurka panchayat (G_8); Patloi river under Keshargarh panchyatya (G_9); Kalabani gram under Kalaboni panchayata (G_{10}). Some general geographical information about the reference points (i.e. water sample collection point) and the location of block are provided in the Table-1 and Figure-1.

Water samples collection: Samples of water were collected from underground drinking tube wells used for house-hold, bathing and irrigation purposes to assess various characteristic for evaluation water quality. Samples were collected from the last week of May to second week of July. At the time of samples collection, temperature range of the water was 27°C to 30°C while range of air-temperature was 31°C to 34°C. The GPS (global positioning system) was employed to pin-point the precise position of each water sample collect point and the horizontal accuracy was ranging from 3.10 meter to 10.70 meter, as detailed in Table-1. Samples were collected into fresh and clean polyethylene bottles with one litre capacity for analysing physiochemical parameters. Before sampling, each container was thoroughly washed with a 5% HNO_3 solution and cleaned with double-distilled water. Additionally, bottles were also rinsed with the water samples during collection of samples. Proper labelling was done to avoid any misidentification of the samples.

Table-1: Some common data about reference points.

Sample ID	Collection Date and time	Co-ordinates			Elevation (meter)	
		Latitude	Longitude	Horizontal Accuracy	Altitude	Elevation Accuracy
G_1	27.5.24; 2.21PM	23.250059	86.591095	3.90	266	0.10
G_2	27.5.24; 2.48PM	23.250059	86.590379	10.70	269	0.27
G_3	27.5.24; 5.31PM	23.346227	86.599092	3.60	267	0.70
G_4	27.5.24; 3.50PM	23.303812	86.656123	5.40	262	0.40
G_5	27.5.24; 4.30PM	23.3215944	86.539626	3.10	272	0.70
G_6	11.7.24;1.01PM	23.28743	86.638361	3.50	267	0.10
G_7	11.7.24;12.33PM	23.288181	86.717064	3.90	269	0.70
G_8	11.7.24;11.32PM	23.368265	86.531605	5.40	266	0.40
G_9	11.7.24;3.32PM	23.314525	86.500483	3.10	264	0.60
G_{10}	11.7.24;4.55PM	23.387829	86.556387	3.80	273	0.70

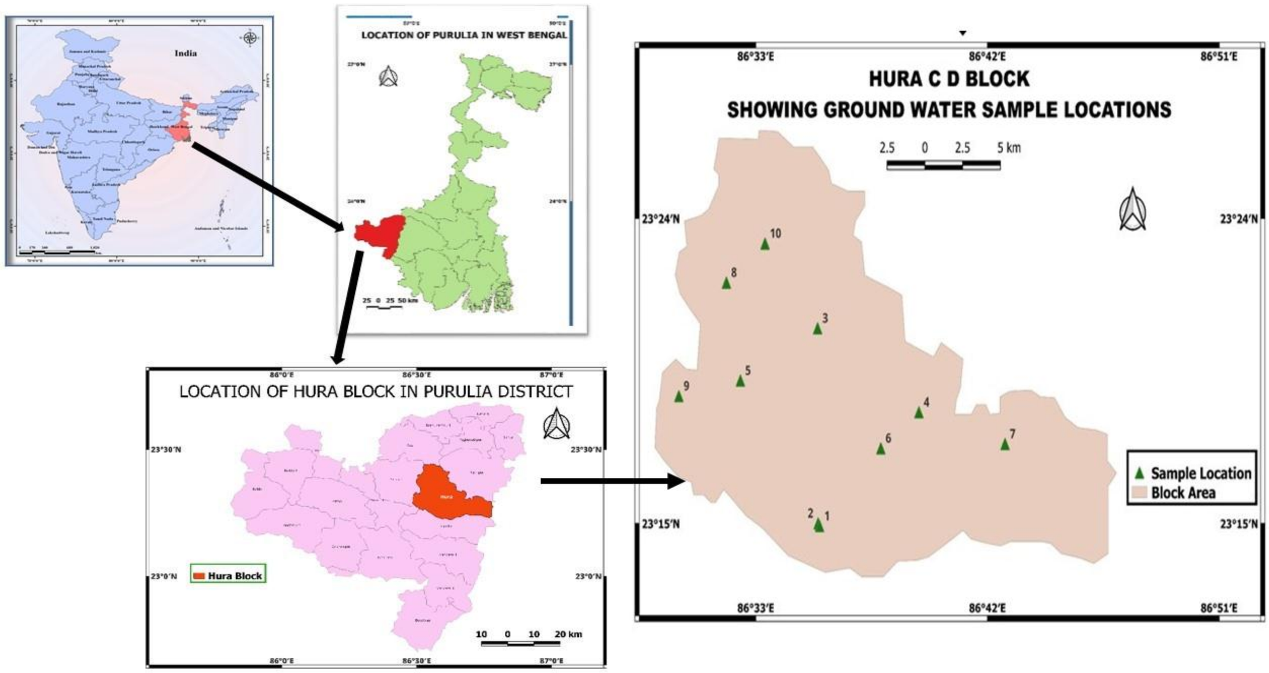

Figure-1: Ground water samples collecting points.

Chemicals and glass goods: Groundwater samples from ten different gram panchayats within the Hura community development block were collected. The chemicals used for the analysis included KI (potassium iodide), NaN_3 (sodiumazide), $Na_2S_2O_3$ (sodium thiosulfate), $K_2Cr_2O_7$ (potassium dichromate), $MnSO_4$ (manganous sulfate), NaOH (sodium hydroxide), HCl (hydrochloric acid), $C_2H_2O_4$, $2H_2O$ (oxalic acid), H_2SO_4 (sulfuric acid), H_3PO_4 (orthophosphoric acid), $(C_6H_{10}O_5)_n$ (starch), KNO_3 (potassium nitrate), EDTA (ethylenediamine tetraacetic acid), Zn $(CH_3COO)_2$,$2H_2O$ (zinc acetate), NH_4OH (ammonium hydroxide), NH_4Cl (ammonium chloride), EBT (Eriochrome Black-T), phenolphthalein indicator, Patton-Reeder's indicator, methyl-red indicator, methyl orange indicator, all sourced from Loba Chemicals, Bombay, India. Other chemicals were of reagent grade. Various glassware like dropper, stopper bottle, watch glass, pipette, burette, volumetric as well as conical flask, measuring cylinder beaker etc. was used for the work.

Analytical Methods: It is well known that parameters of water quality change with time, so it is better to preserve water samples before analysis. The parameters like Temperature, D.O., pH change quickly with time; hence, these parameters are estimated as early as possible. Temperature of water samples as well as air temperature were measured on spot by using glass thermometer with range from 0˚C to 100˚C. Conductivity and pH were measured with Digital conductivity meter 611 made by electronics India (EI) and digital pH meter with model-112 made by electronics India (EI) respectively. Chloride ion was detected by argentometric titration method using potassium chromate solution as indicator[19].

Fluoride ion was estimated through Ion Selective Electrode (ISE) method for fluoride using TISAB (total ionic strength adjustment buffer) buffer and with the help of the Thermo Scientific Orion 4-star meter. Total hardness, calcium ion and magnesium ion were analysed trough titrimetric method by using EDTA Eriochrome-Black-T, methyl red and Patton-Reeder's indicators[20]. Dissolved oxygen of the samples was determined through titration flowing Winkler's method by using some chemicals where starch solution was used as indicator[19]. Parameters like alkalinity, free carbon dioxide and bicarbonate ion were measured through acid-base titrimetric method[20].

Water Quality Index-Weighted arithmetic method: Weighted Arithmetic Water Quality Index (WQI) method is an efficacious and straight-forward method to introduce information about water quality in an excellent way. This method is a assembling of numbers of different water quality parameters which is used to describe the overall quality of water. It is also a measure of the permissibility of water quality for human drinking that considers the associated effects for different parameters related to water quality[21]. In this work, the Water Quality Index has been following method that was originated in the year 1965 by *Horton*[8] and modified in 1972 by *Brown et al.*[9] based on equations given below:

$$WQI = \frac{\sum Q_n W_n}{\sum W_n} \quad (1)$$

Here, Qn indicates Quality rating of n^{th} parameter and Wn indicates unit weight of n^{th} water quality parameter.

Further, regarding quality rating (Qn) scale for any single parameter Brown et al suggest the expression as given in equation:

$$Qn = \left\{\frac{V_n - V_i}{S_n - V_i}\right\} \times 100 \qquad (2)$$

Here, Vn indicates experimental value and Sn indicate standard value as recommended permissible value obtained from the standard table. Vi indicates the ideal value of the water quality parameter. In most cases ideal values (Vi) are considered as zero except pH and dissolved oxygen[22]. Ideal values for pH and dissolved oxygen are considered as7 and 14.4 mg/L.

Unit weight (Wn) for any individual water quality parameter is calculated based on the recommended standard values by using the following equation.

$$Wn = \frac{K}{S_n} \qquad (3)$$

Here, Sn indicates the standard recommended value of particular parameter and K indicates proportionality constant, which is calculated by using the equation given below.

$$K = \left[\frac{1}{\sum \frac{1}{S_n}}\right] \qquad (4)$$

The final status of water quality of a particular water source based on experimented results is guided by the WQI following as per Table-2[8,23-25].

Karl Pearson's Coefficient of Correlation: The term "correlation" refers to a conjunction or link. So, through a correlation study, we may analyse the connection or interrelation of different parameters or variables. The widely used Pearson's coefficient of correlation, denoted by "r" is simply a mathematical method is used to calculate the degree of linear relationship among different variables and it is expressed as

$$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{[n\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2]}} \quad \ldots\ldots\ldots\ldots\ldots (1),$$

Here "r" denotes the correlation coefficient, "n" denotes the total number of records or data for each variable, and X and Y are different variables. The "r" value is always within the range of +1 to -1, i.e., $-1 \le r \ge +1$. The positive (+) and negative (-) values indicate the positive and negative linear relationship respectively, whereas the value zero (0) indicate non-existence of any kind of relationship between the parameters. Closer value of 1 indicates stronger the relationship. As per the guidance that Evans[26] suggested, we may use the various terminology for differentiating the range of values like the terms "very weak" for "r" value 0 to 0.19, "weak" for "r" values 0.20 to 0.39, "moderate" for "r" values 0.40 to 0.59, "strong" for "r" values 0.60 to 0.79 and the term "very strong" for the "r" values 0.80 to 1.00.

Results and Discussion

Scattered data on physico-chemical water quality parameters from several selected groundwater reference points are documented in Table-3 and Table-4. The results were analysed using BIS/WHO reference guidelines, as given in the Table-5. Collected water samples were clear, colourless and free of any objection ableodours. In this study, the experimental temperature ranged were from 26°C-31°C and as per the guidelines of WHO According to WHO guidelines, 15°C is the acceptable limit for drinking water though it is recommended to cool water to 25°C for 30 minutes before drinking. Higher temperature may promote the growth of microorganisms and may change the taste, odour colour etc.

The range of electrical conductivity (EC) (Table-3) of ground water samples are 229µS/cm (G_5) to 1830µS/cm (G_1) in where the acceptable limit (Table-5) of EC for drinking water is 750 µS/cm. In most cases except samples no G_1 and $G_4$the measured results are within the range of acceptable limit. The probable reason for the higher electrical conductivity of ground water may be due to more contact with the dissolved materials like rock materials (salts) at the underground level.

Table-2: Water quality Index (WQI) and its related terminology.

Range of WQI	Status of water	Grade	Probable usages
0 to 25	Excellent quality	A	Ingestion, Irrigation purpose and Industrialisation
26 to 50	Good quality	B	Domestic purpose, Irrigation purpose and Industrialisation
51 to 75	Fair quality	C	Only for Irrigation and Industrialisation purpose
76 to 100	Poor Quality	D	Only for Irrigation purpose
101 to 150	Very Poor Quality	E	Limited to Irrigation purpose
Above 150	Unfit to drink	F	Need proper treatment before use

Table-3: Water samples with its some physical parameters.

Sample ID	Colour	Odour	TDS (mg/L)	E.C. (µS/cm)	Temperature (^oC)	
					Water	Air
G_1	Colourless	Odourless	780	1830	29	33
G_2	Colourless	Odourless	202	260	27	33
G_3	Colourless	Odourless	320	474	27	32
G_4	Colourless	Odourless	562	826	28	34
G_5	Colourless	Odourless	185	229	30	33
G_6	Colourless	Odourless	400	589	27	31
G_7	Colourless	Odourless	360	513	29	34
G_8	Colourless	Odourless	416	558	27	34
G_9	Colourless	Odourless	320	503	30	33
G_{10}	Colourless	Odourless	367	505	27	31

Table-4: Experimental results for different parameters of different position.

Sample ID	pH	Total AK (mg/L)	CO_3^{2-} (mg/L)	Free CO_2 (mg/L)	DO (mg/L)	Hardness (ppm)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	HCO_3^- (mg/L)	F^- (mg/L)	Cl^- (mg/L)
G_1	8.08	40.00	0.00	43.12	7.13	895.00	110.53	55.32	48.80	0.558	397.60
G_2	7.74	25.00	0.00	33.44	6.44	204.06	42.96	24.37	30.50	0.912	71.00
G_3	7.48	27.00	0.00	29.04	6.56	186.16	44.39	26.11	32.94	0.595	113.60
G_4	8.10	55.00	0.00	44.88	7.13	429.60	104.54	50.48	67.10	1.010	156.20
G_5	7.63	38.00	0.00	32.56	7.41	225.54	40.10	24.37	46.36	1.910	85.20
G_6	8.50	45.00	0.00	61.60	6.84	232.70	78.76	26.10	54.90	0.584	78.10
G_7	8.52	37.00	0.00	52.80	6.56	329.36	78.76	32.19	45.14	0.596	56.80
G_8	8.91	40.00	0.00	41.36	7.63	322.20	71.60	34.80	48.80	0.489	73.84
G_9	8.43	38.00	0.00	57.20	7.07	325.78	81.62	20.01	46.36	0.499	85.20
G_{10}	8.40	40.00	0.00	30.80	7.52	340.10	85.92	29.58	48.80	0.466	71.00

The exceptionally high value of EC for sample G_1 indicates a higher presence of dissolved naturally occurring charged particles such as calcium, magnesium, sodium, sulfate, nitrate which are relevant for drinking water guidelines. Experimental results (Table-3) show that except sample G_1, TDS in all other samples fall within the acceptable limits (Table-5). TDS and EC are closely related because the electrical conductivity of water is primarily influenced by the dissolved substances into water. As per BIS, the normal pH range for drinking water is 6.5 to 8.5, and our experimental results (Table-4) of the study area are within the range of 7.48 (G_3) to 8.91(G_8) i.e., a general trend towards weakly alkaline in nature except in one sample (S_2), may be due to pollution related to landfills, chemical dumps or may be any natural phenomena and the results showed the same sequence as those of other researchers[27]. 200 mg/L to 600 mg/L (Table-3) is the prescribed range for alkalinity of drinking water, in where the experimental results for groundwater samples are from 25 mg/L (G_3) to 55 mg/L (G_4) (Table-4, Figure-2) which express that in all samples the alkalinity is much lower than the range of acceptable limit. In this study, these results of alkalinity will be considered as total alkalinity as because during experiment phenolphthalein alkalinity was zero (sample solution remained colourless after addition of phenolphthalein indicator) which implied alkalinity due to presence of carbonate ion (CO_3^{2-}) is nil. In this regard, experiment also expressed that bi-carbonate ion (HCO_3^-) content in the samples are ranges from 30.50 mg/L (G_2)- 67.10 mg/L(G_4). Free carbon dioxide (CO_2) parameters (Table-3) study expressed (Table-3) that the free CO_2 for ground water samples are higher than that of surface water samples.

Table-5: Water quality parameter table according to BIS-10500:2012.

Different parameters	Symbol used	Unit	Limit to accept	Limit to Permissible	Recommended by
Temperature	T	^{0} C	15	--	WHO
pH	pH	------	6.5-8.5	No relaxation	BIS10500:2012
Dissolved solids (total)	TDS	mg/L	500	2000	BIS10500:2012
Electrical Conductivity	EC	µS/cm	750	---	BIS-2009/WHO-2011
Total alkalinity as $CaCO_3$	TAK	mg/L	200	600	BIS10500:2012
Chloride ion	Cl^-	mg/L	250	1000	BIS10500:2012
Calcium ion	Ca^{2+}	mg/L	75	200	BIS10500:2012
Magnesium ion	Mg^{2+}	mg/L	30	100	BIS10500:2012
Total hardness as $CaCO_3$	HD	mg/L	200	600	BIS10500:2012
Fluoride ion	F^-	mg/L	1.0	1.5	BIS10500:2012
Dissolved oxygen	D.O.	mg/L	5	---	BIS-2009/WHO:2011
Bicarbonate ion	HCO_3^-	mg/L	--	--	---
Free carbon dioxide	CO_2	mg/L	--	--	--
Carbonate	CO_3^{2-}	mg/L	--	--	--

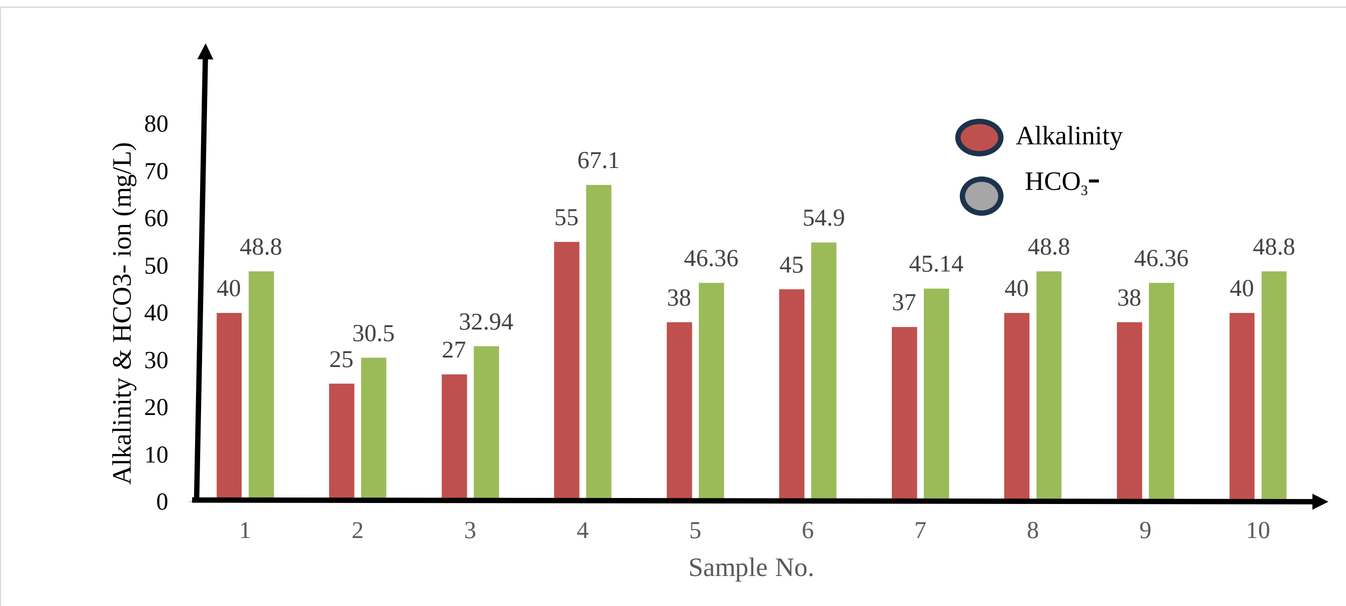

Figure-2: Comparative study of total alkalinity and HCO_3^- of collected water samples.

The required hardness limit of drinking water is 200 mg/L and the permissible limit is 600 mg/L in the absence of any alternative source. Experimental results show (Table-4) that the hardness ranges from 186.16(mg/L) to 895.00 (mg/L) for underground water samples and which are much higher surface water samples (89.50 (mg/L) to 211.11(mg/L) (Table-4, Figure-3). No health-based guiding principle is anticipated by WHO, but higher value of hardness occurs with the formation of soap scum, cloud-like stains, clogged pipes, faded and brittle laundry, corrosion, and deteriorated appliances.

Experimental results of underground water samples for calcium ion show a lowest value of 40.50 mg/L, to a height value of 110.53 mg/L, (Table-4, Figure-4) and for surface water samples results show a range from 10.02 mg/L – 52.98 mg/L, most of which are within the within the range of 75 mg/L-200 mg/L, (Table-4) of limits framed by BIS. The results of magnesium ion are not similar to hardness and calcium ion. Where the normal accepted range of magnesium ion is from 30 mg/L- 100 mg/L, (Table-5), the experimental results (Table-3) are in the range of 20.01mg/L-55.32mg/L which are in general the lower than that of normal limit **(**Table-4, Figure-4).

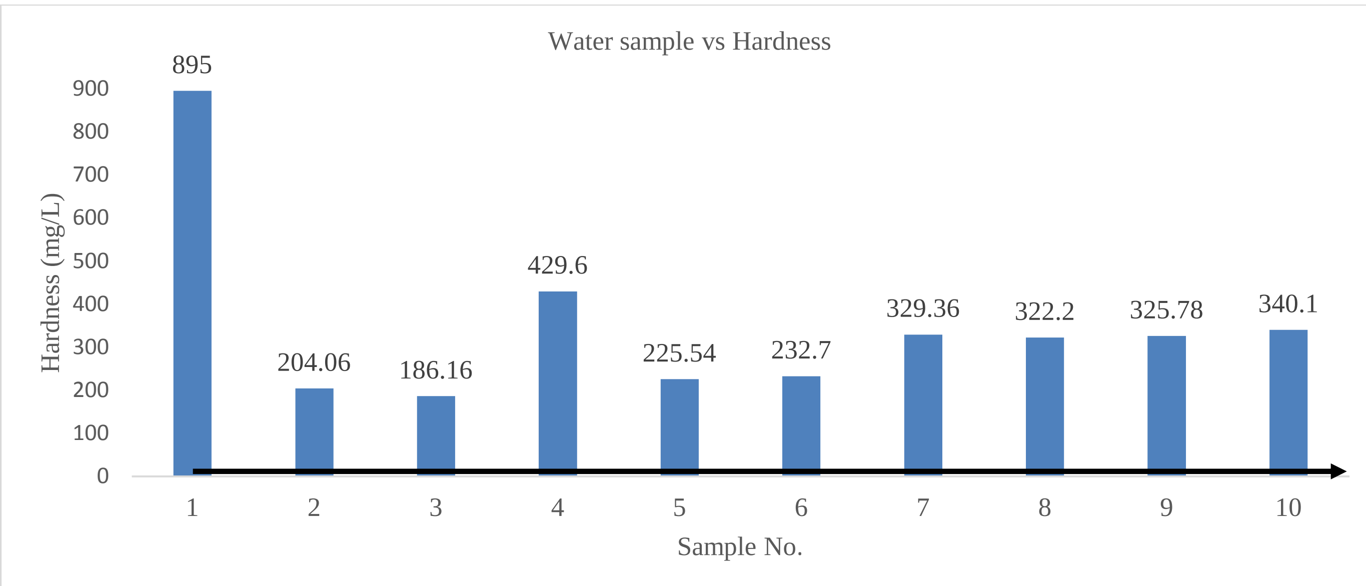

Figure-3: Comparative study in hardness of collected samples.

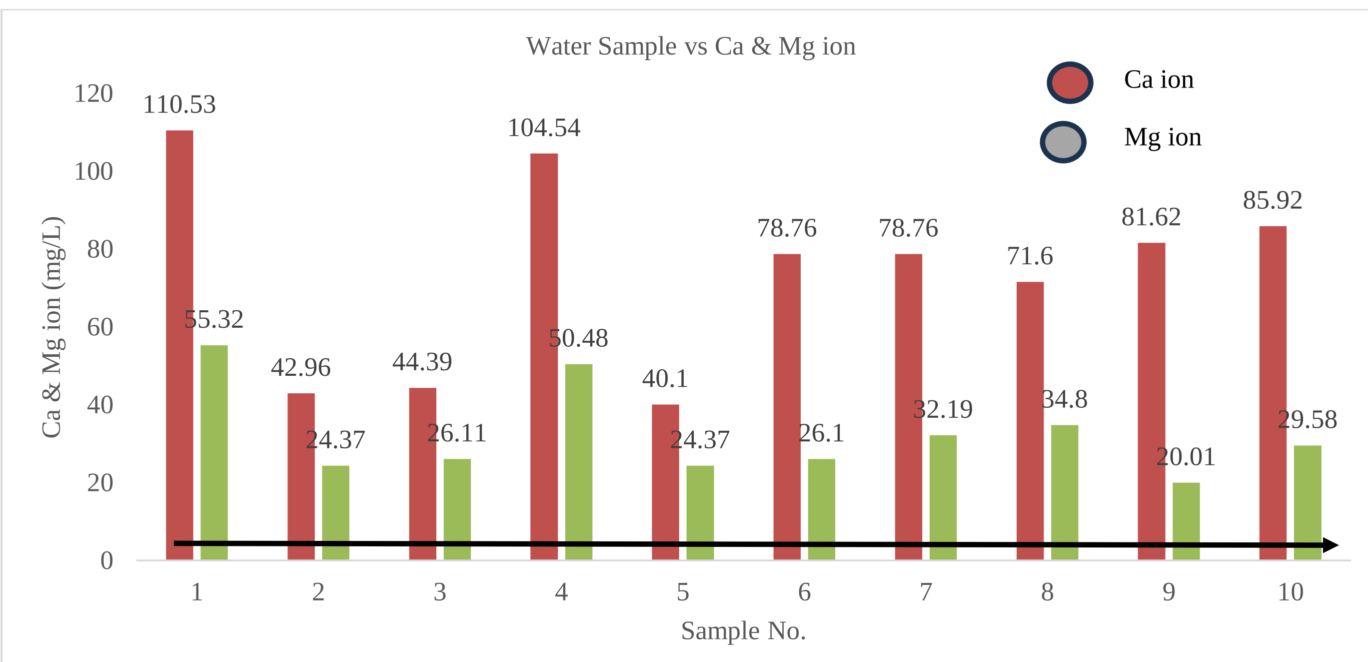

Figure-4: Comparative study of Calcium ion and Magnesium ion content for collected samples.

It may also be observed that in each sample, the magnesium ion concentration is much lower than that of the concentration of calcium ion. In this study, the range of the dissolved oxygen values are from 6.44 mg/L to 7.52 mg/L for underground water samples (Table-4 and Figure-5), whereas the BIS standard values are from 3.0 mg/L to 5 mg/L. So, it may clearly conclude that the D.O. of water samples is much greater than the standard value as prescribed by BIS.

As per the guideline prescribed by BIS the range of acceptable and permissible limits of chloride ion in drinking water is 200 mg/L and 1000 mg/L (Table 5), and as per the WHO guideline, chloride ion in drinking water has no role as such in health-based issue. However, in excess concentration of about 250 mg/L may rise to a noticeable taste. Ranges of experimental results are from 56.80 mg/L -397.60mg/L (Table-4, Figure-6), where, in most cases (except G_1) chloride occurs well below that of those at threshold values.

To detect the fluoride ion concentration for drinking water samples is vital for every researcher. WHO/BIS suggests 1.0 mg/L of fluoride ion concentration as acceptable limit (Table-5) for drinking water that may extend up to 1.5 mg/L (as permissible limit). Experimental show the range of fluoride ion concentration is from 0.466 mg/L (G_{10}) to 1.910 mg/L (G_5) (Table-4, Figure-7) in where most of samples contains fluoride ion concentration below 1.0 mg/L except sample no G_4 and G_5.

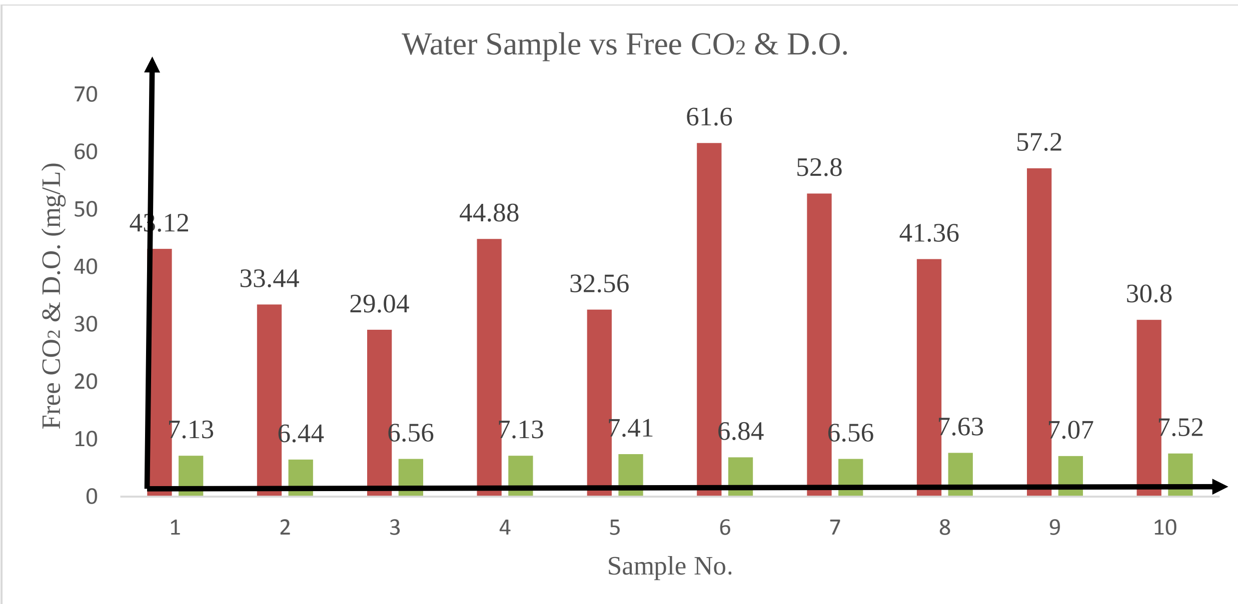

Figure-5: Comparative study of D.O. in the collected samples.

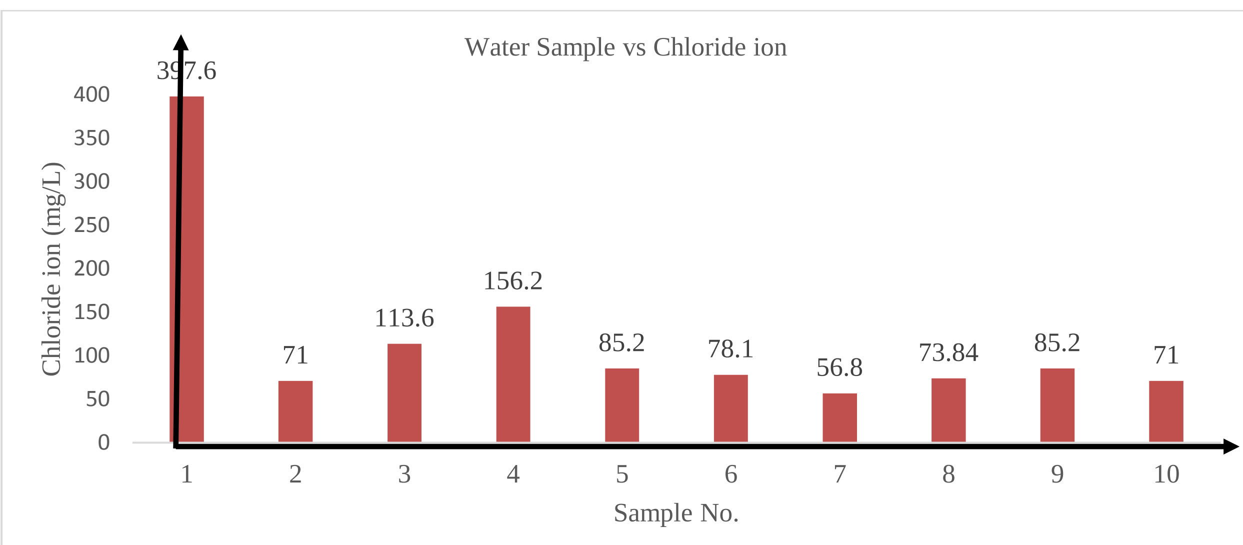

Figure-6: Comparative study in Chloride ion in the collected samples.

The values of WQI (Water Quality Index) have been derived from experimental measurements of selected parameters. Calculations for samples number G_2has been shown in Table-6 in details and WQI for all underground samples have been tabulated in Table-7. In this study, the WQI ranges are from 7.7742 (G_8) to 134.621 (G_5) which indicate the water quality of these samples varies from good (Grade A) to very poor (Grade E) based on the tested parameters (Table-2,7). On average, the WQI for the study area is 43.711, classifying the water as good quality that indicate the water quality is suitable for the use of domestic purpose, irrigation purpose, and industrial uses but requires proper purification for safe drinking to prevent waterborne diseases. Comparative analysis shows that 40% of the samples are of excellent quality and can be used for all purposes, 30% are of good quality, 20% are of fair quality, and only 10% are of very poor quality. Samples G_6, G_8, G_9, and G_{10} are rated as excellent, while sample G_5 is classified as very poor (Table 7). The WQI for the sample sites is ranked in descending order as follows: $G_5 > G_4 > G_2 > G_3 > G_1 > G_7 > G_6 > G_9 > G_{10} > G_8$. A line chart with markers for the comparative analysis of all samples is also provided in Figure-8.

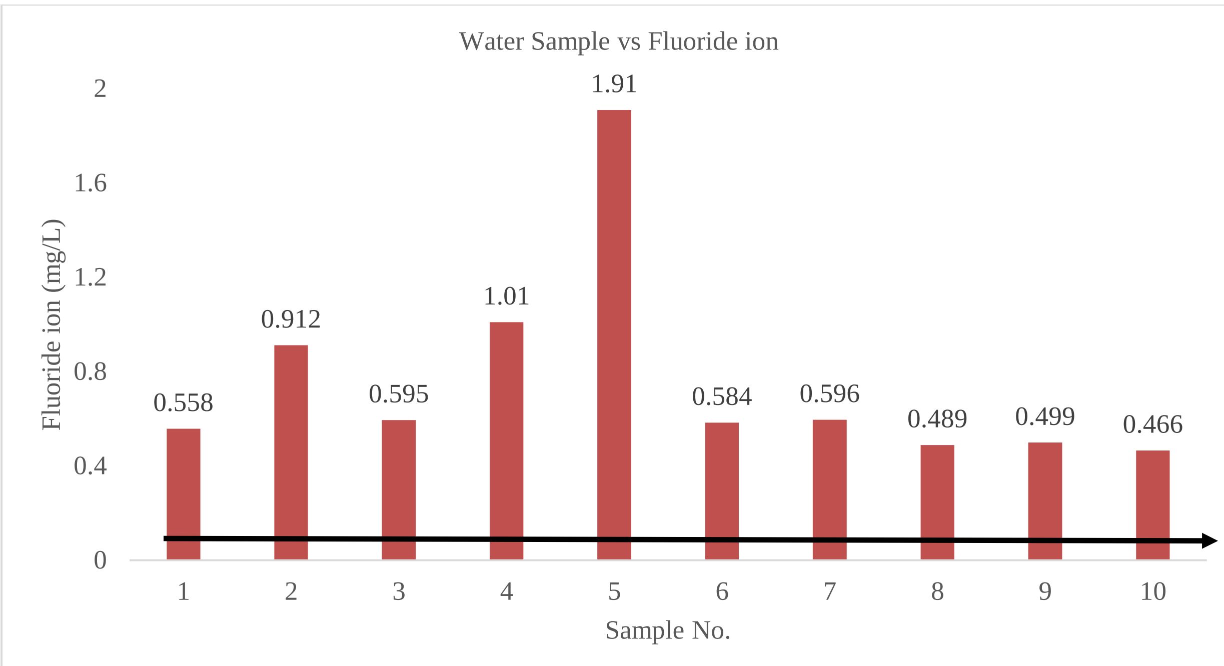

Figure-7: Comparative study of fluoride ion content in the samples.

Table-6: Detailed calculations for (WQI) assessment for the sample G_2.

Parameters	Experimental values (Va)	Standard Values (Vs)	Recommended by	Unit weight (Wi)	Quality rating (Qi)	(Wi.Qi)
TDS	202	500	BIS:2012	0.00141	40.40	0.056964
Conductivity	260	750	BIS:2009	0.001333	34.67	0.032587
alkalinity	25	200	BIS:2012	0.003525	12.50	0.044063
pH	7.74	6.5-8.5	BIS:2012	0.108462	-141.00	-16.0523
Dissolved oxygen	6.44	5	BIS:2009	0.141	84.84	11.96274
Hardness	204.06	200	BIS:2012	0.003525	102.03	0.359656
Calcium	42.96	75	BIS:2012	0.0094	57.28	0.538432
Magnesium	24.37	30	BIS:2012	0.0235	81.23	1.908983
Chloride	71	250	BIS:2012	0.00282	28.40	0.044063
Fluoride	0.912	1	BIS:2012WHO	0.705	91.20	64.296
		ΣWi = 0.999582			ΣQiWi = 63.2272	

K=0.705295; WQI=ΣQiWi /ΣWi =63.25364

Pearson's correlation matrix calculations (Table-8) reveal that electrical conductance has its very strong positive relation with magnesium, hardness, and total dissolved solids, as well as a strong correlation with calcium ions. Similarly, the TDS parameter has a very strong positive correlation with chloride, calcium, magnesium, and hardness, and with bicarbonate ion it shows a moderate positive correlation. The correlation matrix also indicates that hardness has a strong positive correlation with magnesium and chloride ions, and a strong positive correlation with calcium ions. The alkalinity parameter exhibits a very strong positive correlation with bicarbonate ions and a strong relationship with calcium ions.

Table-7: WQI (Water Quality Index) for all the experimented samples.

Sample No	WQI	Grade	Status	Sample No	WQI	Grade	Status
G_1	35.129	B	Good Quality	G_6	23.808	A	Excellent Quality
G_2	63.253	C	Fair Quality	G_7	25.225	B	Good Quality
G_3	46.594	B	Good Quality	G_8	7.7742	A	Excellent Quality
G_4	64.866	C	Fair Quality	G_9	18.677	A	Excellent Quality
G_5	134.621	E	Very poor Quality	G_{10}	17.162	A	Excellent Quality

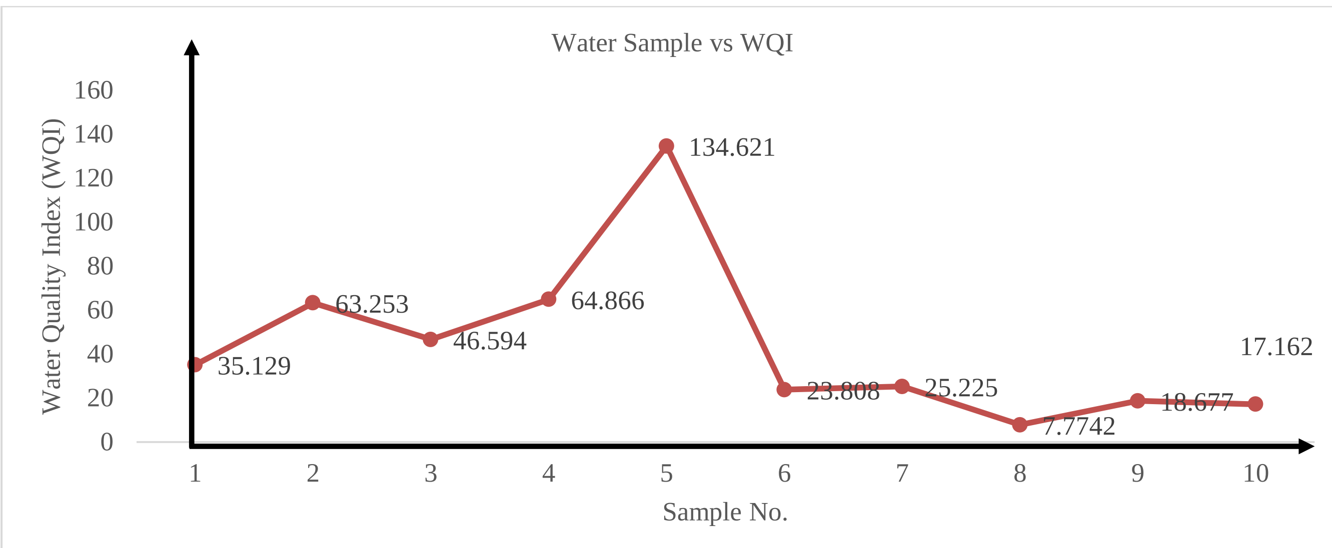

Figure-8: Graphical presentation with markers of WQI for all ground water samples.

Table-8: Water Quality Parameters with Pearson's correlation matrix.

	E.C	PH	Alkalinity	TDS	D.O.	Hardness	**Ca^{2+}**	**Mg^{2+}**	**Cl^-**	**$HCO3^-$**	**F^-**
E.C.	1										
pH	0.10339	1									
Alk	0.34019	0.45404	1								
TDS	0.9559**	0.25483	0.53347	1							
D.O.	0.13513	0.40445	0.50387	0.20682	1						
Ha	0.96511**	0.13426	0.33726	0.90461**	0.24056	1					
Ca^{2+}	0.75712*	0.52155	0.73028*	0.86427**	0.29494	0.76345*	1				
Mg^{2+}	0.84407**	0.09532	0.54485	0.90911**	0.21711	0.83681**	0.74311*	1			
Cl^-	0.95205**	-0.1762	0.18938	0.84887**	0.08975	0.92797**	0.56830	0.79011*	1		
HCO_3^-	0.34019	0.45404	1**	0.53347	0.50387	0.33726	0.73029*	0.54485	0.19889	1	
F^-	-0.31504	-0.5647	0.04405	-0.38699	0.13321	-0.22855	-0.45702	-0.10686	-0.0977	0.04405	1

**very strong; * strong

Additionally, alkalinity shows a moderate positive correlation with TDS, dissolved oxygen (D.O.), and magnesium ions. Experimental results further suggest that calcium ions have a strong relationship with magnesium and bicarbonate ions. The pH parameter shows a moderate positive correlation with alkalinity and bicarbonate ions, and a moderate negative correlation with fluoride ions. There is no strong correlation between fluoride and other parameters. The matrix calculations reveal only a moderate negative correlation between fluoride ions and pH and calcium ions, with no significant negative correlations observed elsewhere.

Conclusion

Projected was to measure some physical as well as chemical parameters of the water quality of the Hura Block area of West Bengal. All the experimented parameters are not within the range as prescribed by BIS and WHO. Considering all the experimented results, it is seen that the average values of total dissolved solids, electrical conductivity, pH, alkalinity, D.O. total hardness, calcium, magnesium and chloride of samples are 391.2 mg/L, 628.7μS/cm , 8.18, 38.5 mg/L,7.02 mg/L, 349.05 mg/L, 73.92 mg/L,32.33 mg/L, and 118.85 mg/L whereas for surface water samples the average values are like 206.20 mg/L, 285.6 μS/cm, 7.88,26.0 mg/L, 8.44 mg/L, 152.92 mg/L, 30.64 mg/L,16.62 mg/L, and 55.38 mg/L respectively which are all within the normal range of the standard, while the average value of dissolved oxygen (D.O.) is 17.39 mg/L, which is much higher than the normal value of the standard value. Free CO_2, bicarbonate (HCO_3^-), Carbonate (CO_3^{2-}) ion content is also measured in where the average reading for ground water samples is 42.68 mg/L, 46.97 mg/L 0.00 mg/L and for surface water samples it is like 16.28 mg/L, 31.72 mg/L and 0.00 mg/L respectively which express that in all the samples Carbonate (CO_3^{2-}) ion content is zero. Fluoride ion content of ground water samples is measured in where the average value is 0.762 mg/L. The sample no. G_1 is remarkable because it shows higher values for most of the parameters.

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