SPATIAL AND TEMPORAL PATTERN OF GROUNDWATER QUALITY IN KEECHERI-PUZHAKKAL RIVER BASINS, CENTRAL KERALA, INDIA

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Abstract

Spatial and temporal pattern of groundwater quality in shallow and deep aquifers of Keecheri-Puzhakkal river basin, central Kerala has been studied. 63 dug well and 7 bore well water samples from the basin area was collected and analyzed for the hydrochemical parameters during post-monsoon, monsoon and pre-monsoon season (2014-15). Chemical quality of water samples indicates that dominant cations are Na^+ and Ca^{2+} and the anions are HCO_3^- and Cl^-. Spatial distribution plots indicate higher pH, EC, Cl^-, total hardness, salinity and TDS in the western part of the basin adjoining the sea inlet (Chettuva). The EC in the dug well water samples ranged from 49-2600 µmho/cm in the pre monsoon and 64-1971 µmho/cm in the post monsoon season. The TDS content ranged from 28-1890 mg/L in the pre monsoon and 40-1399 mg/L in the post monsoon season. In the deep wells (bore well), the EC values ranged from 160-1491 µmho/cm in the pre monsoon and 344-804 µmho/cm in the post monsoon season. Hill-Piper plots shows that Na-Cl is the dominant water type followed by Ca-HCO_3 and Na-HCO_3 type in the shallow wells in pre and post monsoon seasons. Bacteriological analysis of the dug well water samples indicated Total coliforms are higher in density during pre monsoon season. E. coli is present in 28% of the dug well samples in post monsoon, 33% in pre monsoon and 42% samples in monsoon season. Total coliforms are seen in most of the bore wells whereas E. coli is absent.

Keywords: *Groundwater quality, Keecheri-Puzhakkal River basins, Central Kerala*

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1. INTRODUCTION

The quality of groundwater is the resultant of the processes and reactions that act on the water from the moment it condensed in the atmosphere to the time it is discharged by a well or spring and it vary from place to place with the depth of water table. There are many sources that contribute contaminants to the groundwater, e.g., land disposal of solid wastes, sewage disposal on land, agricultural activities, saline intrusion, urban runoff and polluted surface water. Groundwater quality monitoring is an essential step in characterizing groundwater systems. There are many studies on spatial and temporal patterns of groundwater quality considering domestic and irrigation standards [1-6]. Most of the studies focuses on the major ion composition, anthropogenic contaminants, dissolved and trace constituents. Statistical methods were employed to bring out the hydrogeochemical relationships between various parameters [7,8,9,10]. In Kerala region, basin wise studies on groundwater resources and water quality are few [11,12]. There are some studies in the Puzhakkal basin area that focus on brackish water intrusion problems and groundwater potential of deep fractured rock aquifers [13,14]. The main objective of the present study is to assess groundwater status of the river basin (Keecheri-Puzhakkal river basin) in terms of quality and distribution. The basin is part of the central Kerala region has an area of 635 km^2. The lowland region of the basin forms part of the Kole lands (paleo-lagoon) in Thrissur district and the highest elevation is 525 m amsl (Machadmalai) in the foothills of Western Ghats (Fig.1). The length of the mainstream in the Keecheri and Puzhakkal rivers are 51 km and 29 km respectively [12]. The basin area receives an average annual rainfall of 3000 mm. The annual average stream flow is 1024 MCM. A major irrigation dam (Vazhani) is located in the upstream part of the river basin. The Kole land basin extends in most of the lowland region with ridge-runnel topography in the coastal stretches. Geologically lowland regions mainly consist of paleo-beach deposits, fluvial and fluvio-marine deposits (Fig.2). The Kole lands have a significant influence on groundwater environment in these basins [15]. The midland region is mainly covered with Laterite and weathered Charnockites and Charnockite gneisses. The highland areas within the basin mainly consist of Charnockites, Hornblende-biotitite gneisses and Pyroxene granulite with intrusions of Gabbro and Dolerite [16].

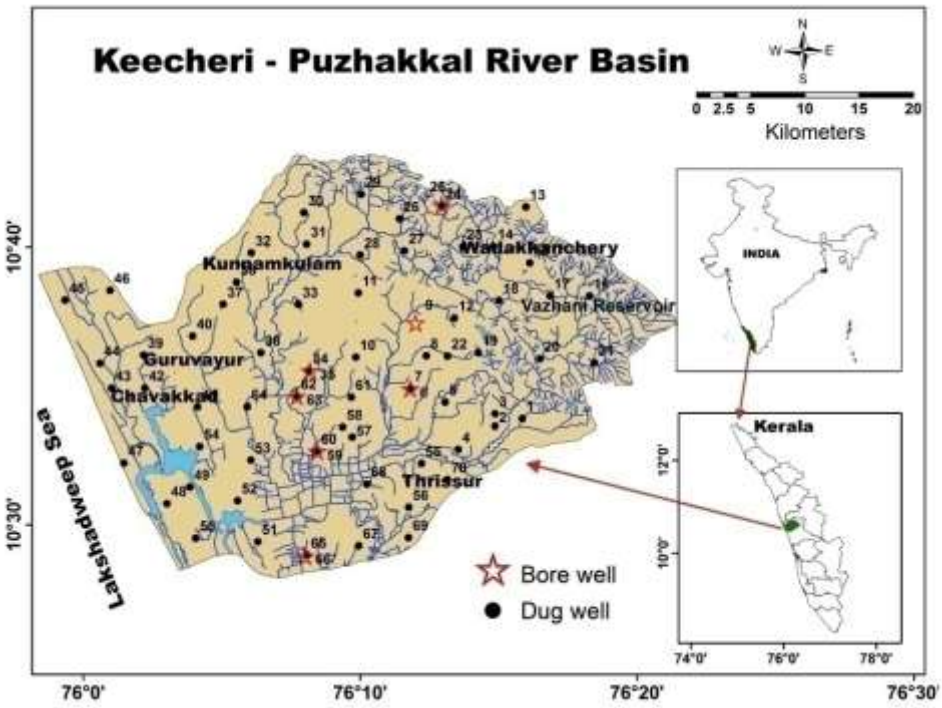


Fig.1. Study area showing water sampling locations

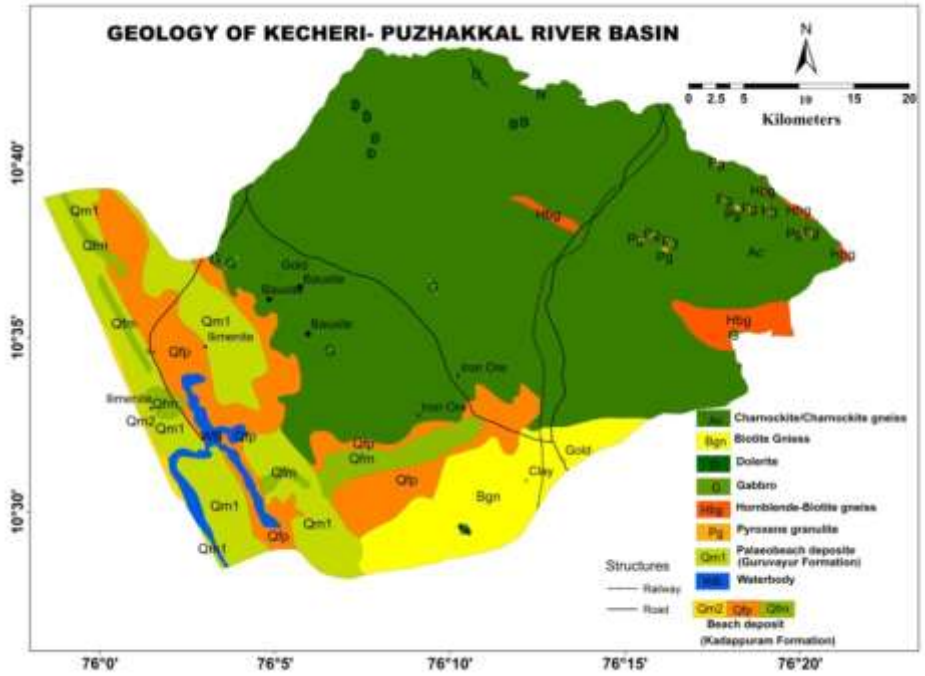


Fig.2. Geology of the Keecheri-Puzhakkal river basin

2. METHODOLOGY

Water samples were collected from dug wells/filter point wells (63 nos.) and bore wells (7 nos.) during post monsoon, monsoon and pre-monsoon seasons (2014-15). Physico-chemical and bacteriological analysis of the samples was carried out in the chemical laboratory as per the standard methods. The pH, TDS, EC and salinity of the samples were measured in the field using handheld multi-parameter instrument. The concentration of major ions (cations and anions), Total alkalinity and Total hardness in the samples was analyzed as per the standard methods [17]. Sodium and potassium in the water samples was analyzed using Flame photometer. Calcium and magnesium was estimated by EDTA titrimetric method, and chloride content was determined by argentometric titration using standard silver nitrate. Carbonate concentration of the water samples was determined titrimetrically. Total alkalinity of the water

samples was determined by using H_2SO_4 titration. Sulphate and turbidity determination were carried out following turbidity method using Nephlo-Turbidity meter. The Nitrate and Nitrite contents of the samples are analysed by using UV-Visible Spectrophotometer. Concentration of iron in the samples were analysed by using 1,10-phenanthroline method. Total Coliform and E.Coli were analysed using standard microbiological method. The most probable number (MNP) test was used to enumerate the total no of bacteria in the samples. Lithological observations of well sections show that in coastal plain region the aquifer is clayey sand to sandy clay. In the midland areas the aquifer is mainly laterites overlain on weathered crystalline basement. River alluvium, sandy soil, clayey soil and fine sand were also found in some areas. The laterite formation is very thin or absent in the foot hill region in the river basin.

3. RESULTS AND DISCUSSION

The minimum, maximum and average values of water quality parameters for the dug wells during the post-monsoon, pre-monsoon and monsoon season are presented in Table 1. The spatial distribution maps of various parameters are presented in Figs 3 to 9.

3.1 In-situ Parameters

3.1.1 pH

Most of the samples have pH within the acceptable drinking water quality limit [18]. The pH of the dug well samples varied from 5.1-7.6 in the post-monsoon and 4.8-8.3 in pre-monsoon. In the monsoon season, the pH range is 4.8-7.7. The spatial plots show that most part of the basin is acidic water, but alkaline nature increases during post-monsoon. Alkalinity of water samples is higher in the low land region compared to midland region. In the bore well samples, pH varies from 6.4-7.5 in the post-monsoon to 6.2-7.9 in the pre-monsoon. The pH varies from 6.1-7.7 in the monsoon season.

3.1.2 Electrical Conductivity (EC)

The EC of the dug well water samples varied from 64-1971 µS/cm in post-monsoon and 49-2600 µS/cm in the pre-monsoon. In the monsoon season, the EC varied from 49.3-1308 µS/cm. In the bore well samples, EC varied from 344-804 µS/cm in the post-monsoon and 160-1491 µS/cm in pre-monsoon. EC values varied from 113-1900 µS/cm in the bore well samples during monsoon. In the dug wells, higher EC values are seen in the samples collected from the wells near to the backwaters and inlet (Fig. 3). The EC values are also higher in the low land areas near to sea inlet in the pre-monsoon season.

3.1.3 Total Dissolved Solids (TDS)

The TDS values are higher than acceptable limit in the shallow wells in some areas during all the seasons. The TDS content in the dug well water samples varied from 38.9-1399 mg/L in the post-monsoon and 28-1890 mg/L in the pre-monsoon. The TDS content varies from 35-9260 mg/L in the monsoon season. In the bore well samples, during post-monsoon the TDS range from 244-572 mg/L and 114-106 mg/L in the pre-monsoon. TDS varies from 80-1340 mg/L in the monsoon season. The TDS content shows an increasing trend during pre-monsoon in the wells towards the coastal plain and inlet compared to the eastern part in the midlands (Fig.4).

3.1.4 Salinity

The salinity of the dug well water samples ranged from 36.4-902 mg/L in post-monsoon, 30-1260 in the pre-monsoon and 30-651 mg/L in the monsoon season. In the bore wells, the salinity ranges from 153-272 mg/L in post-monsoon, 80-752 mg/L in the pre-monsoon and 58-625 mg/L in the monsoon season. Higher salinity is observed in the dug wells and bore wells in the western parts adjoining the backwaters and sea (Fig.5).

3.2 Laboratory Analysis of Water samples

3.2.1 Total Alkalinity (TA)

The total alkalinity values are in acceptable limit both in dug well and bore well samples. The total alkalinity of dug well water samples ranged from 43-172 mg/L in the post-monsoon, 8.9-187.3 mg/L in the pre-monsoon, 3.9-182.2 mg/L in monsoon season. In the bore well samples the total alkalinity varies from 38.7-155 mg/L in the post-monsoon, 44.6-165 mg/L in the pre-monsoon and 19.8-192.1 mg/L in the monsoon season (Fig.6).

Table 1: Physico-chemical parameters of water quality in dug well samples

Sl. No	Parameters	Acceptable limit (	Post-mon 2014				Pre-mon 2015				Mon 2015		
			Min	Max	Av		Mi	Max	Av		Mi	Max	Av
1	Temp. (^oC)	-	28.	29.0	28.2		28.	30.0	29.0		27.	30.0	28.3
2	pH	6.5-8.5	5.1	7.6	5.8		4.8	8.3	6.0		4.8	7.7	5.9
3	EC (µS/cm)	-	64.	1971.	279.		49.	2600.	269.		49.	1308.	215.
4	TDS (mg/L)	500	38.	1399.	197.		28.	1890.	192.		35.	926.0	153.
5	Salinity	-	36.	902.0	126.		30.	1260.	134.		30.	651.0	101.
9	TA (mg/L)	200	4.3	172.0	36.1		8.9	187.3	50.7		3.9	182.2	39.4
6	TH (mg/L)	200	7.5	316.7	46.0		8.2	556.0	70.8		8.4	357.0	56.7
7	Calcium	75	1.5	46.7	11.5		1.6	189.7	16.9		1.7	87.4	14.5
8	Magnesium	30	0.9	53.1	4.2		0.0	64.1	6.9		1.6	77.0	10.0
11	Sodium	-	6.3	120.2	17.0		6.7	468..9	25.3		3.9	187.1	19.3
12	Potassium	-	0.4	39.6	5.7		0.4	16.0	4.4		0.3	27.2	4.5

10	Chloride	250	11.	169.2	32.0		7.2	1417.	57.7		14.	174.0	38.6
14	Sulphate	200	0.8	73.2	9.4		1.0	192.0	15.0		0.6	44.7	9.5
17	Iron (mg/L)	0.3	BD	0.4	0.01		BD	4.2	0.1		ND	ND	ND
15	Nitrate-N	45	BD	1.9	0.6		BD	0.6	0.2		ND	ND	ND
16	Nitrite-N	-	BD	0.1	0.0		BD	0.6	0.0		ND	ND	ND
13	Turbidity	1	0.1	3.7	0.5		BD	60.0	1.9		ND	ND	ND
14	Total Colifoms (MPN index/ 100 ml)	Absent	0	≥240 0	-		0	≥240 0	-		0	≥240 0	-
15	E.Coli	Absent	-	Prese	-		-	Prese	-		-	Prese	-
BDL - Below Detection Level, ND - Not Determined													

3.2.2 Total Hardness (TH)

The TH values are above acceptable limit in some of the areas in the dug wells and bore wells in the basin. The total hardness of the dug well water samples ranged from 7.5-316.7 mg/L in the post-monsoon, 8.2-556 mg/L in the pre-monsoon and 8.4-357 mg/L in the monsoon season. In the bore wells the total hardness values ranges 19.9-37.7 mg/L in the post-monsoon, 49.4-371.1 mg/L in the pre-monsoon and 42-247.8 mg/L in the monsoon season. Spatially higher TH is noted in the western and southern part of the basin in the pre-monsoon and post-monsoon seasons (Fig.7).

3.2.3 Calcium and Magnesium

The calcium and magnesium content is higher than acceptable limit in some of the dug well samples. Calcium (Ca^{2+}) content in the dug well water samples ranged between 1.5 to 46.7 mg/L in the post-monsoon season, 1.6-189.7 mg/L in monsoon and 1.7-87.4 mg/L in the monsoon season. The magnesium (Mg^{2+}) content in the dug well water samples ranged between 0.9-53.1 mg/L in post-monsoon, 0-64.1 mg/L in pre-monsoon and 1.6-77 mg/L in the monsoon season. In the bore wells Calcium content does not show much seasonal variation and within acceptable limit. The magnesium content is higher than acceptable limit during pre-monsoon and monsoon season in the bore wells. Spatially, during the pre-monsoon season the calcium content is higher in western and southern part of the basin.

3.2.4 Sodium

The sodium (Na^{+}) content in the dug well water samples ranged from 6.3-120.2 mg/L in the post-monsoon, 6.7-468.9 mg/L in the pre-monsoon and 3.9-187.1 mg/L in monsoon season. In the bore well samples, the sodium content varies from 10.2-53 in post-monsoon, 5.3-66.3 in pre-monsoon and 7-257.8 in the monsoon season. Na^{+} content is higher in the dug wells and bore well water samples during pre-monsoon and increases towards the western part of the basin.

3.2.5 Potassium

Potassium content in the water samples varied from 0.4-39.6 mg/L in the post-monsoon, 0.4-16.0 mg/L in the pre-monsoon and 0.3-27.2 mg/L in the monsoon season. In the bore wells, the potassium content is very less (0.6-10 mg/L). Spatially the western and southern part of the basin show higher potassium content.

3.2.6 Chloride

The chloride content is above acceptable limit in some of the dug well samples during monsoon season and in bore wells in the monsoon season. The Cl^{-} values in the dug well water samples ranged from 11.3-169.2 mg/L during post-monsoon, 7.2-1417.6 mg/L during monsoon and 14.8-174 mg/L in the monsoon season. In the bore well samples the Cl^{-} content is 26.3-142.9 mg/L in the post-monsoon, 72-130.8 mg/L in the pre-monsoon and 29.6-388.7 mg/L in the monsoon season. Higher chloride content in the water samples is mostly indicative of groundwater salinization caused by seawater intrusion. Higher chloride values are observed towards the coastal region of the basin.

3.2.7 Sulphate

The sulphate content of the dug well and bore well water samples are within acceptable limit during all seasons. The SO_4^{2-} content in the water samples varied from 0.8-73.2 mg/L during post-monsoon, 1-192 mg/L in pre-monsoon and 0.6-44.7 mg/L during monsoon season. The sulphate content varied from 1.8-39.2 mg/L in bore well samples. Higher SO_4^{2-} content is observed in the samples from the western and southern part in dug wells and bore wells.

3.2.8 Iron

The Fe content in the dug well samples range from BDL to 4.2 mg/L. Iron content reported above acceptable limit in some of the wells during pre-monsoon season. The iron values range from BDL to 0.4 mg/L in bore wells. Iron mainly reported in the dug wells in the lowland region of the basin (Table 1).

3.2.9 Nitrate

The nitrate (NO_3-N) content of the dug well and bore well samples are within acceptable limit during all seasons. It varies from BDL to 1.9 mg/L in the dug wells and BDL to 0.7 mg/L in the bore wells (Table 1).

3.2.10 Nitrite

The nitrite (NO_2-N) content of the dug well and bore well samples are within acceptable limit during all seasons. It varies from BDL to 0.6 mg/L in the dug wells and BDL to 0.02 mg/L in the bore wells (Table 1).

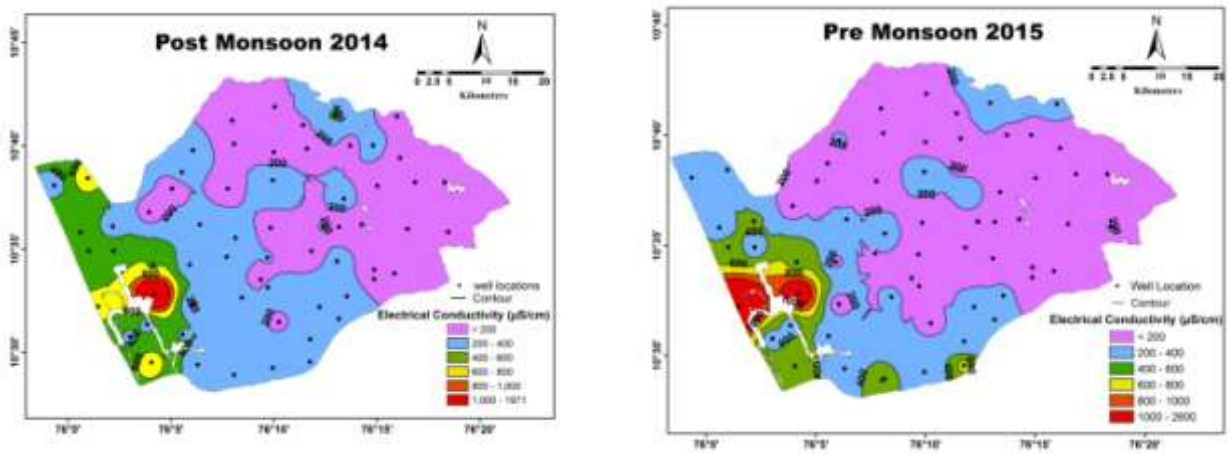


Fig.3. Spatial variation of EC in the dug well samples during post-monsoon and pre-monsoon season

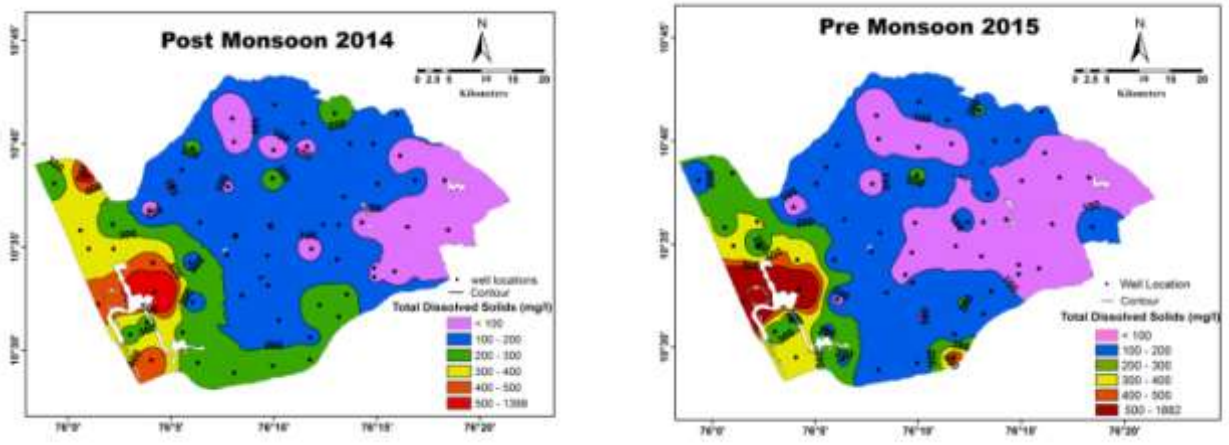


Fig.4. Spatial variation of TDS in the dug well samples during post-monsoon and pre-monsoon season

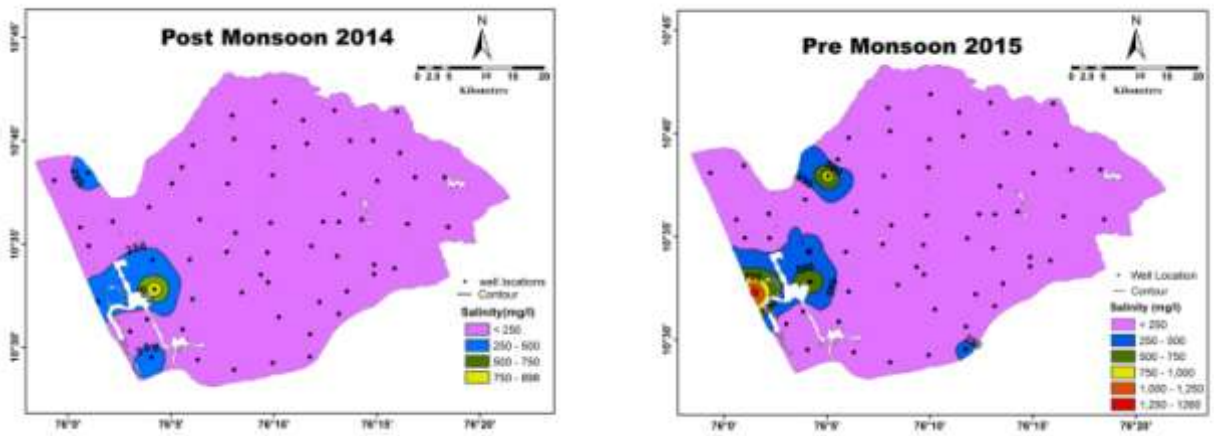


Fig.5. Spatial variation of salinity in the dug well samples during post-monsoon and pre-monsoon season

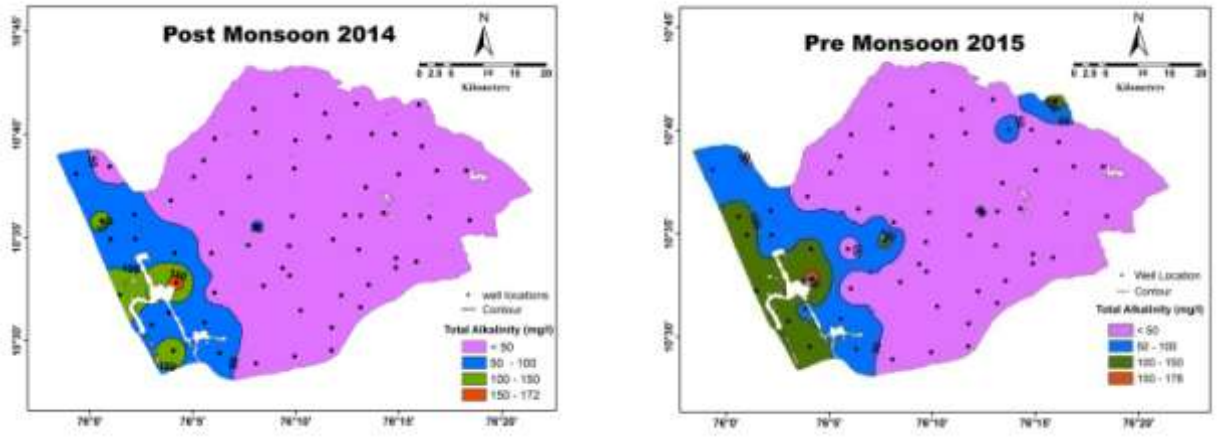


Fig.6. Spatial variation of TA in the dug well samples during post-monsoon and pre-monsoon season

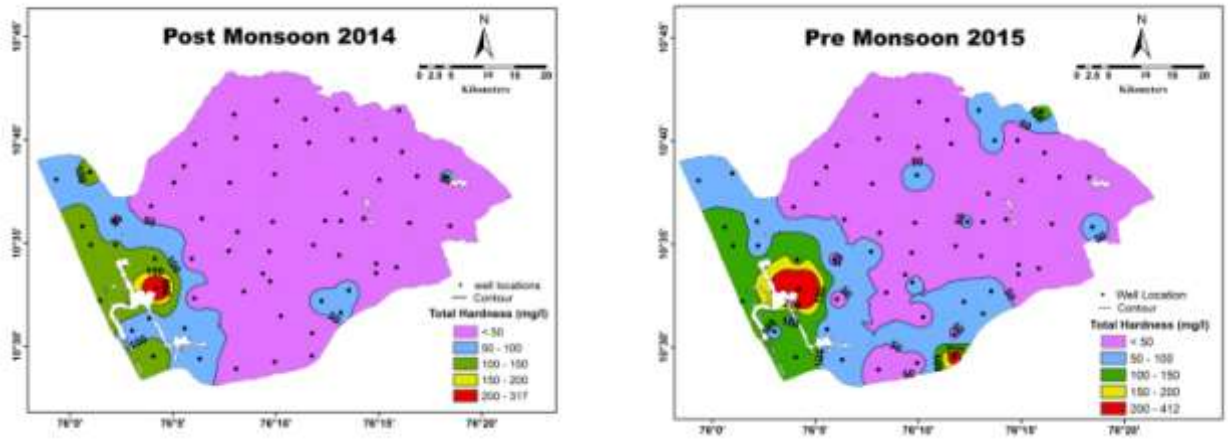


Fig.7. Spatial variation of TH in the dug well samples during post-monsoon and pre-monsoon season

3.2.11 Total Coliforms and E.Coli

Total coliforms are present in most of the dug wells and bore wells during all the seasons (0 to ≥2400 MPN index/100 ml). It indicates that both shallow and deep aquifers are contaminated (Fig.8). E. coli is present in 40% of the dug wells in the pre-monsoon and post-monsoon season. E.Coli is found in one bore well in the post-monsoon and other in monsoon season (Fig.9).

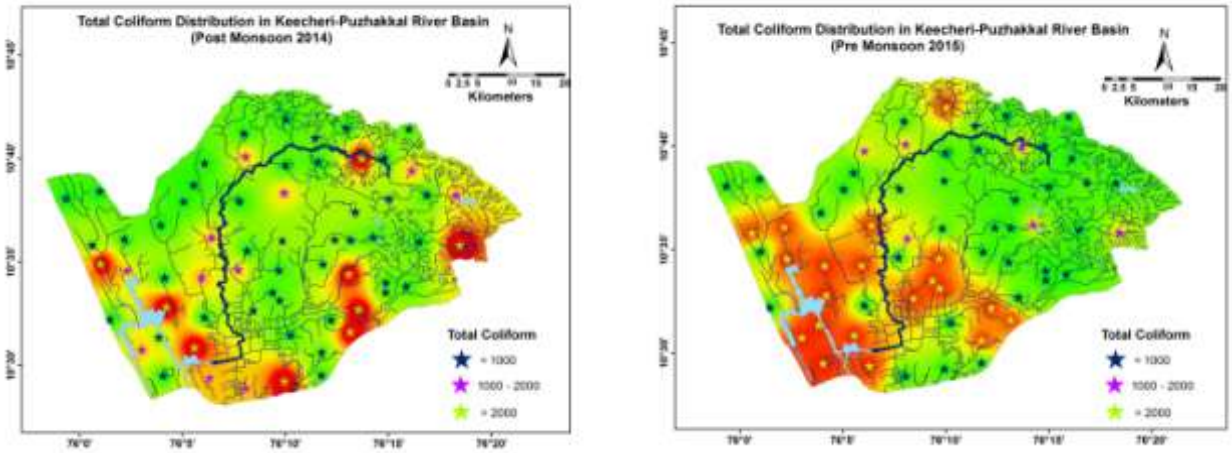


Fig.8. Total coliforms distribution in the dug well samples during post-monsoon and pre-monsoon season

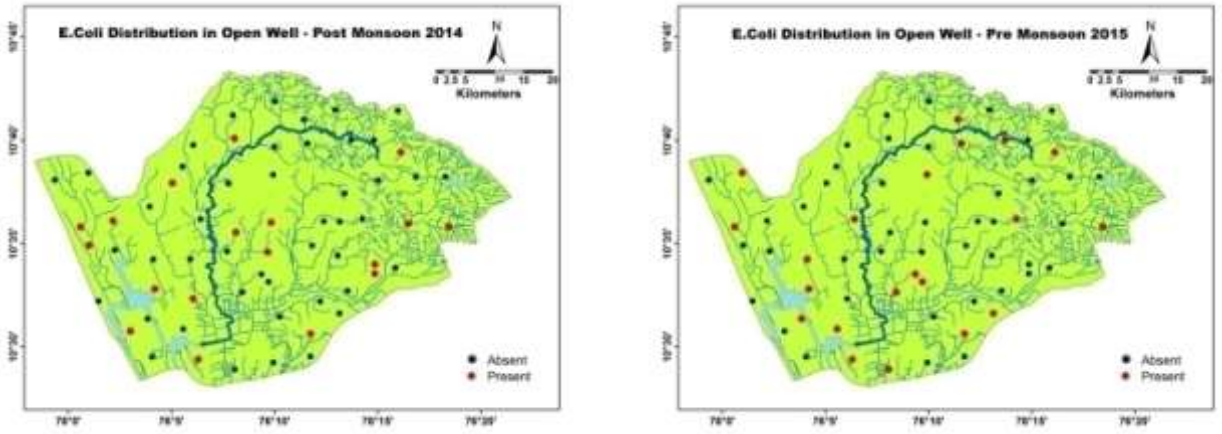


Fig.9. Spatial distribution of E.coli in the dug well samples during post-monsoon and pre-monsoon season

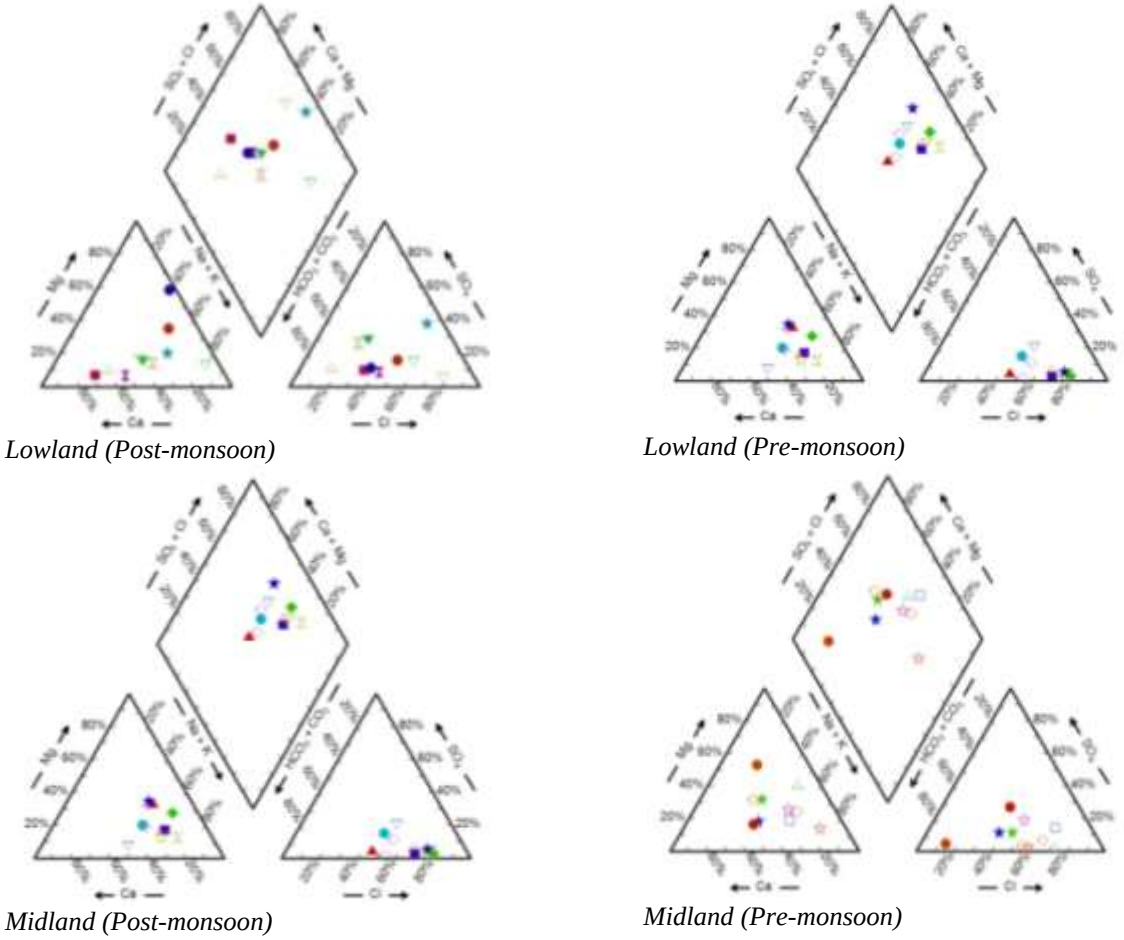
3.3 Hill-Piper Plots and Groundwater Type

The Hill-Piper diagram is used to infer hydro-geochemical facies. The results show that Na-Cl type (60%) hydrochemical facies is dominant in the dug well samples during post-monsoon followed by Ca-HCO_3 (19%) and Na-HCO_3 (11%). Other water types seen are Ca-Cl (5%), Mg-HCO_3 (3%) and Mg-Cl (2%) type. In the pre-monsoon season, the majority dug well samples are Na-Cl type (43%) followed by Ca-HCO_3 (19%) and Na-HCO_3 types (17%). Other water types Mg-HCO_3 (9%), Ca-Cl (8%), Mg-Cl (2%), and Mg-SO_4 type (2%) also seen. In the lowland areas Ca-HCO_3 type is dominant compared to the midland area where Na-HCO_3 type is dominant in post and pre-monsoon seasons. There is more heterogeneity in the major ion composition in the dug well water samples tapping groundwater from the shallow aquifers (Figs 10 and 11). In the bore wells Na-HCO_3, Ca-HCO_3 and Mg-HCO_3 are dominant water types followed by Na-Cl and Mg-Cl types during post-monsoon. In the pre-monsoon season, the dominant water types in the bore wells are Ca-HCO_3, Na-HCO_3 and Mg-HCO_3 followed by Na-Cl and Mg-Cl type.

3.4 Hydro-Geochemical Relationships

3.4.1 Correlation Coefficient

The correlation between various hydrogeochemical parameters of the dug well samples are obtained from Pearson's correlation matrix (Table 2). The post-monsoon results show very good correlation (0.70-0.80) between pH and TH, Ca^{2+}, TA. Very good correlation (0.75-0.95) is seen between EC, TDS, Salinity vs. TH, TA, Cl^-, Mg^{2+}, Na^+, K^+ and SO_4^{2-}. Total Hardness shows very good correlation (0.76-0.87) between calcium, TA, magnesium, sodium, potassium, sulphate and chloride. Calcium and Potassium also shows good correlation (0.70-0.80). Total alkalinity, magnesium, sodium and potassium show very good correlation (0.74-0.90) with chloride. Sodium shows good correlation (0.74-0.83) with K^+ and Mg^{2+}. Potassium also shows very good correlation (0.86) with sulphate. During pre-monsoon similar pattern is also observed. pH and TA has very good correlation (0.89). EC, TDS and salinity has very good correlation (0.71-0.97) with TH, calcium, chloride, sodium, potassium and sulphate. Total hardness and magnesium has very good correlation (0.80). Sodium has very good correlation with calcium and chloride (0.91-0.97). Sulphate has very good correlation (0.74-0.91) with TH, calcium, chloride, sodium and potassium. Correlation coefficients reveal various interrelationships among cations, anions, alkalinity and total hardness in the water samples.



Lowland (Post-monsoon) *Lowland (Pre-monsoon)*

Midland (Post-monsoon) *Midland (Pre-monsoon)*

Fig.10. Hill-Piper plot of the dug well samples from low land and midland during post-monsoon and pre-monsoon

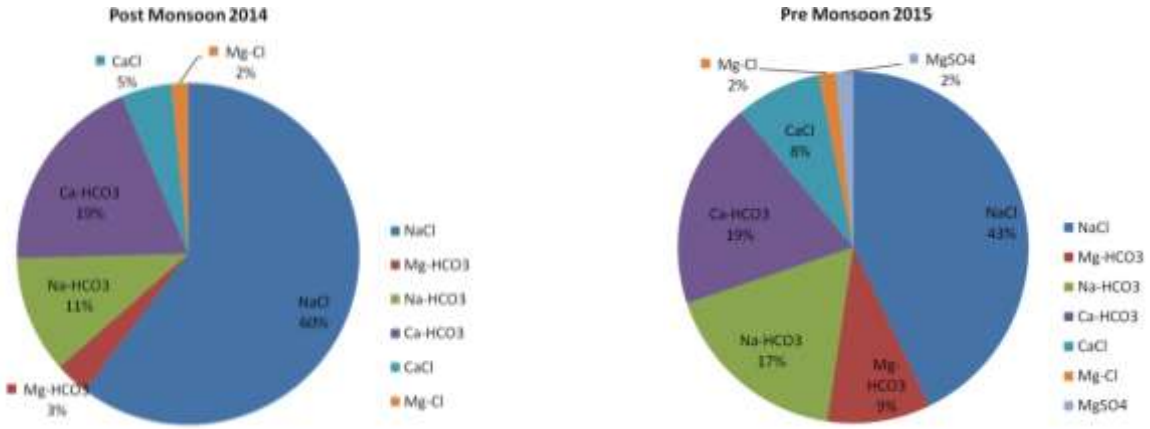


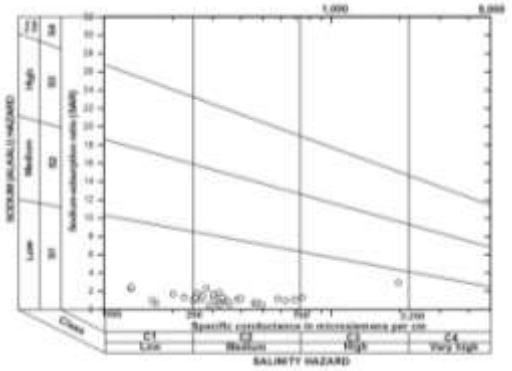
Fig.11. Pie diagram showing different water types during post-monsoon and pre-monsoon season

3.4.2 US Salinity Diagram

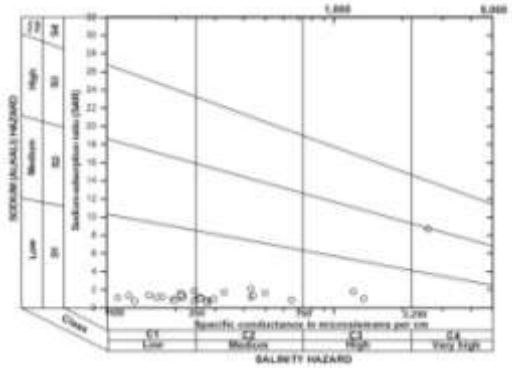
The US Salinity diagram (specific conductance vs. sodium-adsorption ratio) shows that majority of the dug well water samples fall under low-medium salinity hazard and low alkali hazard during all seasons (Fig.12). In the low lands majority of the samples fall under medium salinity hazard in post-monsoon and low to medium hazard in the pre-monsoon season. But in the midland part of the basin most of the samples fall under low salinity hazard.

Table 2: Correlation Matrix showing interrelationships between hydrochemical parameters (post-monsoon), *n=63*

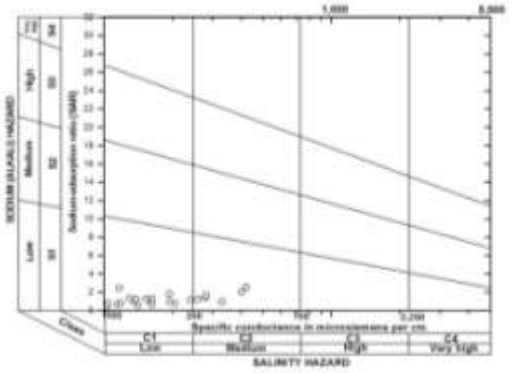
	pH	EC	TDS	Sali-nity	TH	Ca^{2+}	TA	Cl^-	Mg^{2+}	Na^+	K^+	SO_4^{2-}	Fe
pH	1												
EC	0.56	1											
TDS	0.56	1.00	1										
Sali-nity	0.56	1.00	1.00	1									
TH	0.71	0.94	0.95	0.94	1								
Ca^{2+}	0.70	0.67	0.67	0.66	0.79	1							
TA	0.80	0.76	0.76	0.75	0.87	0.80	1						
Cl^-	0.38	0.91	0.90	0.90	0.78	0.49	0.53	1					
Mg^{2+}	0.45	0.84	0.84	0.85	0.81	0.28	0.60	0.74	1	.			
Na^+	0.34	0.91	0.91	0.92	0.78	0.41	0.54	0.90	0.83	1			
K^+	0.50	0.89	0.89	0.89	0.85	0.62	0.70	0.76	0.74	0.80	1		
SO_4^{2-}	0.40	0.78	0.78	0.78	0.76	0.53	0.61	0.59	0.68	0.68	0.86	1	
Fe	0.38	0.44	0.44	0.44	0.49	0.51	0.54	0.32	0.28	0.34	0.40	0.30	1



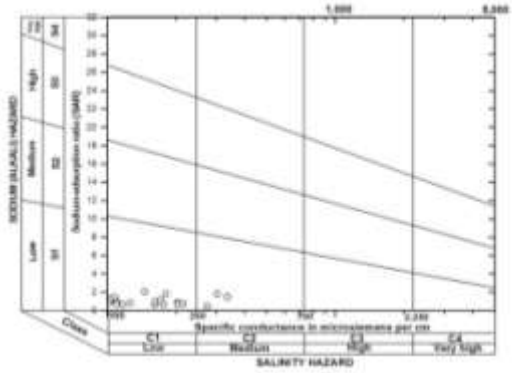
Lowland (Post-monsoon)



Lowland (Pre-monsoon)



Midland (Post-monsoon)



Midland (Pre-monsoon)

Fig.12. US Salinity diagram of dug well samples from low land and midland during post-monsoon and pre-monsoon

4. CONCLUSION

The study attempts to illustrate the scenario of groundwater quality and contributing factors in the shallow and deep aquifers of Keecheri-Puzhakkal river basins. The study also aimed at assessing drinking water quality status (BIS) of dug well and bore well samples from different parts of the study area in view of urbanization and overexploitation of groundwater resources. Lowland and midland region covers most of the basin area. The lowland region forms part of the Kole lands (paleo-lagoon). The Kole land basin extends in most of the lowland region with ridge-runnel topography in the coastal stretches mainly consist of paleo-beach deposits, fluvial and fluvio-marine deposits. The midland region is mainly covered with laterite and weathered rocks. The foot

hill areas mainly consist of massive rock with thin overburden (2-6 m).

Hydrochemical analysis of the dug well water samples (post-monsoon, monsoon and pre-monsoon) shows that pH varies from 4.8-7.7.The electrical conductivity of the samples varies between 49-2600 µS/cm. The TDS level in the water samples ranged from 28-1890 mg/L. The salinity of the water samples ranged from 30-1260 ppm. In the bore wells, the pH ranges from 6.1-7.9. The EC values ranges between 113-1900 µS/cm. The TDS level varies from 80-1340 mg/L. The salinity of the water samples varies from 58-752 ppm. Different water types were obtained from Hill-Piper plots of hydrochemical data. The major ions concentration in the shallow aquifers shows Na-Cl is the major water type followed by Ca-HCO_3 and Na-HCO_3. The wells tapping groundwater from shallow aquifers has more heterogeneity in the major ion concentration of water samples. In the deep aquifers (bore wells) also Na-Cl is the major water type followed by Ca-HCO_3 and Na-HCO_3 in post and pre-monsoon seasons. From hydrochemical facies diagram, seven major water types were identified. Bacteriological analysis of the water samples indicates that total coliforms are present in most of the wells (shallow and deep aquifer) during all the seasons (0 to ≥2400 MPN index/100 ml). E. coli is present in 40% of the dug wells in the pre-monsoon and post-monsoon season. E.Coli is found in one of the bore wells in the post-monsoon and other in monsoon season. The hydro-geochemical relationship of the samples was obtained from Pearson's correlation matrix. Correlation coefficients show interrelationships between EC, TDS, Salinity, TH with major ions. pH also shows correlated significantly with TA, TH and Ca^{2+} as well as chloride with Na^{+}, K^{+} and Mg^{2+}. US Salinity diagram shows that majority of the dug well water samples fall under low-medium salinity hazard and low alkali hazard. In the low land areas majority of the samples fall under medium salinity hazard in post-monsoon and low to medium hazard in the pre-monsoon season. But in the midland part of the basin most of the samples fall under low salinity hazard. The study concludes that high TDS, hardness, salinity, iron, turbidity are the major contaminant in groundwater in the study area. Bacterial contamination (total coliforms and E. coli) is extensive in the dug wells. Total coliforms and E.coli contamination also observed in some of the bore wells.

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