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Hydrogeochemistry and Overall Appraisal of Groundwater Status of Taldangra Block, Bankura District, West Bengal, India

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Abstract: South-western districts of the state of West Bengal, India are considered to be a significantly water-stressed area of the state because of unfavourable geological setting, subsurface lithology, soil cover and surface drainage pattern. Updated geohydrological data on micro-scale i.e., at subdivision or block-level are scanty for Bankura District, West Bengal. For the present study, a geo-hydrological survey was conducted in Taldangra block of Bankura District, West Bengal, during post and pre-monsoon session of 2017–18, to obtain an intense status on present groundwater quality of this water-stressed block. Variation of concentration of major affecting ions and spatial-temporal seasonal variations of water table elevation head and subsurface shift of predominant recharge and discharge zones of the block were demarked explaining the possible reasons. Suitability status of the groundwater for drinking, domestic and irrigation usages was also rated by the estimation of sodium adsorption ratio (SAR), soluble sodium percentage (SSP), permeability index (PI), Piper trilinear diagram.

Key words: Hydro-geochemical, groundwater suitability, Taldangra, Bankura.

Introduction

Water is an utmost essential and mandatory resource for the progress of human civilisation including the survival of the entire biosphere. Multifold usage of this natural resource eventually provides sustainability to our life and comfort. Good water quality resources depend on large number of physicochemical parameters (Srinivasamoorthy et al., 2008). Anthropological factors such as pollution load, cultivation, irrigation, industry and poor drainage plan impart a significant effect on the subsurface groundwater dynamics; its quantity and quality. Therefore, monitoring of accessibility of available water and estimation of its instantaneous quality is essential regularly (Nag and Biswas, 2016). Almost all of these studies were generally confined to a comparatively larger region comprising of a geological terrain such as river basin or coastal areas, which was state or district level mostly. However, evaluating the groundwater scenario more intensely comprising a concise small administrative area such as sub-division to the block level is necessary to frame a sustainable proper water management plan and for the maintenance of its quality. The literature review reveals that except a very few investigations on fluorite contaminations in the NW part of the Bankura District, the present hydrogeological status and its physicochemical characteristics have not been investigated completely in the recent past. According to the last published report of CGWD (Technical Report – no. 278 series D, Groundwater Year Book of West Bengal & Andaman & Nikobar Island 2015-1016) out of the total 23 blocks

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of the district, the blocks at NW marked as 'water-stressed'. In most of the cases, allocation of funds for rural development from the governmental authority is generally disbursed to the administrative units of the districts like local 'block development offices', from there to 'municipalities' or village 'panchayats'. Therefore, there is a need to focus intensely on the groundwater-related issues in micro-scale rather than broad expanded geological terrain to insight the minutes of the problems in details for a 'Block' or 'Subdivision' level. Taldangra is one such block in the NW part of the district. It was traditionally suffering from groundwater-related issues related to sustainability and the overall quality of the groundwater. Therefore, the present study was confined to the Taldangra block, Bankura, West Bengal, India to evaluate and appraise the overall groundwater status. Detailed qualitative appraisal of groundwater was done to evaluate the recent status on drinking, domestic and irrigation suitability.

Study Area

The present study was carried out and restricted in Taldangra block, Bankura District, West Bengal, India (Figure 1). The eastern part has a wider plain of recent alluvium. The area of the block is 349.70 km^2 with an average elevation of 74m. The soil of the area is mainly lateritic and significantly has high porosity and permeability. The South-eastern part of the block consists of a considerably thick pile of recent alluvium and patches of loamy meta-sediments. The country-rock of the area is chiefly Chhotanagpur granite gneiss with enclaves of meta-sediment and characterised by high porosity and permeability. The annual average rainfall in the district is about 1400 mm (http://bankura.

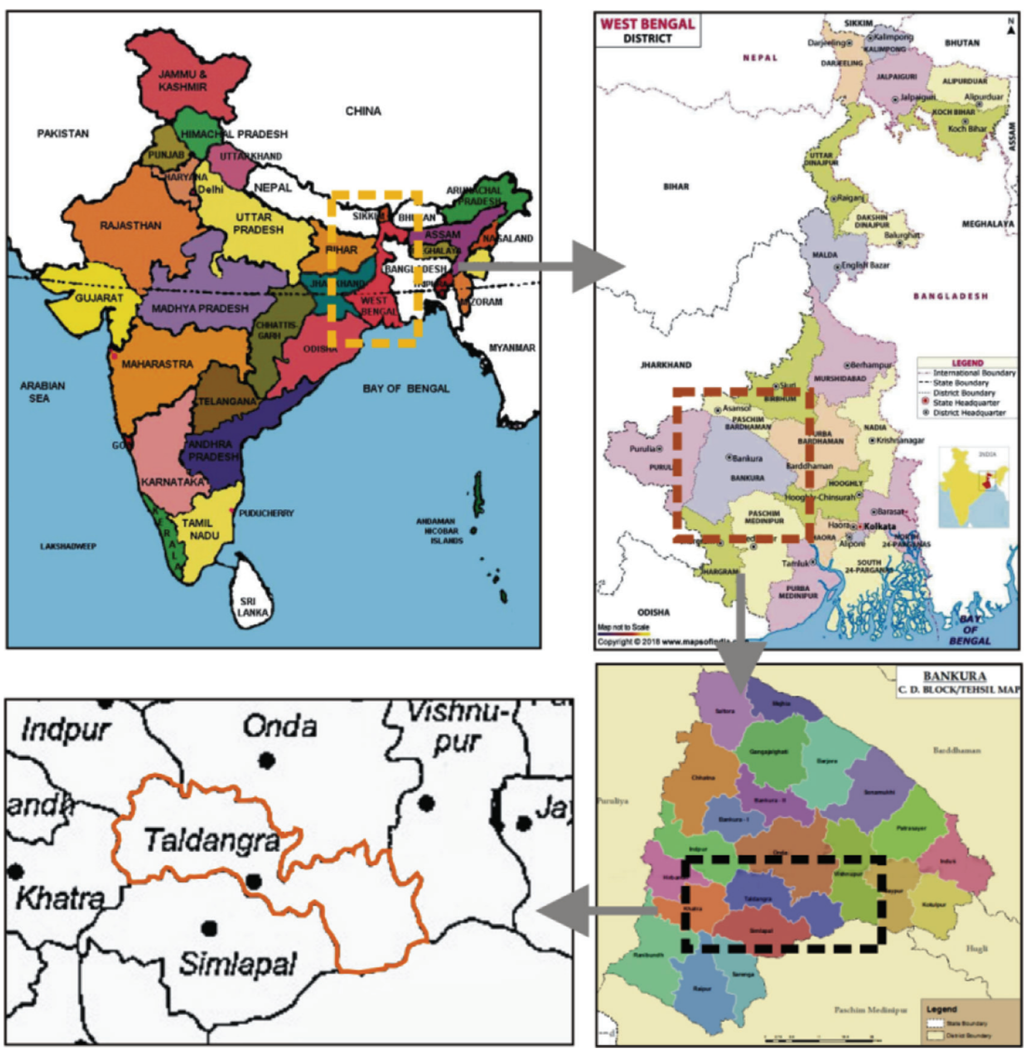

Figure 1: Location of the study area (a) map of India, (b) the state of West Bengal, (c) Bankura District and (d) outline of Talgangra block.

gov.in/) and the bulk rain occurs mostly from June to September. The Dwarkeshawar, Kangshabati, Silabati, and Damodar with their tributaries constitute the main drainage system of the Bankura district. Other important rivers are the Gandheswari, Berai, Sali, and Jaiponda. All these rivers originate from the western upland beyond the geographical boundary of the district and flows in the south-east direction of the district. A major portion of this precipitation is drained out as surface run-off by the inundated nature of basin outlets and below the surface interflow through thinner permeable vadose zone over impervious basement, in a relatively faster rate. Therefore, overexploitation of groundwater for irrigation and domestic purposes resulted in a radical scarcity of water specifically in summer months with a substantial degradation of its quality.

Materials and Methods

The present study comprises of a collective series of field investigations and analysis of groundwater samples thereafter. The groundwater samples were collected during the post-monsoon season (PoM) 2017 and pre-monsoon season (PrM) of 2018. A total of 20 samples were collected from 20 different locations of the block, which were scattered more or less equilaterally having a similar distance in-between. In-situ measurements of ground water table (GWT) depth (m, below ground level) were measured by inserting the 'Solinst 100m Water level indicator' (model 101B) through the studied well. Thereby the location wise elevation head (m, above mean sea level) of the ground water table (GWT) was estimated by the difference between GWT depth and the altitude of the studied well (as recorded by GPS). Instantaneous measurements of some major physicochemical parameters of the collected samples were taken by using Hanna portable multi-parameter water testing instrument (model HI98194). The major physical parameters measured in-situ were pH, electrical conductivity (EC), and total dissolved solids (TDS).

Obtained data from the chemical analysis following the standard chemical procedure (APHA, 1995) were used to estimate the fluctuation of concentration of major ions to evaluate the status of overall suitability of groundwater towards health, domestic and irrigation purposes. Parameters such as sodium adsorption ratio (SAR) and soluble sodium percentage (SSP) were derived to estimate the suitability for agricultural and drinking purposes by plotting these values on standard reference diagrams such as Wilcox, U.S. Salinity (US Salinity Lab, 1954) and Piper diagrams (Piper, 1944). Spatial and temporal variation maps of major affecting parameters were done by extracting the studied Block area from TNT MIPS 2017 - GIS-based software and were made geo-referenced.

Results and Discussions

The present study intends to understand the overall variations of major physicochemical parameters measured for the studied block. Suitability of groundwater quality for domestic and irrigation purposes was evaluated through the estimation of standard chemical parameters. The spatio-temporal and fluctuation of groundwater table head were also estimated to get an idea on the directional movement of potential recharge and discharge zone of the block for PoM and PrM seasons. Table 1 represents the location wise elevation head of the groundwater table and major physicochemical parameters measured in-situ were pH, total dissolved solids (TDS) and electrical conductivity (EC), the variation of concentration of major cations and anions for PoM and PrM periods.

Water Table Depth and Seasonal Shifts

Figure 2a, b reveals the fluctuation contours of subsurface water table elevation head and metre above mean sea level (MASL). Overall, it shows that the

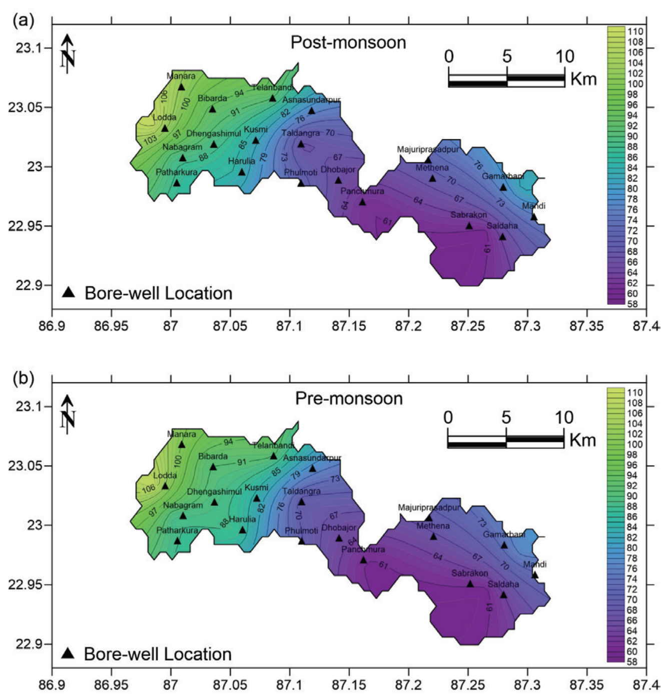

Figure 2: Spatial fluctuation of groundwater table head (MASL) for (a) PoM and (b) PrM.

Table 1: Chemical Analysis Result for PoM and PrM Seasons

Sr no.	*Physico-chemical parameters*	*Season*	*Max*	*Location*	*Min*	*Location*	*Average*
1	WTH (m)	PoM	104.7	Lodda	61.3	Sabrakon	79.9
		PrM	104.0	Lodda	60.5	Panchmura	79.0
2	pH	PoM	7.16	Bibarda	5.39	Majuriprasadpur	6.17
		PrM	7.02	Bibarda	5.30	Majuriprasadpur	6.06
3	EC	PoM	1966	Lodda	20	Majuriprasadpur	358
		PrM	2231	Lodda	51	Majurprsadpur	410
4	TDS	PoM	785	Lodda	21	Majuripasadpur	164
		PrM	816	Lodda	24	Majuriprasadpur	200
5	Cl (mg/L)	PoM	243.90	Majuriprasadpur	28.00	Manara	109.22
		PrM	398.95	Nabagram	43.13	Mandi	182.12
6	HCO^{3-} (mg/L)	PoM	248.25	Lodda	34.82	Majuriprasadpur	133.62
		PrM	235.00	Lodda	20.12	Saldaha	83.78
7	SO^{4-} (mg/L)	PoM	92.91	Nabagram	10.07	Majuriprasadpur	48.35
		PrM	80.12	Harulia	9.34	Majuriprasadpur	43.77
8	Ca (mg/L)	PoM	246.96	Lodda	32.66	Majuriprasadpur	151.3
		PrM	333.60	Lodda	50.08	Majuriprasadpur	180.30
9	Mg (mg/L)	PoM	37.47	Bibarda	4.80	Majuriprasadpur	20.44
		PrM	33.66	Lodda	2.64	Majuriprasadpur	18.36
10	Na (mg/L)	PoM	42.00	Lodda	8.50	Asnasundarpur	26.53
		PrM	54.10	Lodda	6.00	Asnsundarpur	33.29
11	K (mg/L)	PoM	20.00	Lodda	0.67	Majuriprasadpur	10.54
		PrM	16.03	Nabagram	0.36	Majuripasadpur	6.09
12	F (mg/L)	PoM	0.7	Asnasundarpur	0.02	Saldaha	0.3
		PrM	1.0	Lodda	0.01	Asnsundarpur	0.3

maximum water table head was located at the Western (W) to the North-western (NW) corner of the block. The maximum height of the water table head is observed at Lodda, which is located at the Western part of the block for both PoM (104.7 m) and PrM (104.0 m) period that gradually descended towards the Eastern (E) to southeastern (SE) part of the block. The SE part of the block shows the minimum elevation of the water table lowest at Sabrakon. The minimum head was noted 61.3 m and 61.2 m during PoM and PrM, respectively. Vector plots (Figure 3a, b) of subsurface water movements validate that the flow is from E to SE corner of the block and this move is comparatively faster during PoM season than PrM. Three prominent recharge zones were demarked, of which two were at the central part (near Taldangra and Panchmura) and one is at the SE portion (South of Sabrakon and Saldaha) of the block. Overall flow direction was from E to SE from the Western side of the block. Whereas the flow vectors of the eastern side of the block was directed mostly towards the southwest, forming a prominent recharge zone at the southeast corner of the block

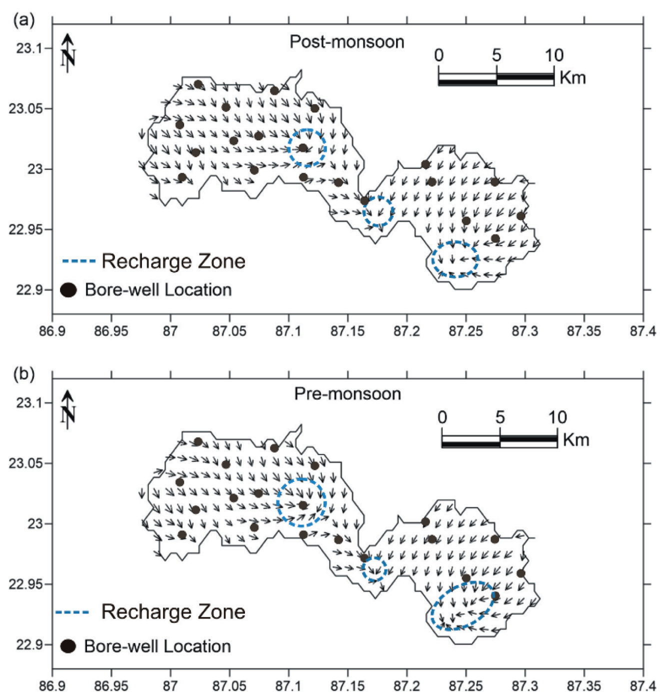

Figure 3: Vector plot showing the spatial fluctuation of groundwater table head (MASL) for (a) PoM and (b) PrM.

(south of Sabrakon). However, it is to be mentioned here that a considerable area of the extreme SE corner of the block was covered by dense bushy jungles and practically devoid of inhabitation. Thus, it was not possible to access that corner fringe of the block after the location of Saldaha. Vector plots of subsurface flow revealed the existence of potential recharge zones in the area both for pre- and post-monsoon seasons. Presences of dense vegetation having negligible inhabitation and practically no irrigation were supposed to be the prime reasons for that area to evolve as a prospective zone for recharge and stagnancy of groundwater. Regular and frequent pumping of the ground water for the irrigation purpose results in scarcity of surface water bodies and outlets causes a low-pressure zone in the central areas. Continuous suction from the ground water table in the summer seasons was responsible for the formation of concentric clusters of flow vectors. Moving further SE (Sabrakon; Saldaha), an overall increase of vegetations and lessening of the population are significant factors for the stagnancy of groundwater and convergence of flow vectors to form a considerably expanded recharge zone.

Physicochemical Parameters Measured in situ

Obtained measures on major physicochemical parameters in in-situ condition both for the PoM and PrM period are presented in Table 1. For all the studied locations, physical parameters that were measured instantaneously include pH, EC, and TDS.

The pH of the groundwater of the block was more or less close to the standard (Table 2) and the mean value of pH varies from 6.17 in PoM to 6.06 in the PrM period. It implies that the water is feebly acidic in nature.

Figure 4a, b shows the variations of contours of pH during PoM and PrM seasons. The limits of pH ranged between 7.16–5.39 and 7.02–5.30. The maximum value of pH both during PoM and during PrM time

Table 2: Ranges of physicochemical parameters of groundwater and comparative status

Sl. No.	*Parameters measured*	*PrM*		*PoM*		*WHO (2008)*		*BIS (1991) IS:10500*	
		Measured ranges	*Mean*	*Measured Ranges*	*Mean*	*Acceptable Limits*	*Highest Permissible*	*Acceptable Limits*	*Highest Permissible*
1	pH	5.3 7.0	6.1	5.4 7.2	6.1	7.0 8.5	6.5 9.2	6.5 8.5	8.5 9.2
2	EC (µS/cm)	51 2231	410	20 1966	358	750	1,500	–	–
3	TDS (ppm)	24 816	200	21 785	164	500	1,500	500	2,000
4	HCO^3 (mg/L)	20.1 235.0	83.78	34.8 248.3	133.62	200	600	200	600
5	SO_4 (mg/L)	9.3 80.1	43.77	10.0 92.9	48.35	200	600	200	400
6	Cl (mg/l)	43.1 398.9	182.12	28.0 243.9	109.22	250	600	250	1,000
7	F (mg/L)	0.01 1.0	0.3	0.02 0.7	0.3	0.6 0.9	1.5	0.3	No relaxation
8	Ca (mg/L)	50.1 333.6	180.30	32.7 246.9	151.3	75	200	75	200
9	Mg (mg/L)	2.6 33.7	18.36	4.8 37.5	20.44	30	150	30	100
10	Na (mg/L)	6.0 54.1	33.29	8.5 42.0	26.53	50	200	–	–
11	K (mg/L)	0.4 16.0	6.09	0.7 20.0	10.54	100	200	–	–
12	TH	24 916	204.8	15 728	221.2	100	500	300	600

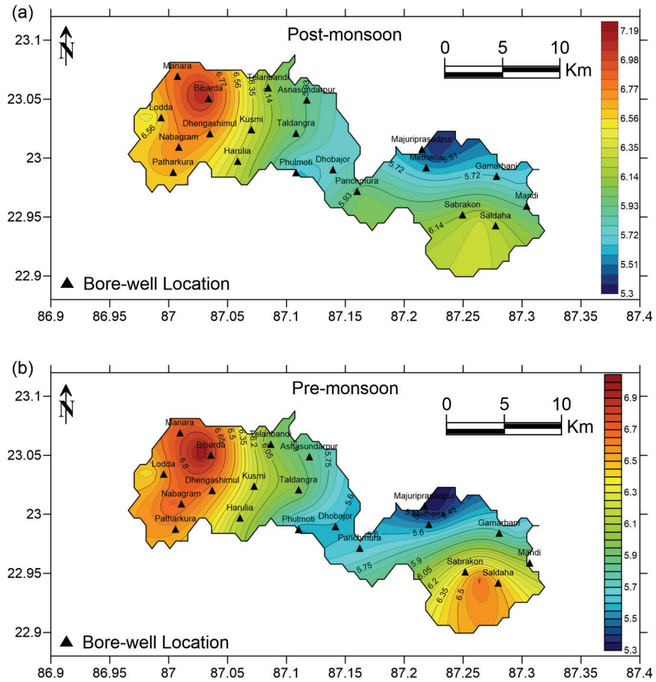

Figure 4: Spatial distribution of pH during (a) PoM and (b) PrM.

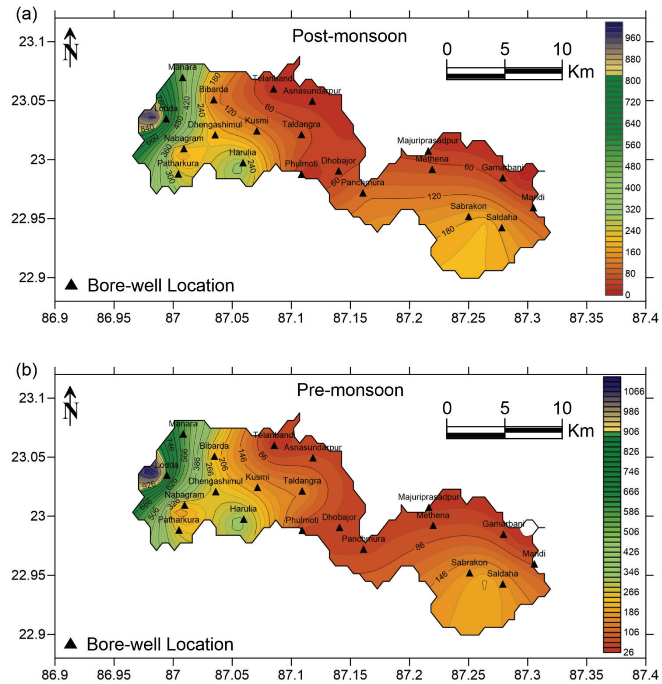

Figure 5: Spatial distribution of TDS: (a) during PoM and (b) during PrM.

was recorded at Birbada, situated at the North-western corner of the block and the minimum pH value, i.e., 5.30 during PrM was recorded at Majuriprasadpur, at the Eastern side of the block.

Figure 5a, b, represents the spatial variation plots of TDS during PoM and PrM season, respectively. The mean of TDS of the block rises to 816 ppm during PrM from 785 ppm in PoM. Though, as a whole, the ranges are within the permissible limits of 'Fresh Water' category (TDS < 1000, as per WHO (2008).

Physicochemical Parameters Measured in the Laboratory

Figure 6a, b reveals the variations of Na^+ concentration during PoM and PrM seasons, respectively. During PoM season, concentration ranges from 8.50 mg/L at Asnasundarpur to a maximum of 42.00 mg/L at Lodda. The concentration of Na^+ in PrM season ranges from 6mg/L at Asnasundarpur to a maximum of 54.10mg/L at Lodda having a mean of 33.29 mg/L. Therefore, it shows a slight increase in Na^+ average concentration as a whole in PrM.

Figure 7a, b shows the plots of Cl^- concentration. The concentration of chloride varies from 28.00 mg/L (Manara) to 243.90 mg/L (Majuriprasadpur) with an average of 109.22 mg/L during PoM and from 43.13 mg/L (Mandi) to 398.95 mg/L (Nabagram) with an average of 182.12 mg/L during PrM. From the contour

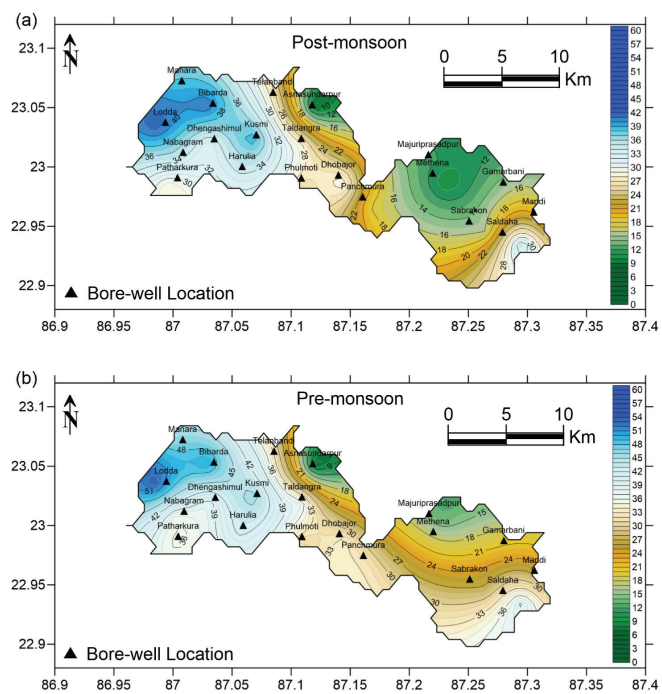

Figure 6: Spatial distribution of Na^+: (a) during PoM and (b) during PrM.

plot (Figure 7a, b), it was evident that during PrM, the concentration of Cl^- increased substantially in the block. The zone of high concentration shifted from the extreme western side of the block towards its South and Eastern part from PoM to PrM.

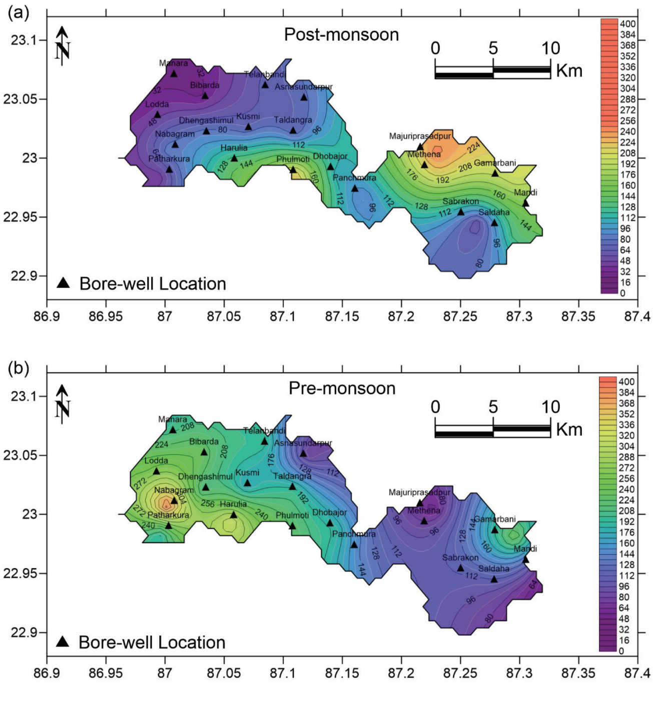

Figure 7: Spatial distribution of Cl^{-}: (a) during PoM and (b) during PrM.

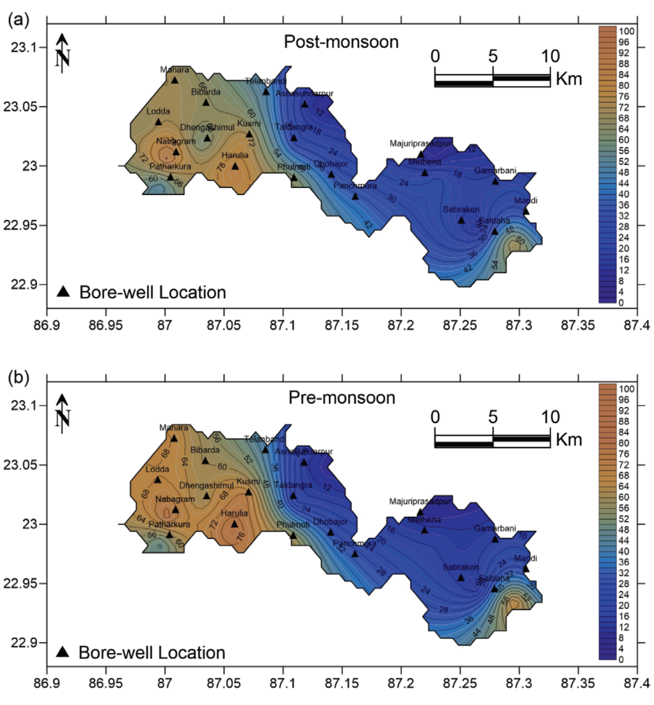

Figure 8: Spatial distribution of SO_4^{2-}: (a) during PoM and (b) during PrM.

Figure 8a, b shows a steep decrement of SO_4^{2-} from PoM to PrM. Central, E and SE parts of the block show a steady fall of SO_4^{2-} concentration during PrM compared to its PoM. The concentration of SO_4^{2-} during PoM increases at all the locations of the block and varies between 10.07 mg/L at Majuriprasadpur and 92.91 mg/L at Nabagram with an annual average value of 48.35. The sporadic quantum rises in SO_4^{2-} concentration in PoM was noted in Nabagram at the westernmost area of the block, where the thickness of the soil cover was minimum and lateritic in nature.

Some of the areas at the extreme south of the district were reported to have high fluoride (F^{-}) concentration than the highest permissible limit of 1.5 mg/L (Chakrabarti and Bhattacharya, 2013). The concentration of fluoride (F^{-}) was tested for all the collected samples. However, the concentration of the fluoride in the studied water was observed to be negligible and none of the samples exceeded the permissible limit based on WHO (2008) during both PrM and PoM sessions (Table 2). Thus, F^{-} concentration in the studied area is considered not to be harmful for irrigation and domestic uses. Table 2 reveals a comparative analysis of estimated ranges of concentrations of the major controlling ions of the block-water with that of the reference acceptable and permissible ranges according to the WHO (2008) and BIS guidelines (IS 10500:2012) for safe drinking purpose.

Appraisal of Water Quality for Domestic and Irrigation Purposes

Sodium Adsorption Ratio (SAR)

Figure 9a, b represents the plots of obtaining SAR value in the US salinity diagram for the classification of irrigation waters (Richards, 1954) both for PoM and PrM periods, respectively. The maximum SAR value in both PoM and PrM season was observed at Saldaha and the minimum value to be observed at Asnasundarpur. An increase in SAR value was observed during PrM than PoM and is constricted at the Eastern region of the block. According to the standard specified for water quality indices, the SAR value < 20 is considered to be excellent for irrigation (Richards, 1954). In the present study, the average SAR value during PoM is 0.39 while during PrM is 0.46, which suggests that the water of the block is suitable for usage. Figure 9a, b reveal the plots on US Salinity Diagram (after Richards, 1954), based on the SAR values, both for the PoM and PrM respectively. It reveals that overall water of the block fall in low sodium hazard zones and constricted at the basal-most portion of C1-S1, C2-S1, C3-S1 classes, both during PoM and PrM. Therefore, it seems that the water of the block is moderately suitable for irrigation. Here it is to be mentioned that due to close proximity

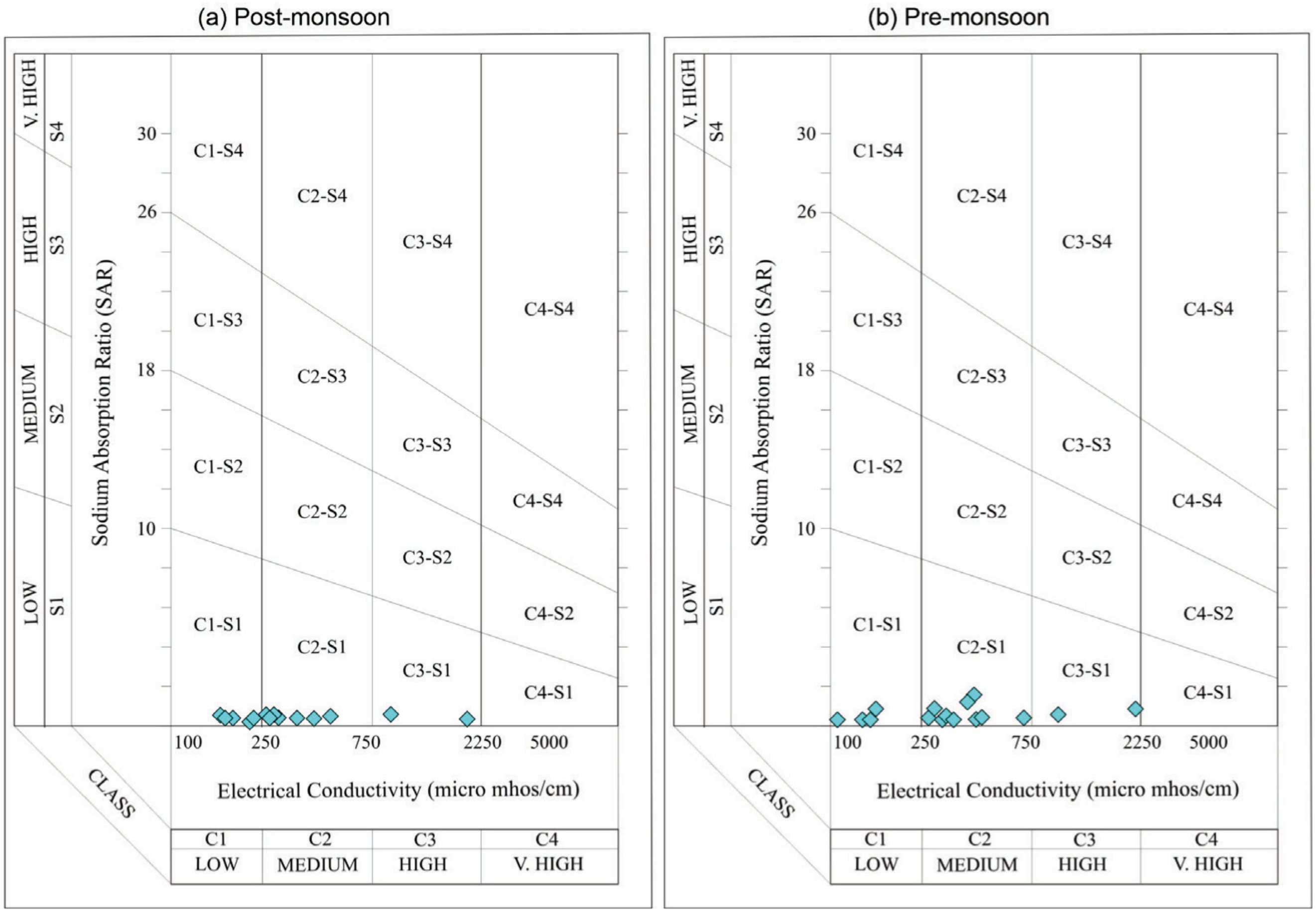

Figure 9: US Salinity Diagram: (a) PoM and (b) PrM (after Richards, 1954).

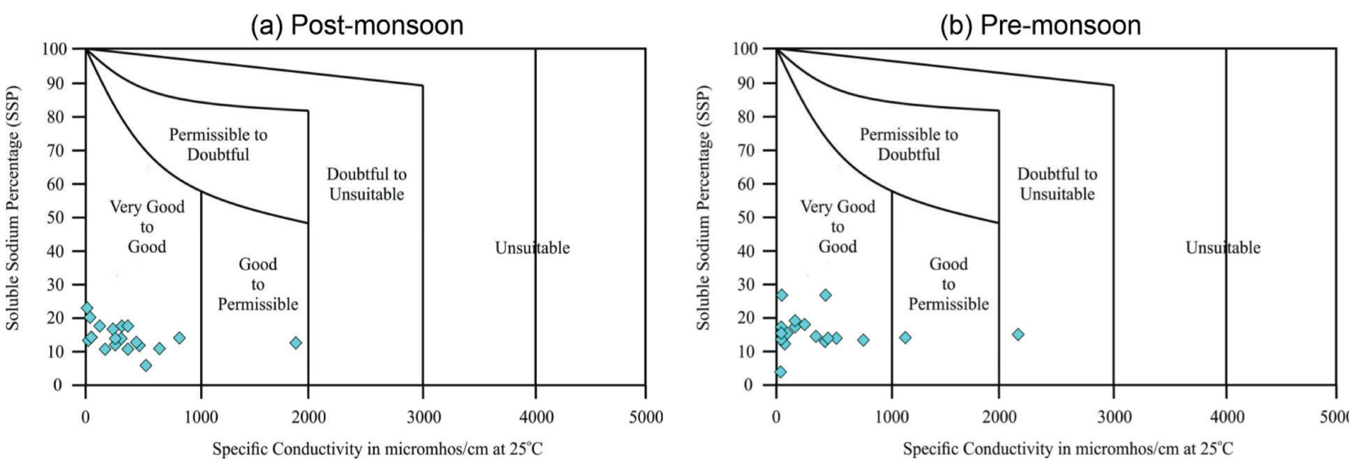

Figure 10: Wilcox Diagram: (a) during PoM and (b) during PrM.

of value, some of the data points coincided with the adjacent one.

Soluble Sodium Percentage (SSP) and Permeability Index (PI)

The absorption of sodium by clay particles is facilitated due to the release of calcium and magnesium ions resulting in internal drainage patterns in the soil causing high sodium ion concentration in soil (Todd, 1980).

The SSP values range from 6.45 to 22.37 meq/L in post-monsoon and 3.62–26.91 meq/L during pre-monsoon season. Figure 10a, b represents the ‘Wilcox Diagram’ as shown by the plots of SSP versus EC values (Wilcox, 1955). It is evident from the plots that mostly the water of the block is grouped in the "Very Good to Good" domain. Whereas, in stray, one to two samples fall in "Good to Permissible" categories, for both during PoM and PrM, respectively, except Lodda during PrM, which falls in 'Doubtful to Unsuitable'. 'Permeability Index' of the studied water samples of the block (after Doneen, 1964) is represented by the Figure 11a, b and the water quality data are constricted mostly in Class I and Class II waters, which are categorised as good for irrigation

Hydro-geochemical Facies

The Piper Trilinear diagram is represented by plotting the major cations and anions to determine the geochemical evolution of groundwater. This diagram is a graphical representation of the chemistry of water samples and their drinking suitability. This diagram reveals similarities and differences among water samples because those with similar qualities will tend to plot together as groups (Todd, 1980). Piper trilinear diagram (Piper, 1944) is useful to bring out chemical relationships for reactions in water in more definite

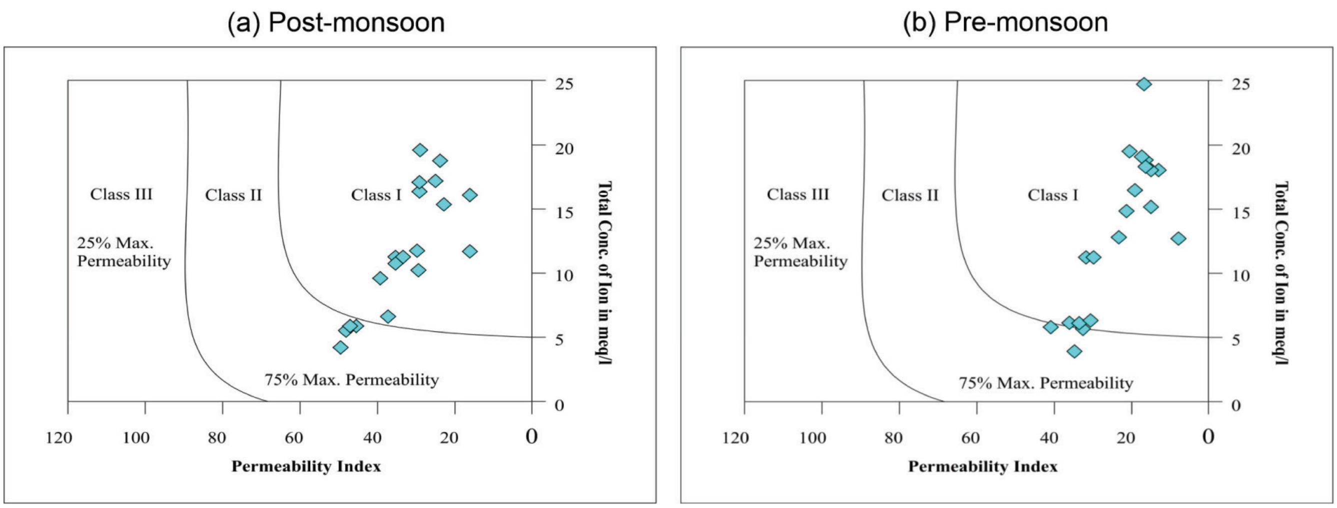

Figure 11: Doneen's Chart for P.I. values (a) during PoM and (b) during PrM.

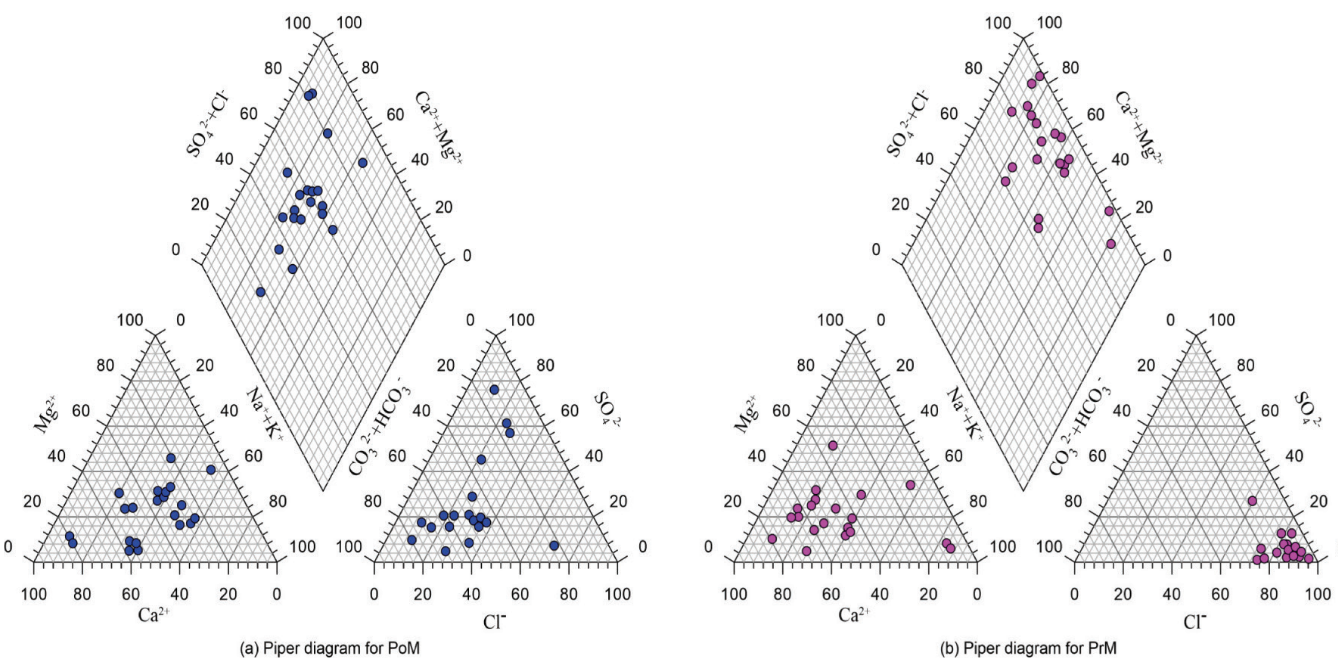

Figure 12: Piper Trilinear Diagram (a) during PoM and (b) during PrM.

terms (Apambire et al., 1997). Figure 12a, b shows the Piper diagram of the water during PoM and PrM seasons, respectively, and indicates that the water is fresh in nature during PoM while sulphate-rich in PrM.

Conclusions

The present study reports a new set of current data and up to date hydro-chemical appraisal of groundwater of the studied block. An intense evaluation of geohydrological status of the block was carried out in terms of its suitability for drinking and irrigation purposes. The water table depth of the studied block varies between the ranges of 2.7 m and 33.3 m during PoM and 3.5 m and 35.0 m during PrM. A steady increase in water table depth was noted towards SE direction and matched with the general geomorphological slope with a substantial thickening of permeable loose soil cover. The pH of the water shows mild acidity throughout the studied area. During PrM, the acidity was increased slightly at the E to SE part of the block. Flow vector plots revealed that these block areas are the most prominent recharge zones during PrM and POM. Higher values of EC were noted during PrM as compared to PoM.

Determination of groundwater suitability for irrigation and drinking purposes, through the estimation of SAR, SSP, and PI value showed that the water is mostly suitable for irrigation and safe for drinking purposes except for one or two locations (Lodda, Saldaha). The observations from the Piper diagram divulge that the water samples of most of the bore well are freshwater type with few places to be sulphate-rich during pre-monsoon time (Harulia, Kusmi and Saldaha) but, as a whole, most places of this block are suitable for drinking purposes.

Therefore, finally, it is concluded that the overall availability and stability of the groundwater below the surface is not adequate because of the highly porous and permeable lateritic thin soil cover. Suitability of the water both for domestic and irrigation purposes of this study area may be termed as 'good' to 'moderate' with a few exceptions on a local scale. Therefore, because of the gradual enhancement of anthropological stress due to population growth, expansion of irrigation and infrastructure, it requires a more concise and specific water management plan for the studied block to maintain the sustainability of availability and suitable quality.

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