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Research Paper

Groundwater geochemistry of shallow and deep aquifers from Jalgaon district, northern Maharashtra (India)

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Abstract

This paper contains assessment of groundwater quality with reference to drinking and agricultural use in Jalgaon district, Northern Maharashtra (India). In present study 53 groundwater samples were collected in post monsoon (2010) and pre monsoon period (2011) from different location of Jalgaon district. Analytical results of geochemical analysis of groundwater compare with World health Organization and Indian Drinking Water Standards. Groundwater quality of study area has been deteriorated predominantly due to over exploration and anthropogenic activities.
Geochemistry of groundwater shows that the Ca > Mg > Na > K and HCO_3 > Cl > SO_4 > CO_3^{2-} trend. Most of the groundwater samples are observed as Ca-HCO_3 Type. Groundwater samples of the study area show higher concentration of TDS (>1000 ppm), Cl (>1000 ppm), NO_3 (>45 ppm), K (> 10 ppm), Ca (>200 ppm), HCO_3 (> 600 ppm) and B (<1 ppm). Irrigation water quality has been inadequately affected by salinity hazards and residual soluble carbonate (RSC).

Keywords: *Groundwater Geochemistry, Shallow and Deep Aquifers, Medical Geology, Irrigation Hazards, Deccan Trap, India.*

1. Introduction

Water quality is become one of the most important aspects in our living environment and that chemistry of groundwater has a bearing on our health and livestock. Due to insufficient availability of surface water to meet the requirement of human activities groundwater remains only option to supply the increasing demand of water. Groundwater is primarily source of water supply for drinking, agricultural and domestic to many countries and states in the world. In recent years water contamination has been recognized as one of the major issues in India. The quality of groundwater is declining due to heavy industrialization and agricultural activities. The chemical alteration of meteoric water depends upon mineral species, duration of solid water interaction, dissolution of mineral species and anthropogenic source (Fathy and Traugott, 2012).
Significance of hydrochemistry in groundwater has led to detailed studies of geochemical evolution of groundwater. The present study area water quality has been deteriorated especially in dug/bore wells mainly due to over exploitation of water and excessive use of fertilizers (Golekar, 2014). It is clear that infiltration of effluents has responsible to the contamination of aquifers. The aim of present work was assessment and investigation of groundwater geochemistry with respect to drinking and agricultural purpose from Jalgaon district, Northern Maharashtra, India.

2. Description of the study area

The study area is situated in Jalgaon district, Northern Maharashtra. India. Geographical coordinates of study area Latitude 20.15 N to 21.25 N and Longitude 74.55 E to 76.28 E. Study area falls under survey of India toposheets number - 46 O/8, 46 P/5, 46 p/9, 46 O /16 and 46 P/1. Location map of study area are shown in figure 1.

2.1. Geology

Study area predominately covered by Deccan Basalts which is Cretaceous to Lower Eocene age and along river courses covers thick alluvium of Quaternary age. Different types of basaltic flows have been reported from southern part of study area. The entire area flows variation in physical characteristics there is a transition from the ‘Aa’ type and ‘Pahoehoe’ type. The basaltic flow represents a sequence of eruptions with fine grained basalt, vesicular, amygdaloidal, fractured, jointed, porphyritic and massive layers of basalts. Each flow consisting of lower is massive unit and upper vesicular basalt. Successive lava flows are separated by inter trappean red bole which is varying thickness from 0.5 to 1 meter. Northern part of study area covered by thick alluvium of Quaternary age which is silt and clay layers. Geological map of Jalgaon district has shown in figure 2.

2.2. Geomorphology

The drainage pattern is dendritic to sub dendritic and soil type is black cotton. The study area shows two geomorphic units viz. 1) Northern part of study area is represented by thick alluvium of Tapi River tract. The Younger and Older Alluvium are represented by interbeded layers of silt and clays with varying thickness of 70 m. The Jalgaon, Dharangaon and Yawal block is covered by thick alluvium of silt and clay. 2) Southern part of study area exhibits detached hills of Deccan Trap (Erandol Block). Drainage map of the area under study has shown in figure 3.

2.3. Hydrometeorology

Study area falls under semi-arid climatic zone. The average annual rainfall is about 650 mm/per annum. The mean maximum temperature ranges from 29.5^{0}C to 48^{0}C in months of May. The mean minimum temperature ranges from 12^{0}C to 24^{0}C in month of December- January. The high relative humidity concentration 83.63% occurs in rainy season, viz. June to October. Long term rainfall data (1998-2007) suggests decrease in rainfall 2003 to 2005 and sharp increase in 2005 and 2006 (Golekar et al. 2013).

2.4. Hydrogeology

Groundwater of study area occurs in deep wells under semi-confined to confined conditions due to thick pile of clay found intermittently in alluvium area. Fluctuation of water table varies from 0.5 to 8 M. Water level fluctuation in alluvium area is less than the basaltic area (Patil et al. 2010). Groundwater is an important source of water supply for agriculture in the region. Deep water level areas have been observed in parts of Daharangaon and Yawal sub district (CGWB, 2009). Groundwater occurs in weathered, vesicular, jointed and fractured basalts under unconfined condition. Northern part of study area generally drilled hand pump and open well due to shallow groundwater table. Southern part of the study area mainly in Daharangaon and Yawal sub district, groundwater level is extremely deep due to overexploitation, predominately drilled tube well used for drinking and irrigation (Golekar et al. 2013). The occurrence groundwater in the investigated area is controlled by rainfall, topography, vegetation and drainage.

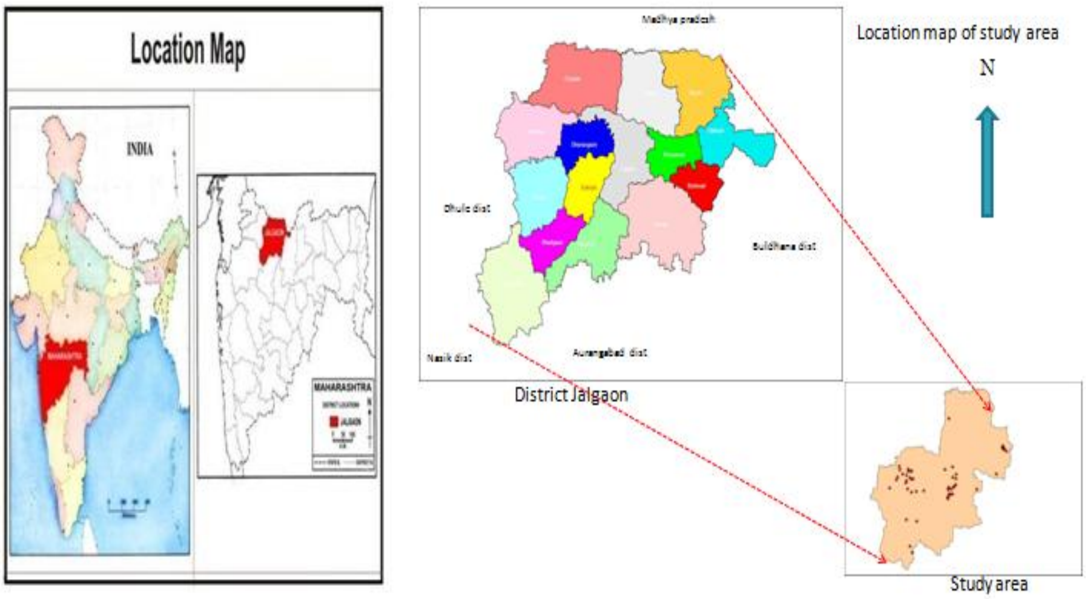

Fig. 1: Location Map of Study Area

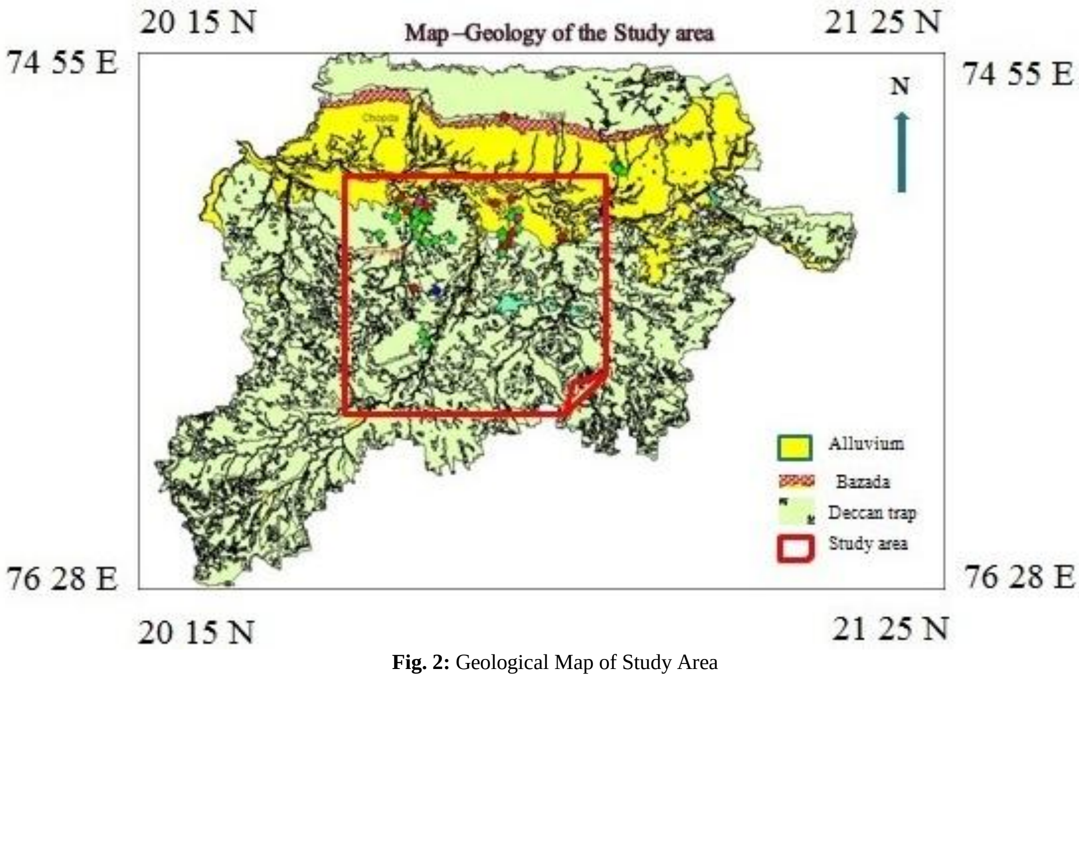

Fig. 2: Geological Map of Study Area

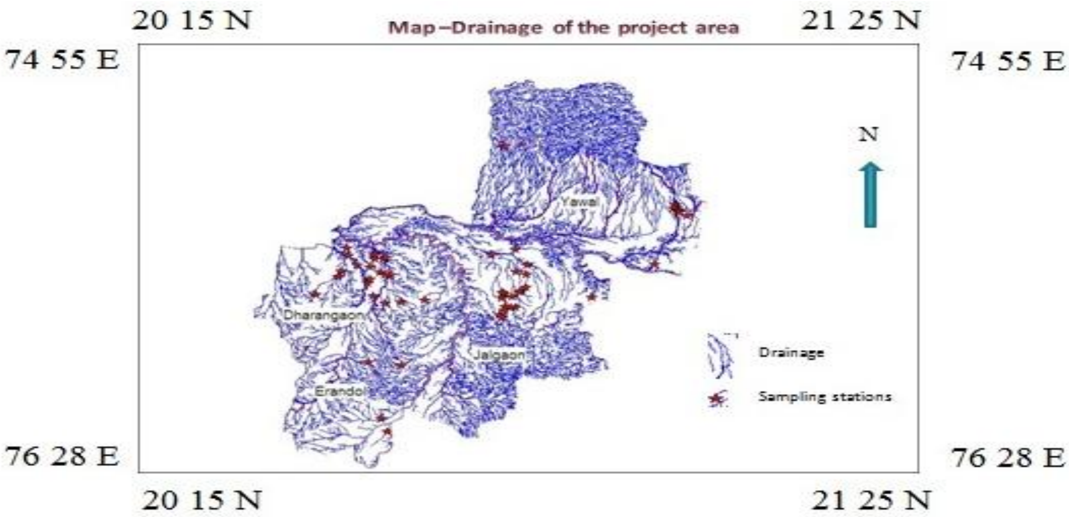

Fig. 3: Drainage Map of Study Area

3. Materials and methodology

53 samples instead of shallow (3 to 20 m) and deep aquifers (32 to 70 m bgl) were collected during post monsoon (December - 2010) and pre monsoon (May - 2011). Geochemical analysis of groundwater samples were carried out adopted by standard technique and procedure (APHA, 1998). pH, EC and TDS were measured on digital water analysis kit. Total hardness and calcium determined by standard EDTA (0.01 M) titrimetric method. Carbonate and bicarbonate determined by standard hydrochloric acid (0.01 N) titrimetric method. Chloride ion determined by standard silver nitrate titrimetric method. Sulphate, Nitrate and Phosphate estimation was done by the standard colorimetric method. Boron was analyzed by colorimetric method using carmine solution. Sodium, Potassium and Magnesium analyzed by double beam atomic absorption spectrometer (AAS) acetylene gas based. The precise locations of sampling points were determined in field through GPS (Global Positioning System) GARMIN and gave exact Latitude, Longitude and Altitude. A medical survey was carried out in selected villages from the area under study whereas nitrate, fluoride and total hardness were observed exceeding the BIS limits. The doctors of these villages were also contacted and enquired about the occurrence of methaenoglobinaemia (blue baby), fluorosis and kidney stones in the doubtful villages.

4. Result and discussion

Statistical summary of groundwater quality parameters along with BIS drinking water standards are given in Table 1.

Table 1: Statistical Summary of Groundwater Quality Parameters with BIS Drinking Water Standards

n = 53			Post Monsoon 2010			Pre monsoon 2011			Classification	
Sr	Category	Parameter	Max	Min	Avg.	Max	Min	Avg.	Highest Desirable	Permissible Limit
	General	pH	8.5	6	7.55	8.2	6.2	7.04	6.5 - 8.5	-----
		EC	5150	335	1822	4640	328	1952.4	1400	-----
		TDS	3240	220	1040	3030	216	1257	500	2000
		TH	1610	164	525.9	1540	120	501.73	300	600
		TA	1080	152	527.2	1085	159	544.4	200	600
2	Cation	Ca	438	13	103.9	445	17	105.25	75	200
		Mg	56.5	8.5	17.66	22.6	6.4	15.8	30	100
		Na	19.7	13.5	16.86	21.6	13.2	17.75	NA	NA
		K	20	0.7	3.78	22.2	0.4	4.25	10	10
3	Anion	HCO_3	1020	152	493	1085	159	517	NA	NA
		CO_3	174	0	42.43	90	0	31.92	NA	NA
		SO_4	220	2	57	348	14	107	200	400
		Cl	618	50	220.6	753	21	246.24	250	1000
		NO_3	60.3	0.5	13.59	56.4	0.5	13.89	45	NR
		PO_4	139	1	26.38	85	0	7.56	NA	NA
4	Trace	Boron	1.3	0.2	0.6	1.6	0.3	0.65	1	5

All parameter expressed in ppm Except EC in µs/cm and pH Where, n = number of groundwater samples, NA = Not available

4.1. Drinking water quality status

pH was groundwater samples varies from 6.5 to 8.5 for post monsoon and pre monsoon from 6.1 to 7.7 which is alkaline.
Concentration of total hardness in study area is observed exceeds than permissible limit of BIS (BIS, 2003). Total hardness results reveal that the 80 percent groundwater samples exceed than permissible limit. In deep aquifer total hardness is high as compared to shallow aquifer. According to (Table 2) Durfor and Becker's classification of total hardness, groundwater is very hard at all locations except three sites (Burton & Cornhill 1977).

Table 2: Durfor and Becker's Classification of Groundwater Samples Based on TH Ppm

Sr. no.	Classification of groundwater	Hardness (ppm)	No. of samples	
			SA	DA
1	Soft	0 - 60	0	0
2	Moderately hard	61 - 120	0	0
3	Hard	121 - 180	0	3
4	Very hard	>180	All	27

(Where, SA = Shallow Aquifer, DA = Deep aquifer)

TDS in water originates from natural sources, sewage, urban and agricultural runoff and industrial wastewater. The concentrations of total dissolved solid for post monsoon in shallow aquifer range from 414 to 3240 ppm and in deep aquifer 220 to 2390 ppm. The concentrations of pre monsoon is in shallow aquifer 467 to 3030 ppm and deep aquifer 216 to 2490 mg/. Desirable limit of TDS is 500 ppm and maximum permissible limit is 1400 ppm as per BIS, if TDS above 2100 ppm it is not suitable for any purpose. According to TDS limit of BIS, 80 and 90 percent samples for post monsoon and pre monsoon season respectively above desirable limits. In the present study out of 53 samples, 17 groundwater samples are unsuitable for drinking and irrigation purpose. In early studies, contrary relationships were reported between TDS concentrations in drinking water and the incidence of cancer and cardiovascular disease (Burton & Cornhill 1977; Sauer, 1974). The groundwater samples were classified regarding TDS (Table 3). Most of the groundwater is fresh and suitable for drinking purposes based on TDS (Rabinove et al. 1958).

Table 3: Rabinove and Et Al Classification of Groundwater Samples Based on TDS (Ppm)

Sr. No.	Classification of groundwater	Total dissolved salts (ppm)	No. of samples
1	Non-saline	<1000	27
2	Slightly saline	1000 - 3000	25
3	Moderately saline	3000 - 10000	1
4	Very saline	>10000	Nil

Calcium concentration in shallow aquifer is more as compared to deep aquifers. Calcium ion concentration in groundwater samples in pre monsoon period is exceeds than post monsoon indicates the overexploitation of water from subsurface in summer season. Natural source of the calcium in groundwater may be cause of calcite, plagioclase feldspar minerals and zeolite cavities in basaltic rock of investigated area. The average abundance of Ca in earth crust in basaltic rocks about 77600 ppm (Konrad & Dennis 1994). They may cause of high concentration of this element in groundwater.

Magnesium ion concentration in all water samples of investigated area is within permissible limits of BIS for drinking water standards (30 ppm). Magnesium ion concentration in groundwater slightly increases in pre monsoon period as compared to post monsoon period because of overexploitation. Sodium concentration is insignificant in all water samples of both seasons.

Potassium concentration in study area observed exceeds than permissible limit of BIS (Ravikumar & Venkatesharaju 2010). Sample number 1, 4 and 5 for post monsoon and 1, 2, 4, 5, 41, 47 and 48 for pre monsoon period potassium exceeds than desirable limit of drinking water standards as per BIS limit.

Total alkalinity concentration for post monsoon in shallow aquifer varies from 125 to 750 ppm and deep aquifer from 125 to 900 ppm. The pre monsoon total alkalinity concentration in shallow aquifer varies from 130 to 640 ppm and deep aquifer from 120 to 825 ppm. In investigated study area 90 percent samples are above the permissible limit of alkalinity as per BIS drinking water standard.

Chloride concentration range varies from 67 to 618 ppm for post monsoon in shallow aquifer and deep aquifer is 50 to 589 ppm. In the post monsoon shallow aquifer range is 78 to 753 ppm and deep aquifer is 21 to 703 ppm. 30 % water samples of post monsoon and 60 % water samples of pre monsoon season not safe for drinking because it exceeds than the desirable limit whereas desirable limit of chloride for drinking water is about 250 ppm (BIS, 2003). The average abundance of Cl in earth crust in the basaltic rocks about 200 ppm (Konrad & Dennis 1994]. Chloride in groundwater from both factors they may be natural or anthropogenic such as run-off, use of inorganic fertilizers, septic tank effluents, animal feeds, industrial effluents and irrigation drainage.

Bicarbonate concentration of post monsoon in groundwater varies from 152 to 1020 and pre monsoon varies from 159 to 1085 ppm.

Nitrate concentrations occur in groundwater samples ranges from 0.3 to 63.4 ppm of the study area. The nitrate level in water samples from study area 6 and 10 percent of post monsoon and pre monsoon respectively exceeds than permissible limit of drinking water standards where limit is 45 ppm (BIS, 2003). Higher concentration of nitrate in groundwater they may be extreme use of nitrogen fertilizers, human and animal wastes (Janardhana et al. 2009). Jalgaon district is 3rd rank for the use of chemical fertilizers in India. High nitrate concentration in drinking water causes infant of methaenoglobinaemia widely known as Blue baby disease.

Sulphate concentrations below 4 meq/l is very excellent, 4 to 7 meq/l is good, 7 to 12 meq/l is permissible 12 to 20 in doubtful and above 20 is unsuitable (James et al. 1982). In the current study area most of the groundwater samples are under excellent category except one site (sample no. 48/ pre monsoon 2011) above permissible limit of sulphate ion as per BIS limits.

Boron in drinking water more than 1 ppm it is not considered to human consumption. The excessive amount of boron can affect the central nervous system (APHA, 1998). Boron concentration in the study area observed varies from 0.7 to 1.3 ppm (limit of 1.0 ppm, BIS, 2003). Some shows boron concentration more than 1 ppm in shallow aquifer (post monsoon). The average abundance of Boron in earth crust is about 12 ppm but high in basalts rocks about 15 ppm they may be one cause of boron in groundwater of area under study. Phosphate in groundwater recognized to increase application of fertilizers in agricultural sectors.

Phosphorous addition to the water bodies even in small amount can be produced growth of algae and aquatic vegetation they may be causing eutrophication of the aquatic system (Handa, 1990). The phosphorus is also content in various minerals (Hamilton, 1992). Phosphate has been reported in groundwater by several investigators (Raju, 1979; Shriniwas & Rajendra Prasad 1997; Mondal et al. 2005). The present study area covered by basaltic rocks mainly composed of pyroxene, plagioclase minerals. Pyroxene and plagioclase minerals having 89 and 25 ppm phosphorus content respectively (Konrad & Dennis 1994). Phosphorous in the groundwater is observed range from 1.00 to 139.00 ppm for post monsoon and 0.00 to 85 ppm for pre monsoon which is beyond the permissible limits in few exceptional sites of the study area. Some ground samples of the study area phosphorous level is high due to excessive use of fertilizer in form of NPK 15:15:15, 18:18:10, 10:26:26 and superphosphate.

4.2. Irrigation water quality status

Assessment and suitability of groundwater for the irrigation purpose is calculated based on TDS, electrical conductivity, Kelly's ratio, residual sodium carbonate, permeability Index, Na percentage, corrosivity ratio and Mg ratio. Statistical summary of Irrigation water quality parameters and characteristic ratios are given in table 4.

Table 4: Statistical Summary of Irrigation Parameters and Characteristic Ratios

Irrigation parameter	Season	Maximum	Minimum	Average
SAR	post	0.7	0.2	0.4
SAR	pre	0.7	0.2	0.4
RSC	post	14.3	-16.6	2.3
RSC	Pre	14	-18.6	2.2
MR	post	147.2	9.3	42.8
MR	Pre	122.5	7.2	40.1
Na %	post	114.8	6.2	26
Na %	pre	102.2	6.5	26.6
CAI 1	post	17.4	0.9	5.9
CAI 1	pre	21.1	-0.7	6.6
CAI 2	post	17.3	1.3	6
CAI 2	pre	21.1	0.3	6.7
CR	post	2.8	0.1	0.5
CR	pre	4	0.1	0.7
KR	post	0.5	0	0.2
KR	pre	0.5	0	0.2

(Where, SAR = Sodium Adsorption ratio, RSC = Residual soluble carbonate, Na% = Sodium percentage, CAI I = Chloro alkaline indices I, CAI II = Chloro alkaline indices II, CR = Corrosivity ratio, KR = Kelly's ratio)

4.2.1. Electrical conductivity (salinity hazards)

Electrical conductivity is a good measurement of salinity hazard to crops as it reflects the TDS in groundwater. The EC concentration for post monsoon in shallow aquifer varies from 618 to 3240 µs/cm and deep aquifer 335 to 3690 µs/cm. The EC concentration of pre monsoon period in shallow aquifer ranges from 703 to 3030 µs/cm and deep aquifer ranges from 328 to 3740 µs/cm.

According to Mondal, water has been classified for irrigation purpose point of view as (1) Fresh (<1500 µs/cm), (2) Brackish (1500-3000 µs/cm) and (3) Saline (>3000 µs/cm) (Mondal et al. 2005). Based on these classification water samples of the study area each group clearly shows 50 percent samples in post monsoon and 45 percent sample in pre monsoon were fresh quality, 40 percent sample in post monsoon and 35 percent samples in pre monsoon were brackish nature. In the study area 10 percent sample for the post monsoon and 15 percent samples for the period of pre monsoon fall under the saline water category.

4.2.2. Sodium adsorption ratio (SAR)

SAR is express as per Richards (Richard, 1954),

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

Where all ionic concentration expressed in meq/l
Table 5 shows classification of water with reference to the SAR (Raghunath, 1987). If SAR concentration is less than 10 water is excellent for irrigation suggest that the all samples of post monsoon and pre monsoon fall under the excellent category.

Table 5: Classifications of Sodium Adsorption Ratio

SAR Ratio	Water quality	Post Monsoon (2010) No of samples		Pre Monsoon (2011) No of samples	
		SA	DA	SA	DA
0-06	Excellent	23	30	23	30
06-09	Increasing Problem	Nil	Nil	Nil	Nil
>10	Serve Problem	Nil	Nil	Nil	Nil

(Where, SA= Shallow aquifer, DA= Deep aquifer)

4.2.3. Residual sodium carbonate (RSC)

The RSC is calculated as per Eaton (1950),

$$RSC= (CO_3 + HCO_3) - (Ca+ Mg) \quad (2)$$

Where all ionic concentration expressed in meq/l
The groundwater having excess of CO_3^- and HCO_3^- concentration over the Ca^{++} and Mg^{++} in excess of limits and there are unfavorably effects on agriculture (Raghunath, 1987; Eaton, 1950). The RSC concentrations for shallow aquifer (post monsoon) ranges from -16.56 to 11.78, concentrations for pre monsoon ranges from -18.6 to 9.35 and deep aquifer (Post monsoon) ranges from -6.54 to 14.33 and pre monsoon it ranges from -8.70 to 13.98. Lloyd and Heathcote (1985) have classified irrigation water based on RSC as suitable (< 1.25), marginal (1.25 to 2.5) and not suitable (> 2.5). Accordingly the shallow aquifer is excellent quality but deep aquifer is not suitable to irrigation because of its RSC concentration > 2.5.

4.2.4. Magnesium ratio

MR is express as,

$$MR= (Mg \times 100) / (Ca + Mg) \quad (3)$$

Where all ionic concentration expressed in meq/l
Magnesium ratio observed in groundwater sample range from 9.26 to 147.2 for post monsoon, 7.21 to 122.5 for pre monsoon period. If the concentration of magnesium ratio less than 50 it is suitable to irrigation purpose (Pandian & Sankar 2007). In study area 35 percent samples of the post monsoon and 30 percent samples of pre monsoon is higher than 50 % MR shows unsuitable to irrigation purposes.

4.2.5. Sodium percentage (Na %)

Sodium concentration is an important measure for defining the type of irrigation. The Sodium percentage is calculated as per Doneen (1962),

$$\text{Sodium Na \%} = (Na \times 100) / (Ca + Mg) \quad (4)$$

Where all ionic concentration expressed in meq/l
Sodium percentage in shallow aquifer (post monsoon) varies from 6.19% to 36.78% and deep aquifer is 8.83 to 114.75. Shallow aquifer (pre monsoon) varies from 6.45 to 40.05 and deep aquifer is 8.35 to 102.16. According to Na % groundwater has classified as excellent (< 20%), good (20%-40%) and permissible (40% - 60%) some doubtful (60%-80%). The Na % in sample no. 23, 29 and 31 from deep aquifer was not suitable to irrigation.
Wilcox has proposed a method for rating irrigation waters is used, based on percent sodium and electrical conductivity (Wilcox, 1955). The diagram consists of five distinct areas such as excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable and unsuitable. Total 53 groundwater samples analyzed their hydrochemistry out of 85 percentage samples belonging to excellent, good to excellent and good to permissible type during post monsoon but 80 percent of samples in pre monsoon seasons fall in excellent, excellent to good, good to permissible types. The remaining samples are doubtful to unsuitable types in both seasons of study area.
SAR (Sodium Adsorption Ratio) is an important parameter for determining suitability of groundwater to irrigation because it is a measure of alkali / sodium hazards to crops (Richard, 1954). Kumaresan and Riyazuddin (2006) have discussed their results using Wilcox diagram. Wilcox plot by SAR values versus electrical conductivity of groundwater. Wilcox plots shows that the 60 percent of post monsoon and 70 percent of pre monsoon groundwater samples falls in field of C3S1, indicating high salinity and low SAR water. While 30 percent sample of post monsoon and 25 percent samples of pre monsoon season falls in field C4S1, indicating very high salinity and low SAR which is not suitable to irrigation. Wilcox diagram shows in figure 4 and 5 for post monsoon and pre monsoon season respectively.

4.2.6. Corrosivity ratio (CR)

Corrosivity ratio expressed as,

$$CR = (Cl + SO_4) / 2\,(HCO_3 + CO_3) \quad (5)$$

Where all ionic concentration expressed in meq/l
If CR concentration is greater than 1, their effect of corrosion leads to loss in carrying capacity of pipes (Pandian & Sankar 2007). In post monsoon season samples number 43 , 44 and pre monsoon season 43,44, 45,46,47 and 48 have CR more than 1 which suggests the unsafe zone remaining all samples are showing concentrations less than 1 that is safe zone. When high concentrations of chloride occurred in water that promotes the corrosion of metal pipes because chloride increases the electrical conductivity of water and thus increase its corrosivity. In metal pipes, chloride reacts with metal ions to form soluble salts. In lead pipes, a defensive oxide layer is built up, but chloride enhances galvanic corrosion (Gregory, 1990).

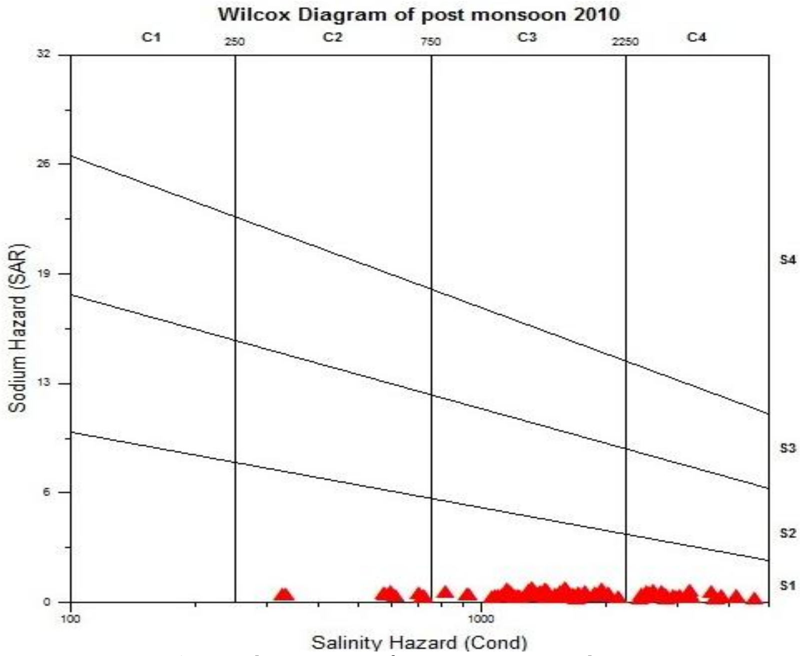

Fig. 4: Wilcox Diagram of Post Monsoon Groundwater

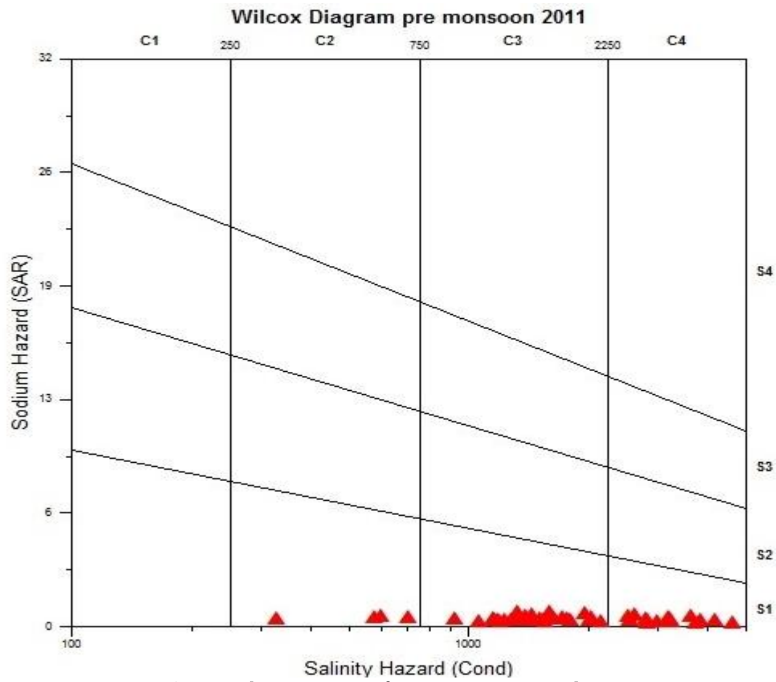

Fig. 5: Wilcox Diagram of Pre Monsoon Groundwater

4.2.7. Kelly's ratio (KR)

Kelly's ratio is expressed as,

$$\text{Kelly's Ratio} = Na / (Ca + Mg) \qquad (6)$$

Where all ionic concentration expressed in meq/l
If KR is greater than 1water is not suitable to irrigation and its cause's alkali hazards to soil (Karnath, 1987). All groundwater samples of the study area Kelly's ratio shows less than 1 suggesting suitable for the irrigation.

4.2.8. Boron hazards

Boron is a necessary element for plant development. Boron is essential in relatively small amounts but greater than needed it becomes toxic. For some crops, if 0.2 ppm boron in water is essential but 1 to 2 ppm may be toxic. Boron classification for irrigation water quality as per Doneen, it gives in table 6 (Doneen, 1962). Study area water falls under the Class I and II type of water.

Table 6: Doneen Classifications of Boron Hazards

Class of Irrigation water	Class I	Class II	Class III
Concentration of Boron	< 0.5 ppm	0.5 to 2.00 ppm	> 2.00 ppm
Boron classification in the study area	30%	70%	0%

4.3. Characteristic of groundwater chemistry

4.3.1. Chloro alkaline indices

The ion exchange between the groundwater and its surroundings during residence or travel can be understand by studying the Chloro alkaline Indices expressed as (Schoeller, 1977),

$$CAI - I = Na + K / Cl \qquad (7)$$

$$CAI - II = [Cl - (Na + K)] / [SO_4 + HCO_3 + CO_3 + NO_3] \qquad (8)$$

Where all ionic concentration expressed in meq/l

According to Schoeller all samples are negative ratio indicating Base Exchange. Whereas, the Base Exchange positive concentrations are sign of the reaction is chloroalkaline equilibrium and negative concentrations are sign of chloroalkaline is disequilibrium.

4.3.2. Hydro chemical facies of groundwater

Classification of groundwater with reference to hydrochemical processes by using piper diagram (Piper, 1953). Piper diagram has shown in figure 6 and 7 for post monsoon and pre monsoon respectively. It shows that the most of analysed groundwater samples falls in the field of Ca-HCO_3 and Ca-Cl-HCO_3 water types shows that the alkaline earth metals (Ca^{++} + Ma^{++}) exceeds than alkali metals (Na^+ + K^+) and weak acid anions (CO_3 + HCO_3) exceeds than strong acid (Cl + SO_4^{-2}) strong acid anions.

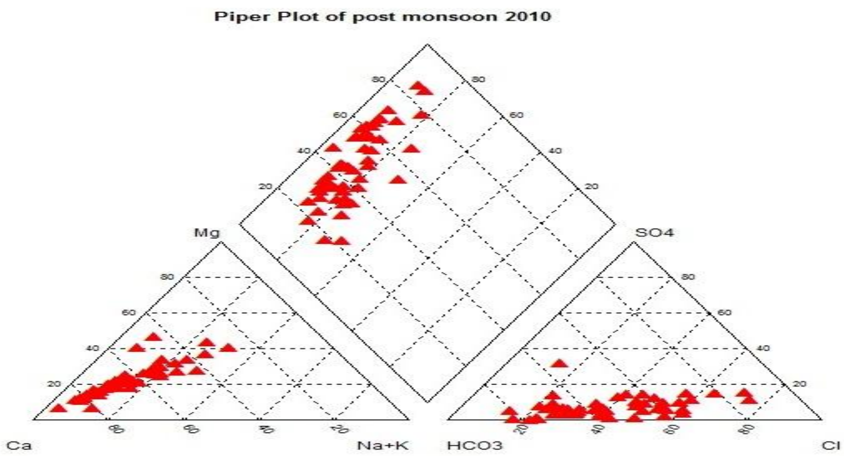

Fig. 6: Piper Trilinear Diagram of Post Monsoon Groundwater

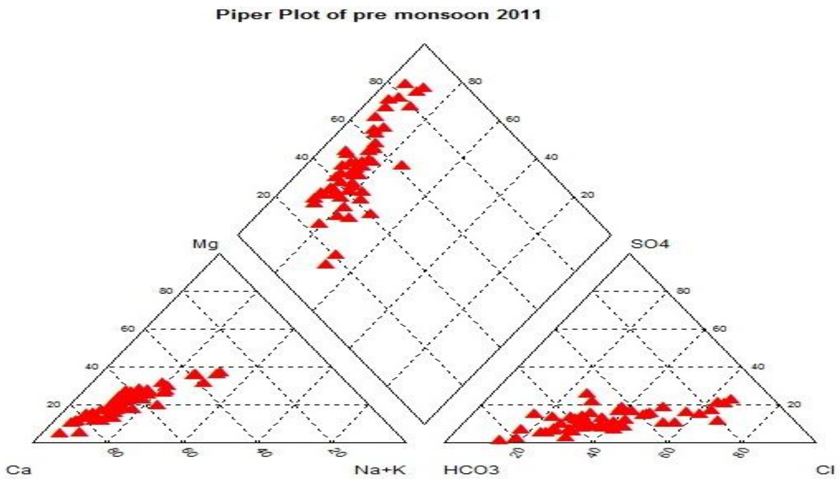

Fig. 7: Piper Trilinear Diagram of Pre Monsoon Groundwater

5. Summary and conclusions

Groundwater of the study area shows alkaline earth (ca and mg) exceeds than alkalis (Na and K), weak acids (HCO_3) exceeds than strong acids (Cl, SO_4 and NO_3). The Ca, Mg and HCO3 indicate hardness is dominated by the alkaline earth and weak acids. The geochemistry of the groundwater of the study area shows Ca > Mg > Na > K and HCO_3 > Cl > SO_4 > CO_3^{2-} trends. Hence groundwater from the study area shows dominant of calcium bicarbonate.

The water increases its major ions and electrical conductivity in pre monsoon period as compared to post monsoon period due to over exploitation of groundwater. The homogeny in the quality of groundwater from the shallow and deep aquifers in study area, it has been observed concentration of major ion and physical parameter like EC and TDS concentrations in shallow aquifer is higher than deeper aquifer. Higher concentration of NO_3 in some samples indicates anthropogenic pollution due to the excessive use of nitrogenous fertilizers in highly cultivated areas seems responsible for high concentrations.

Although the majority of people affected due to water borne diseases by anthropogenic or geogenic those are live in rural area consume the water without treatment. They are depend on untreated plants, lakes, rivers, surface water or tube wells they may be contamination and its impact on human health.

Groundwater quality of the study area mainly affected due to anthropogenic activities and overexploitation of groundwater for agricultural practices. The study area facing problem of salinity, this is impact of excessive withdrawn of groundwater. In general the boron is low in the fresh water however high in brackish and saline water. Boron observed in the groundwater indicators of salinity, entire study area 20 percent samples observed the saline nature because of EC > 3000 µmohs/cm, B > 700 µg/l and > 1500 ppm TDS. The calculated parameter of irrigation water quality like SAR, Kelly's ratio, RSC and sodium percentage shows that groundwater can be used for irrigation without any hazards but RSC trends are increasing in the area which doubtful.

From the medical survey in the area under study revealed that the no medical report on methaenoglobinaemia and dental fluorosis disease was observed. The drinking water source of few villages having high values of total hardness in the groundwater samples was probability to have harmful effects like kidney stones and other related diseases. The villagers were surveyed for these kidney stones and a rare incidence was reported.

6. Recommendations

Whereas, high concentrations of TDS (>500 ppm), Cl (> 250 ppm) and NO_3 (> 45 ppm) restrict the direct use of water for the drinking purposes. Portability of drinking water is mainly based on recommended guidelines of permissible limit for certain parameter as per BIS 2003. When water contamination exceeds than the permissible limit it is unfit for human consumption. All ions in groundwater samples increasing trends of pre monsoon as compared to post monsoon period they may be cause of excessive withdrawn of groundwater.

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