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Suitability of Groundwater for Domestic and Irrigational Practices of Bellary Taluk, Karnataka, India

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Abstract- Suitability of water for drinking and agriculture of Bellary Taluk of Karataka State was considered under present investigation. 49 representative water samples were collected each during Pre-monsoon (May) and Post-monsoon (November). Sutability of water samples for drinking was determined by considering irrigational parameters such as- SAR, Na%, RSC, EC, TDS, KI, PI, PSS, NCH, TH, MR, MH, Wilcox diagram and USSL diagram. From the study it was found that most of the parameters are safe and within allowable limits except F, Th and TDS during both season for drinking suitability. While based on agricultural suitability parameters it was found that on an average 18 water samples from both seasons are not suitable for agriculture. The reason for these is anthropogenic activities and geogenic processes. Thus, there is need in Bellary Taluk to monitor the water quality at regular times for sustainable development and management of groundwater resources.

Key words- Groundwater, water quality, drinking and agricultural suitability, Bellary Taluk

1. INTRODUCTION

The major part of rural community in hard rock terrain of India depends on groundwater for drinking and agricultural purposes. In recent times due to indiscriminate usage of groundwater has lead to stress on groundwater quality regime of hard rock terrain particularly in Karnataka. Thus it becomes inevitable to study the groundwater quality suitability for drinking and agriculture purposes.

Anthropogenic activities and geological processes deter the quality of water as the later passes through different geological formations and later affected by former (Sullivan et al 2005, Stamatis 2010, Gnanachandrasamy et. al. 2014).

Poor quality of water adversely affects the human health and plant growth (WHO 2004; Nag and Ghosh 2013). The importance of water quality in human health has recently attracted a great deal of interest. In developing countries like India, around 80 % of all diseases are directly related to poor drinking water quality and unhygienic conditions (Olajire and Imeokparia 2001; Prasad 1998; David et al. 2011; Limbachiya 2011; Kaveh Pazand and Ardeshir Hezarkhani 2013, Khadri et al. 2013). In general, the assessment of water quality criteria is based on the consideration of physicochemical properties of the soil and the impact on crop yield. Numerous publications have reported that urban development and agricultural activities directly or indirectly affect the groundwater quality (Giridharan et al. 2008).

Previously studies have been carried out by different authors and researchers to study the water quality of Bellary and adjoining areas but those studies were on regional scale and not detailed and also longtime back (Garemalla, 1998 and Hegde, 2004).

Thus present study has been carried out to study the suitability of water of Bellary taluk for drinking and agriculture purposes.

2. STUDY AREA

Bellary Taluk of Karnataka State is under taken in present study. The study area geographically lies between Latitude 15^0 00'N to 15^0 25'N and Longitude 77^0 08'E to 77^0 40'E and is covered in Survey of India (SOI) toposheets numbered 57A/15, 57A/11, 57A/16, and 57E/3. The location map of the study area with respect to India is shown in the Fig. 1.

The study area experience dryness in major part of the year with hot summer and little rainfall during SW monsoon seasons (June-Sept) and NE-monsoon (Nov-Jan). The Summers are hot (40-420C) and winters are cold (15-200C). The annual rain fall in the area is 452 mm and last ten year data shows decreasing trend in rainfall. The streams are non perennial with waters during August to September.

Geologically, the Bellary Taluk encompasses hard rock terrain, hard rock terrain comprising gneiss, younger granites and schistose formation of Archean age. The soils of the taluk are derived from Granites, Gneisses and schistose rocks. The Sandy loam soil mixed with black and grey soil occurs along the stream beds. The red soil major type of soil in the area occurs mainly at elevated places, fringes of hills and which is derived gneisses and granites.

3. METHODOLOGY

49 each representative groundwater samples were collected each during pre- and post-monsoon. Samples were collected in one liter polyethylene cans which were pre-rinsed in labotatory using dil. HCl and distilled water and also rinsed with collecting water sample in the field. The physico-chemical parameters such as EC, pH, TDS, TH, Ca, Mg, Na, K, CO3, HCO3, Cl, SO4 and F were determined. Parameters pH, EC was measured at field site using portable digital meter. TDS was further manually calculated using EC value (Todd, 1950). Other parameters were analyzed volumetrically using Titration method. Na and K were analyzed by Atomic Absorption Spectrophotometer. Fluoride was analyzed using Ions selective electrode method. SO4 was analyzed using colorimeter. The obtained minimum, maximum average and standard deviation have been tabulated in Table 1. To understand the groundwater suitability of Bellary Taluk for irrigation 20 different parameters as proposed by different researchers are used and for drinking purposes BIS standards were used.

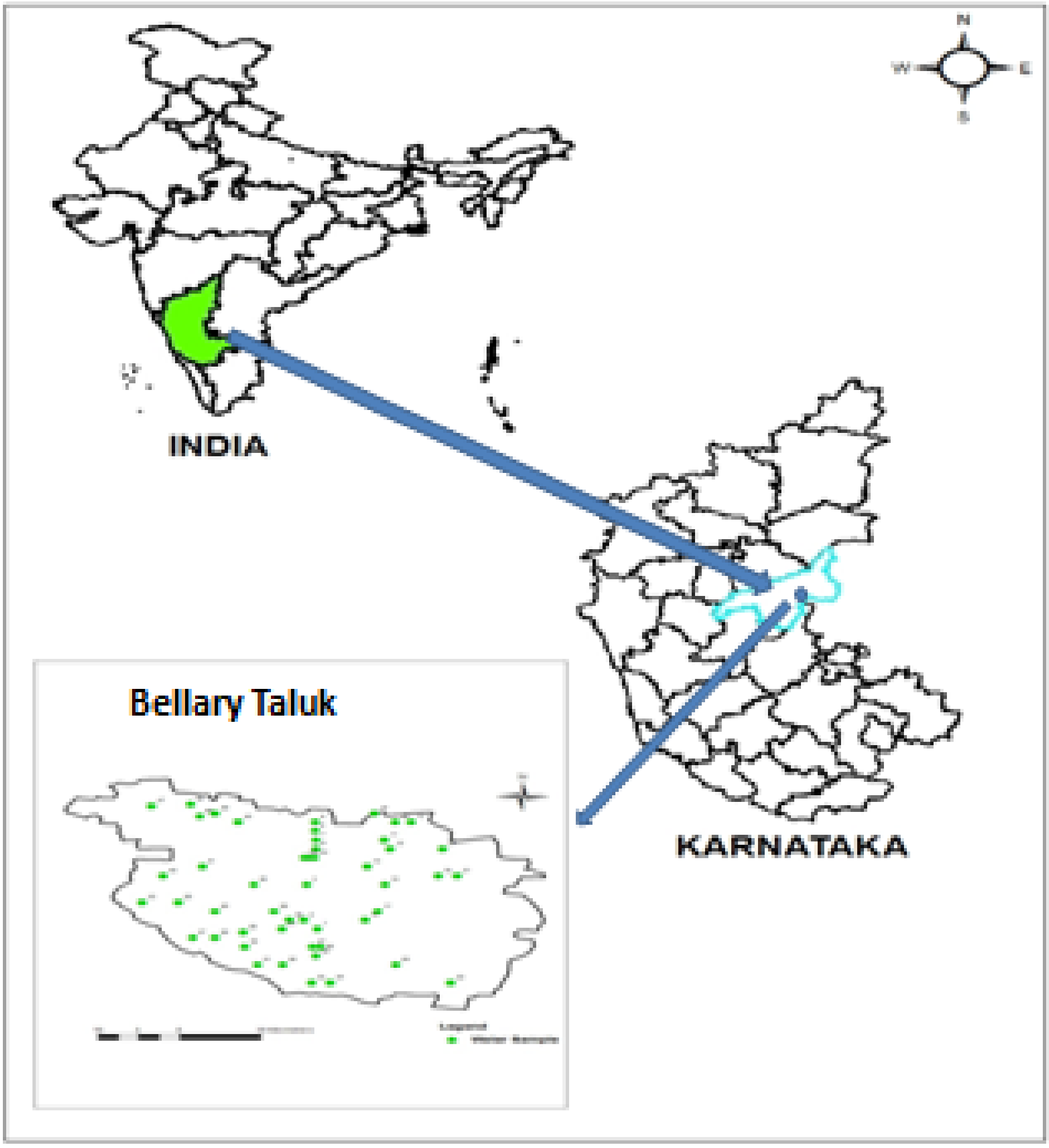

Fig. 1 Location of study area with respect India

Table 1. Maximum, Minimum and Average values of chemical analysis

Sl.No	Parameters	Pre-Monsoon				Post-Monsoon			
		Min	**Max**	**Avg**	**SD**	**Min**	**Max**	**Avg**	**SD**
1	**EC**	400	12300	2914	2805	260	11180	2457	2395
2	**TDS**	100	7940	1755	1754	128	3940	1028	918
3	**Ph**	5.92	8.86	7.48	1	4.47	8.94	7.40	1
4	**TH**	24	1298	407	345	68	3848	700	704
5	**Ca**	8	569	107	130	13	709	112	120
6	**Mg**	0	120	38	35	0.49	200	23	33
7	**Na**	4	481	200	162	1	179	61	40
8	**K**	0	1575	123	267	0	207	52	42
9	**SO_4**	6	470	131	142	10	459	153	138
10	**Cl**	24	1968	379	463	21	1795	305	380
11	**HCO_3**	60	680	249	149	120	620	313	121
12	**CO_3**	0	160	61	35	0	120	25	33
13	**F**	0.20	6.0	1.63	1	0.20	4	1.4	1

All values are in mg/L except pH and EC (EC is in µmhos/cm)

4. RESULTS AND DISCUSSION

The following parameters as proposed by various researchers are used in order to understand the groundwater suitability for agricultural purposes. The parameters are tabulated in subsequent tables and interpreted (Table 2 to 21). Table 22 shows groundwater suitability for drinking purposes based on comparison with BIS (2005) standards.

Table 2: Percentage of Na by Wilcox, 1955		$Na\% = \frac{Na + K}{Ca + Mg + Na + K} \times 100$	
Classification		**Pre-Monsoon**	**Post-Monsoon**
Excellent	<20	6	8
Good	20-40	8	16
Permissible	40-60	11	15
Doubtful	60-80	12	9
Unsuitable	>80	12	1

Table 3: Percentage of Na by Eaton, 1950	$Na\% = \frac{Na + K}{Ca + Mg + Na + K} \times 100$

Classification		Pre-Monsoon	Post-Monsoon
Safe	<60	25	39
Unsafe	>60	24	10

Table4:Sodium Absorption Ratio by Richards, 1954		$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$	
Classification		**Pre-Monsoon**	**Post-Monsoon**
Excellent	<10	35	48
Good	10-18	4	1
Fair	18-26	9	-
Poor	>26	1	-

Table 5: Electrical Conductivity by Sarma et al,1982		• **µmhos/cm**	
Classification		**Pre-Monsoon**	**Post-Monsoon**
Excellent	<200	-	-
Good	250-750	6	9
Permissible	750-2000	23	21
Doubtful	2000-3000	2	5
Unsuitable	>3000	18	14

Table 6: Total Dissolved Solids by Davis and De Wiest, 1966 and Carroll, 1962.			
Classification		**Pre-Monsoon**	**Post-Monsoon**
Fresh	0-1000 ppm	25	33
Good	1000-10000 ppm	24	16
Saline	10000-100000 ppm	-	-
Brine	>100000 ppm	-	-

Table 7: Residual Sodium Carbonate by Richards, 1954		$RSC = (CO_3 + HCO_3) - (Ca + Mg)$	
Classification		Pre-Monsoon	Post-Monsoon
Good	<1.25	28	31
Medium	1.25-2.50	5	8
Bad	>2.50	16	10

Table8: Kelley's Index by Kelly, 1940		$KI = \frac{Na}{Ca + Mg}$	
Classification		Pre-Monsoon	Post-Monsoon
No alkali hazards	<1	26	37
Alkali Hazards	>1	23	12

Table 9: Permeability Index by Doneen, 1962		$PI = \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na}$ **X100**	
Classification		Pre-Monsoon	Post-Monsoon
Safe	<25%	3	7
Allowable	25-75%	25	22
Unsafe	>75%	21	20

Table 10: Potential Soil Salinity by Doneen, 1962		$PSS = Cl + \frac{1}{2} SO_4$	
Classification		**Pre-Monsoon**	**Post-Monsoon**
Excellent	<3	14	15
Good to Injurious	3-5	12	9
Injurious to Unsatisfactory	>5	23	25

Table 11: Non Carbonate Hardness by Ragunath, 1987		$NCH = (Ca + Mg) - (CO_3 + HCO_3)$	
Classification		**Pre-Monsoon**	**Post-Monsoon**
Presence of NCH	Positive value of NCH	25	20
Absence of NCH	Negative value of NCH	24	29

Table 12: Total Hardness by Ragunath, 1987		$TH = (2.497Ca + 4.115Mg)$	
Classification		**Pre-Monsoon**	**Post-Monsoon**
Soft	0-55	7	3
Slightly Hard	56-100	10	8
Moderately Hard	101-200	13	13
Very Hard	201-500	11	19
Very Very Hard	>500	8	6

Table 13:Magnesium Ratio by Lloyd and Heathcoat 1995		$MR = \frac{Mg}{Ca}$	
Classification		**Pre-Monsoon**	**Post-Monsoon**
Suitable for Irrigation	<50	22	35
Unsuitable for irrigation	>50	27	14

Table 14: Magnesium Hazards by Szabolcs and Darab, 1964		$MH = \frac{Mg}{Ca + Mg} \times 100$ **epm values**	
Classification		**Pre-Monsoon**	**Post-Monsoon**
Suitable	<50%	33	44
Marginal	50-65%	7	4
Unsuitable	>65%	9	1

Table 15:Wilcox Diagram by Wilcox, 1948		**Fig**	
Classification		**Pre-Monsoon**	**Post-Monsoon**
Excellent To Good	AREA 1	3	8
Good To Permissible	AREA 2	6	18
Permissible To Doubtful	AREA 3	16	4
Doubtful To Unsuitable	AREA 4	4	5
Unsuitable	AREA 5	20	14

Table 16: USSL Diagram by Wilcox,1948			**Fig**	
Classification			**Pre-Monsoon**	**Post-Monsoon**
Salinity	**SAR**	**Classes**		
Low	Low	$C_1 S_1$	-	-
Low	Medium	$C_1 S_2$	-	-
Low	High	$C_1 S_3$	-	-
Low	Very-High	$C_1 S_4$	-	-
Moderate	Low	$C_2 S_1$	3	7
Moderate	Medium	$C_2 S_2$	1	2
Moderate	High	$C_2 S_3$	1	-
Moderate	Very-High	$C_2 S_4$	2	-
Medium High	Low	$C_3 S_1$	9	22
Medium High	Medium	$C_3 S_2$	3	-
Medium High	High	$C_3 S_3$	1	-
Medium High	Very-High	$C_3 S_4$	8	-
High	Low	$C_4 S_1$	3	9
High	Medium	$C_4 S_2$	3	1
High	High	$C_4 S_3$	1	-
High	Very-High	$C_4 S_4$	-	-
Very High	Low	$C_5 S_1$	5	7
Very High	Medium	$C_5 S_2$	6	1
Very High	High	$C_5 S_3$	1	-
Very High	Very-High	$C_5 S_4$	-	-

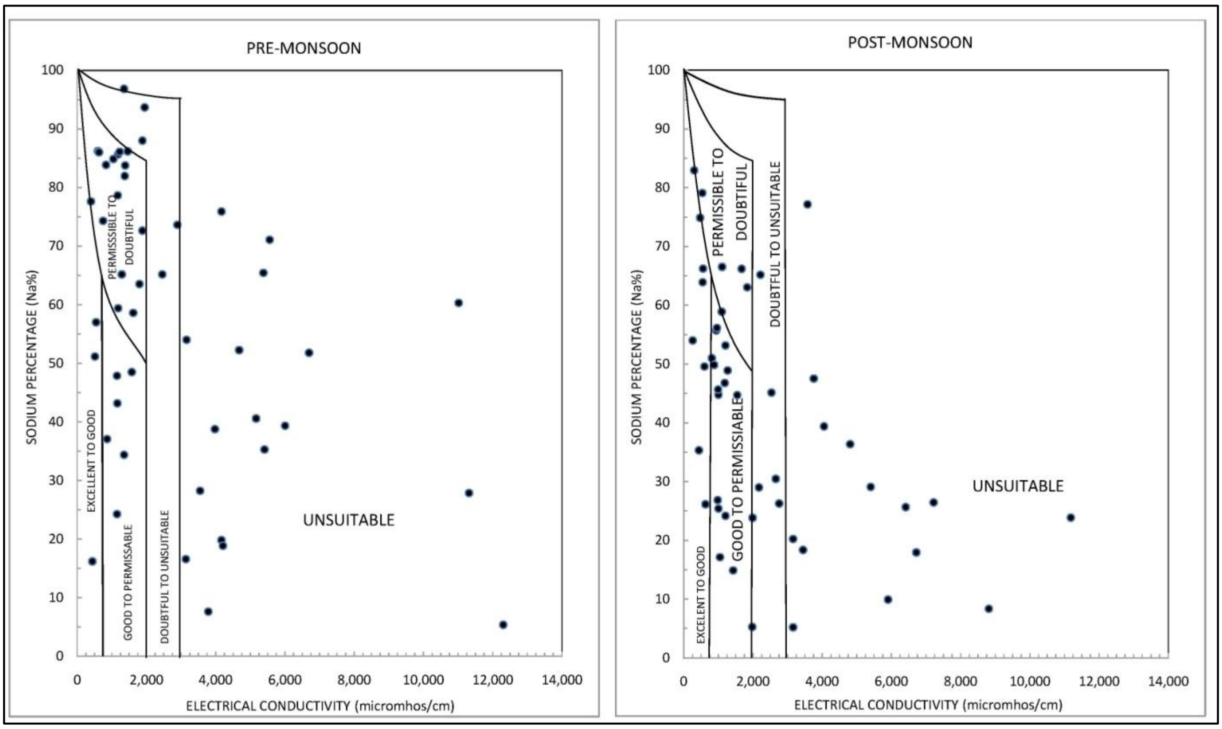

Fig. 2. Wilcox diagram for pre and post monsoon

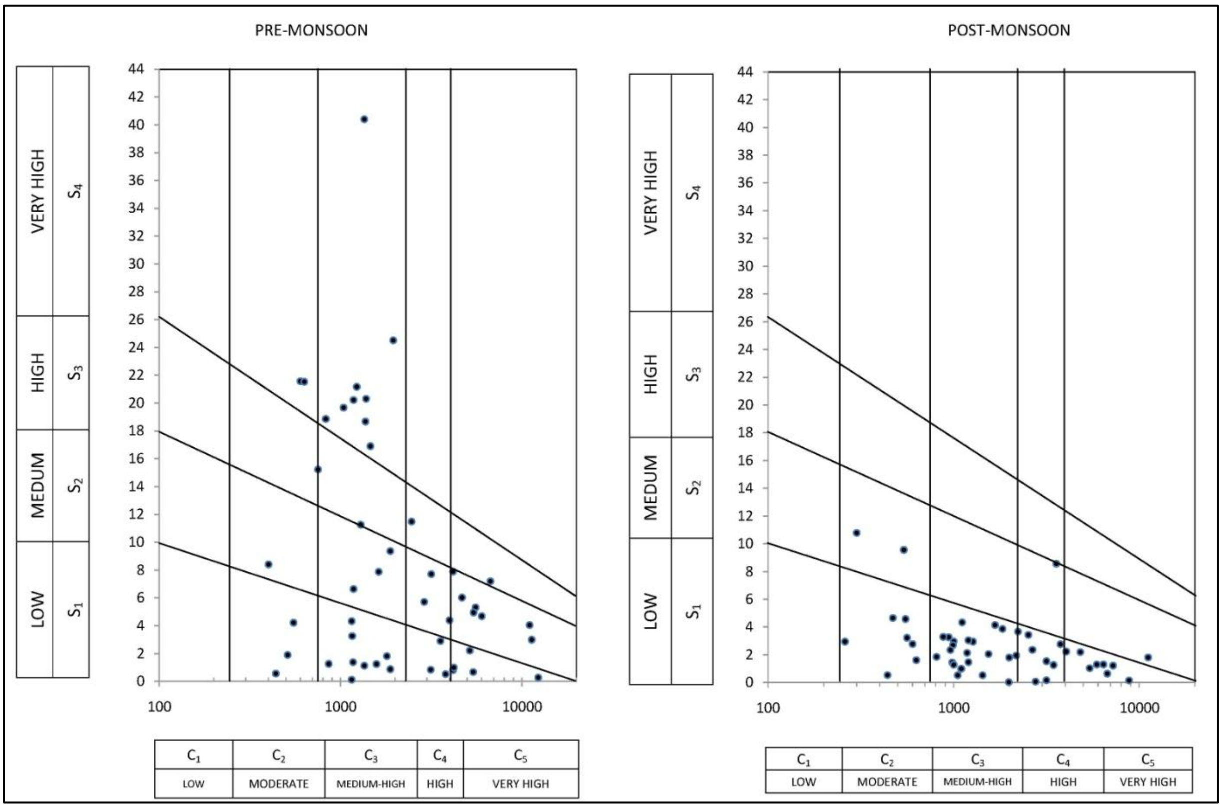

Fig. 3. USSL diagram for pre and post monsoon

Table 17: Ayer's classification, 1977		**Based Cl concentration epm values**	
Classification		**Pre-Monsoon**	**Post-Monsoon**
No Problem	<4	26	26
Increasing Problem	4-10	6	7
Severe Problem	>10	17	16

Table 18: Ayer's classification, 1977		**Based HCO_3 concentration epm values**	
Classification		**Pre-Monsoon**	**Post-Monsoon**
No Problem	<1.5	4	-
Increasing Problem	1.5-8.5	42	46
Severe Problem	>8.5	3	3

Table 19: Ayer's classification, 1977		**Based SO_4 concentration epm values**	
Classification		**Pre-Monsoon**	**Post-Monsoon**
Excellent	<4	33	32
Good	4-6.5	4	5
Permissible	6.5-12	12	12
Doubtful	12-20	-	-
Unsuitable	>20		

Table 20: Ayer's classification, 1977		Based on Ec	
Classification		Pre-Monsoon	Post-Monsoon
No Problem	<0.75	6	9
Increasing Problem	0.75-2.75	24	15
Severe Problem	>2.75	19	25

Table 21: Ayer's classification, 1977		**Based on RSC**	
Classification		**Pre-Monsoon**	**Post-Monsoon**
Safe	<1.25	29	22
Marginal	1.5-2.5	4	20
Not Suitable	<2.5	16	7

4.1 Interpretation of Groundwater Quality for Agricultural Suitability

The quality of water used for agriculture practices is an important factor in productivity and quality of the crops. The distribution of soluble salts depends on factors like; chemical composition of water, nature and composition of the soils and sub-surface, topography, amount of water used and method of its application, kind of crop grown, climate, rainfall etc,. High percentage of dissolved salts contributes to stunted growth of plants. The impact of sum of dissolved salt is more important than the toxicity caused by a single constituent. Effects of salts on soils causes changes in soil structure, permeability and aeration, indirectly affects the plant growth.

Based on the sodium percentage value (Wilcox, 1955) 50% samples during pre-monsoon and most of samples during post-monsoon fall in Excellent to Permissible category (Table 2). Further, according to Eaton (1950) 50% samples are safe during pre-monsoon and most of samples safe during post-monsoon (Table 3). Based on SAR values (Richards, 1954) which infers that most of the samples are Excellent (Table 4).
Based on EC values (Sarma et al, 1982) it indicates that 60% of samples fall in Good to Permissible class during both season and 40% of them fall in Doubtful to unsuitable (Table 5). Based on RSC values (Richards, 1954) it depicts that 60% of samples belongs to Good category during both seasons and 40% belongs Medium to Bad category during both seasons (Table 7). Kelley's index (KI) values (Kelley, 1940) suggest that nearly equal number of samples during pre-monsoon show either alkali hazards or no alkali hazards while during post-monsoon samples most of the samples show no alkali hazards (Table 8).
Based on permeability index (PI) (Doneen, 1962) values it was found that most of the samples fall in Allowable to Unsafe category while during pre-monsoon few samples fall in safe category (Table 9). Based on Potential Soil Salinity (PSS) (Doneen, 1962) values it depicts that 50% samples belongs to ingenious to unsatisfactory category during both seasons and rest of samples fall equally in excellent and good to injurious category (Table 10). Non-Carbonate Hardness (NCH) (Raghunath, 1987) values depicts that nearly equal number samples (Table 11) are positive and negative values suggests presence and absence of NCH in both seasons. Based on the Total hardness (TH) (Ragunath, 1987), most of the samples falls under slightly hard, moderately hard and very hard category during both seasons (Table 12). Based on Magnesium Ratio (MR) values (Lloyd and Heathcoat, 1985) it depicts that nearly equal number of samples belongs to Suitable and Unsuitable category during pre-monsoon and most of the samples belongs to suitable category during post-monsoon (Table 13). The Magnesium Hazard (Szabolcs and Darab, 1964) values suggest that most of the samples of both seasons belong to Suitable category (Table 14).
According to Wilcox diagram (Fig. 2 and Table 15) samples show maximum number of sample belongs to Permissible to Doubtful and Unsuitable class during pre-monsoon and during post-monsoon Good to Permissible and Unsuitable class. USSL diagram (Fig 3 and Table 16) shows that most of the samples fall in category from moderate- low (C2S1) to very high-high (C5S3) values of salinity and SAR during pre-monsoon while during post-monsoon maximum number of samples fall in C3S1, C2S1, C4S1 and C2S2 areas indicating medium high to low, moderate to low, high to low, moderate to low and moderate to medium values of salinity and SAR respectively.
Based on Cl concentration (Ayer, 1977) suggest that the 50% of samples falls in No problem category during both seasons and rest of samples shows increasing problem to severe problem category during both season (Table 17). The HCO_3 concentration (Ayer, 1977) suggest that maximum number samples shows increasing problem category during both seasons while few samples fall in No problem and Severe category during both seasons (Table 18). Based on SO_4 concentration (Ayer, 1977) it depicts that more than 50% samples shows Excellent category during both seasons and rest of samples belongs to Good to Permissible category during both seasons (Table 19). Based on EC values (Ayer, 1977) it suggests that maximum number samples belongs to increasing problem to severe problem category and few samples belongs no problem category during both seasons (Table 20). Based on RSC values (Ayer, 1977) it shows that more than 50% samples fall in safe category and rest of the samples belongs to marginal and not suitable category during pre-monsoon while during post-monsoon most of the samples fall in safe and marginal category with few samples fall in not suitable category (Table 21).

4. 2 Interpretation of Groundwater Quality for Drinking Suitability

The groundwater for drinking and domestic purposes should be potable and it should satisfy the physical, chemical and bacterial criteria which indicates the safety of water for ingestion, cooking and sanitary purposes. The potability of groundwater depends on safe and good to drink and which is supposed to be colorless, odorless and in pleasant taste. In the present study the water samples during both the season are compared with standards as prescribed by Bureau of

Indian Standards (BIS, 2012). The comparisons are tabulated in the Table 22. From the comparison study it was found that nearly 50% samples during both pre- and post-monsoon exceed the permissible and allowable limits.

Table 22 Groundwater water quality comparison of with Drinking water Standards of BIS (2012)

Chemical Parameters	Maximum		No sample exceeding during Pre-monsoon		No sample exceeding during Post-monsoon	
	Permissible	Allowable	Permissible	Allowable	Permissible	Allowable
TDS	500	2000	25	16	27	7
pH	6.5-8.5	-	21	-	28	-
TH	200	600	18	12	24	18
Ca	75	200	11	8	19	6
Mg	30	100	18	4	11	1
SO_4	200	400	8	4	11	4
Cl	250	1000	16	4	20	2
F	1	1.5	11	19	16	17

5. CONCLUSION

Based on the above study and interpretations following conclusions are drawn. The Bellary taluk forms part of hard rock terrain which comprises gneiss, younger granites and schistose formation of Archean age. The soils of the taluk are derived from Granites, Gneisses and schistose rocks. The Sandy loam soil mixed with black and grey soil occurs along the stream beds. These rocks are highly weathered and posses number of fractures and joints. These openings help for transporting rain water into subsurface and groundwater occurs under unconfined aquifer conditions. The areas experiences semi arid climatic conditions. The peoples of this area are dependent on groundwater for agriculture and drinking purposes. Overall 20 parameters were determined to evaluate the suitability of groundwater of Bellary Taluk for agriculture and drinking. Based on this authors suggest that groundwater samples of Bellary taluk cannot be freely used and it is suggested that, every farmer in these watersheds have to go for regular water quality testing at regular intervals and before start of agriculture practices and domestic purposes. Further, it is also advised to farmers that they select suitable crops. Also a detailed study of groundwater quality characterization of Taluk is essential to know the suitability of water for agricultural and drinking purposes and further conservation and development of water resources.

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