



Hydrochemistry and Application of GIS in Groundwater Quality in Nagalapura Taluk, Bellary District, Karnataka, India

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ABSTRACT

The assessment of groundwater quality is essential for the conservation of natural resources. Hence, this study aims to assess the hydrochemistry of groundwater in and around the Nagalapura Taluk in Bellary district, Karnataka, India. The groundwater quality variables are mapped using a Geographic Information System (GIS). For the hypothesis, the mean value of ten groundwater quality variables was obtained from 50 bore well samples (2016-2018). To assess the lead ions and type of water, the USSL, SAR, and Na% were measured. Ionic ratio and Gibbs graphs were used to demonstrate the chemical reactions in the water samples. ArcGIS was used for spatial analysis of the quality variables. The results showed the order of $\text{Cl}^- > \text{SO}_4^{2-} > \text{HCO}_3^-$ with water types $\text{Na}^+\text{-Cl}^-$ and Cl^- , and the order of $\text{Na}^+ > \text{Mg}^{++} > \text{Ca}^{++} > \text{K}^+$ with Na^+ and Mg^{++} as the dominant anion and cation, respectively. The hydrochemistry of groundwater is determined by the geological structure in 64 percent of the water samples examined. The Wilcox diagram shows that no-alkali exposure to the crops is expected. Forty one samples (82%) fit within the C3-S1 group; this category is fit for irrigational needs. Only 01 and 03 samples showed maximum SAR during two seasons like pre-monsoon and post-monsoon periods. The maps showed that groundwater in the selected sites is usually of higher quality, whereas the presence of dolomite indicates a reduction in water quality.

INTRODUCTION

Groundwater is the water present beneath Earth's surface in rock and soil pore spaces and the fractures of rock formations (Freeze 1979). Water enters the ground in the lower layer where the discharge ends, which contains wells, springs, rivers, lakes, and the ocean. The world's freshwater supply contains 62% groundwater, which is 0.65% of the total amount of water on Earth (EPA 2009). Man-made activities on land, land use, changes in the soil layer, and ground-water percolation impact the quality of groundwater. Although groundwater testing and drilling, which includes strata analysis, are good methods for determining the depth of the aquifer and the ideal site for a bore-well, they take time and often require skilled manpower (Madan et al. 2010, Mukherjee et al. 2012, Mallick et al. 2015). On the other hand, using GIS, remote sensing, and satellite images to assess groundwater resources is beneficial and cost-effective (Adiat et al. 2012, Verma & Singh 2013). Honarbakhsh et al. (2019) used a GIS-based approach with the Groundwater Quality Index (GWQI) to analyze groundwater quality in Marvdasht located in the semi-arid region

of Iran. For this purpose, they used groundwater quality data that were collected in a five-year period (2010-2015). During the study period, the groundwater quality index (GWQI) indicated that only 3% of the total area (10km²) was of low quality. Mg^{++} , total hardness (TH), and Na^+ were predicted to be the most sensitive water quality variables. Elubid et al. (2019) reported the spatial distribution of groundwater quality parameters in some parts of Gedare State by using GIS and the total water quality index (TWQI). Major cations and anions were found in 38 bore wells identified in this study. Furthermore, the groundwater quality is controlled by sodium and bicarbonate ions that defined the composition of the water type to be Na-HCO_3 .

Furthermore, as reported by Hemant and Limaye (2012), Kesari et al. (2016), and Madan et al. (2010) in several parts of India, groundwater quality is deteriorating due to massive industrial effluent dumping and mining activities. The reduction in precipitation in arid places leads to an increase in the public's use of water for drinking and irrigation purposes (Mallick et al. 2015). Groundwater resources can be defined as the only vital and alternative resource for the people in dry

areas, particularly to encourage human life through agriculture activities. With the above literature review, the present work is undertaken to generate groundwater level zonation image-based thematic maps utilizing remote sensing and GIS for improved groundwater resource utilization, planning, and management.

Seasonal maps are used to evaluate field experts' opinions and data analysis. Several experiments to assess the quality and hydrochemistry of groundwater were conducted in and around Nagalapura Taluk, Bellary district, using Pie, Schoeller, and Piper diagrams, as well as maps, to assess groundwater quality in and around Nagalapura Taluk.

MATERIALS AND METHODS

Geology of Hospet, India

Geologically, rocks of granodiorite and granite are associated with iron and manganese ore bands. These rocks are joined and intruded by doleritic dykes. Unlike hard rocks, which are partially weathered up to 5 meters below the surface, schist and phyllite can weather up to 20 meters deep.

Experimental Work

The groundwater samples obtained from twenty-five different locations in and around the Nagalapura taluk were examined and analyzed and interpreted for this study. The sampling locations in this study were identified in five different zones of the city, and groundwater samples were taken. In a GIS model, interpretation strategies that integrate ground-based and remote sensing data are developed. Critical steps include acquiring all relevant data, processing, and constructing the database. Capacity levels and data are required in assessing the study area to generate GIS data. Geologic, hydrologic, topographic, vegetation, and soil maps are among the data types available, and so are satellite imagery, geological logs, bore well locations with latitude and longitude, and hydrological data such as water quality, aquifer test data, and reports from local and regional study areas.

Collection of Samples

Groundwater samples are collected in five-liter plastic cans that have been washed and rinsed twice with distilled water. All samples were carried to the laboratory using ice-boxes and kept refrigerated at 4°C APHA, 2005. The Fig. 1 gives the sampling location map and details of the locations are given in Table 1. Samples were analyzed for physico-chemical variables, using respective methods as per APHA, 2005. Statistical analysis was also applied to the results and tabulated.

RESULTS AND DISCUSSION

According to preliminary research, Nagalapura district provided the best opportunity to collect the most relevant data across the study area. 50 bore wells were chosen from a GPS field survey of the study area, and water samples were collected from these 50 locations. Hydrochemistry and all other data have been entered into the GIS. The spatial pattern of various water quality variables is discussed in this paper. During the present investigation, thematic map hardness of groundwater revealed that 80% of the groundwater samples in the pre-monsoon period, 76% of the groundwater samples during the monsoon period, and 75% of the groundwater samples during the post-monsoon period had hardness in the range of 300 to 600 mg.L⁻¹. During the pre-monsoon season, 6% of the groundwater samples (Fig. 2(a)), 5% of the groundwater samples during monsoon (Fig. 2(b)) and 4% of the groundwater samples during the post-monsoon period (Fig. 2(c)) had hardness less than 300 mg.L⁻¹ (Hemant & Limaye 2012). It was observed that 28% and 22% of the groundwater samples during pre- and post-monsoon periods had hardness above 600 mg.L⁻¹. In both seasons, it was evident that more than 20% of the groundwater samples exceeded the permissible limit set by BIS and WHO drinking water standards. The hardness of water is caused due to occurrence of carbonates and bi-carbonates of Ca⁺⁺ and Mg⁺⁺, Cl⁻, NO₃⁻, and SO₄²⁻ of Ca⁺⁺ and Mg⁺⁺. The maximum content of TH was found in HW-41 (M.M.Halli near Anjinappa home), which is above the permissible limit. Most of the selected locations had TH content within the permissible limit. Spatial distribution of TH during pre- and post-monsoon periods, and monsoon periods are given in Fig. 2(a), 2(b), and 2(c) respectively.

Maximum hardness was observed at HW-41 (M.M.Halli near Anjinappa home) (1280 mg.L⁻¹) in all the seasons during the study period, while it was 143 mg.L⁻¹ in HW-43 (D.N.Keri Devalapura near Shayari Durugamma Temple) during post-monsoon and monsoon periods. However, it was 195 mg.L⁻¹ in HW-42 (D.N.Keri near Nandibanda) during the pre-monsoon season. Pujari, et al. (2012) recorded TH of 808 mg.L⁻¹ during the rainy season in Kovaya, the coastal area of Gujarat whereas Champidi et al. (2011) recorded 1685 mg.L⁻¹ of TH in the Erasinosa area of eastern Attica.

The perusal map of the Ca⁺⁺ content showed that 82% and 81% of groundwater samples have calcium concentrations in the range of 75 mg.L⁻¹ to 200 mg.L⁻¹ during pre- and post-monsoon periods, and monsoon periods.

Table 1: Location of the bore-well samples in the Hospet Taluk, Bellary District.

Sl. No.	Village	location	Latitude and Longitude	Sl. No.	Village	Location	Latitude and Longitude
HW-1	Hossur	Kichadi Net	15 ^o 16'08.20N 76 ^o 23'26.82E	HW-26	Bylavaddigeri	Dharmasagara	15 ^o 14'55.55N 76 ^o 31'53.64E
HW-2	Hossur	Near Railway Gate	15 ^o 16'08.10N 76 ^o 23'26.50E	HW-27	Bylavaddigeri	Kakubalu	15 ^o 14'55.43N 76 ^o 31'53.60E
HW-3	Nagenahalli	Nagenahalli	15 ^o 17'50.23N 76 ^o 24'12.59E	HW-28	P K Halli	Ganesh Temple	15 ^o 16'22.58N 76 ^o 28'37.77E
HW-4	Nagenahalli	Basavadurga	15 ^o 17'50.17N 76 ^o 24'12.30E	HW-29	P K Halli	Ingalagiri	15 ^o 16'22.17N 76 ^o 28'37.41E
HW-5	Kamalapura	Opp SriKari College	15 ^o 18'21.53N 76 ^o 28'27.34E	HW-30	P K Halli	P K Halli	15 ^o 16'22.38N 76 ^o 28'37.52E
HW-6	Seetharam Tanda	Seetharam Tanda Cross	15 ^o 16'30.48N 76 ^o 24'15.63E	HW-31	Hosapete (T B Dam)	Muttumariyamma Temple	15 ^o 16'27.64N 76 ^o 21'10.28E
HW-7	Seetharam Tanda	Mustafa Darga	15 ^o 16'30.17N 76 ^o 24'15.10E	HW-32	Hosapete	Industrial Area	15 ^o 16'27.81N 76 ^o 21'10.40E
HW-8	Seetharam Tanda	N R Camp	15 ^o 16'30.22N 76 ^o 24'15.30E	HW-33	Hosapete	Sanaki veerabadra temple	15 ^o 16'27.79N 76 ^o 21'10.38E
HW-9	Bukkasagara	76 Venkarta-pura	15 ^o 21'03.28N 76 ^o 31'50.64E	HW-34	Hosapete	Chittavadigeppa temple	15 ^o 16'27.75N 76 ^o 21'10.26E
HW-10	Bukkasagara	Near Anjaneya Temple	15 ^o 21'03.36N 76 ^o 31'50.22E	HW-35	Kallahalli	Vyasanakere Station	15 ^o 13'05.08N 76 ^o 24'14.94E
HW-11	Bukkadagara	SC-ST Keri	15 ^o 21'03.14N 76 ^o 31'50.10E	HW-36	Kallahalli	Kaniverayan Gudi	15 ^o 13'05.29N 76 ^o 24'14.82E
HW-12	Ramasagara	near Renu-kamma House	15 ^o 16'03.02N 76 ^o 23'04.68E	HW-37	Kallahalli	Jambaiha Hola	15 ^o 13'05.31N 76 ^o 24'14.41E
HW-13	Ramasagara	near Shi-vamurthy House)	15 ^o 16'03.20N 76 ^o 23'04.41E	HW-38	Danaapura	Galemma temple Hola	15 ^o 19'29.73N 76 ^o 35'32.63E
HW-14	Sanaapura	near Narasim-ha House	15 ^o 16'03.36N 76 ^o 23'04.22E	HW-39	Danaapura	Hampinkatte	15 ^o 19'29.52N 76 ^o 35'32.38E
HW-15	Sanaapura	near Kurugo-su Basappa House	15 ^o 16'03.08N 76 ^o 23'04.12E	HW-40	Danaapura	Ayyanhalli	15 ^o 19'29.81N 76 ^o 35'32.42E
HW-16	Devasamudra	near Health Centre	15 ^o 20'49.07N 76 ^o 38'07.89E	HW-41	M M Halli	Anjinappa Home	15 ^o 09'29.33N 76 ^o 20'48.93E
HW-17	Devasamudra	Krishna Naga-ra Camp	15 ^o 20'49.28N 76 ^o 38'07.52E	HW-42	D N Kere	Nandi Banda	15 ^o 35'41.24N 76 ^o 53'52.60E
HW-18	Devasamudra	Harejayagnuru	15 ^o 20'49.32N 76 ^o 38'07.49E	HW-43	D N Kere (De-valapura)	Shyari Durgamma Gudi	15 ^o 35'41.48N 76 ^o 53'52.77E
HW-19	Hampadevan-ahalli	Chikka Jaya-ganuru	15 ^o 19'38.45N 76 ^o 41'35.41E	HW-44	D N Kere (Gol-larahalli)	near Gowdru Ven-katesh House	15 ^o 06'67.54N 76 ^o 22'20.30E
HW-20	Hampadevan-ahalli	Near Dugu-lamma Temple	15 ^o 19'38.45N 76 ^o 41'35.34E	HW-45	Nagalapura	Hullinamane	15 ^o 08'36.55N 76 ^o 23'54.98E
HW-21	Devalapura	opp Ma-hadevana House	15 ^o 35'42.10N 76 ^o 53'52.99E	HW-46	Nagalapura	Byalakundi	15 ^o 08'36.17N 76 ^o 23'54.60E
HW-22	Devalapura	Nallapur	15 ^o 35'42.26N 76 ^o 53'52.54E	HW-47	Nagalapura (Gunda)	Near gowri Swami	15 ^o 08'36.24N 76 ^o 23'54.76E
HW-23	Gadiganuru	Opp Mallikar-juna House	15 ^o 12'24.40N 76 ^o 35'21.35E	HW-48	Chilakanahatti	Thimlapura	15 ^o 04'33.23N 76 ^o 21'02.73E
HW-24	Gadiganuru	Opp Hospital	15 ^o 12'24.20N 76 ^o 35'21.41E	HW-49	Chilakanahatti	Pootalakatte	15 ^o 04'33.17N 76 ^o 21'02.51E
HW-25	Bylavaddigeri	Opp Hospital	15 ^o 14'55.68N 76 ^o 31'53.66E	HW-50	Chilakanahatti	Ajanta Nagalinga mata	15 ^o 04'33.29N 76 ^o 21'02.61E

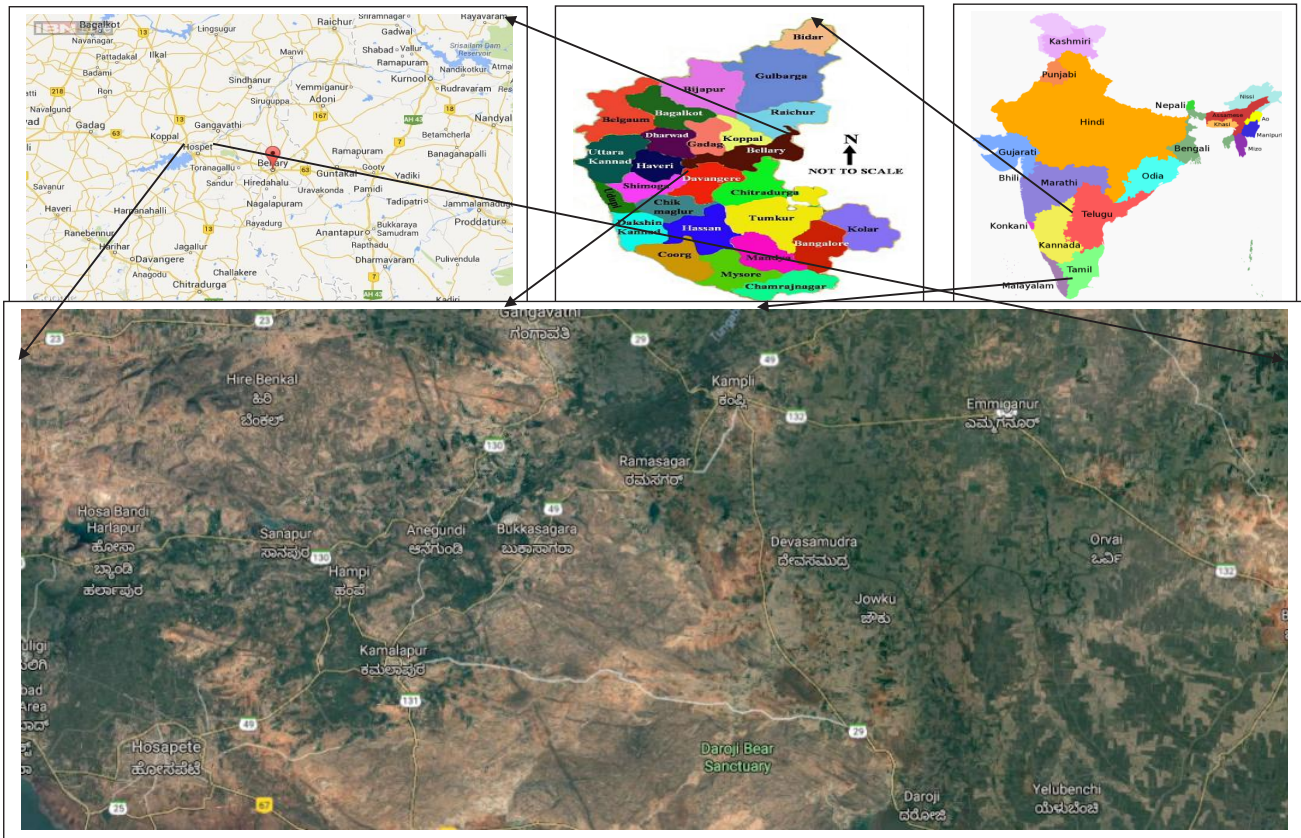


Fig. 1: Location map of the north-east of the Hospet Taluk, Bellary region.

Calcium content in the groundwater samples (Fig. 3(c)) ranged from a minimum of 40 mg.L^{-1} in HW-17 (Ramasagara near Sugandi Renukamma House) to a maximum of 412 mg.L^{-1} in HW-27 (Byluvaddigere near Kakubaal) during post-monsoon season. In the monsoon period (Fig. 3(b)), the calcium content ranged from a minimum of 42 mg.L^{-1} in HW-42 (D.N.Keri near Nandibanda) to a maximum of 412 mg.L^{-1} in HW-50 (Chilakanahatti near Ajatha Nagalinga Mata). In the pre-monsoon season (Fig. 3(a)), the calcium content ranged from a minimum of 20 mg.L^{-1} in HW-48 (Chilakanahatti near Thimmalapura) to a maximum of 421 mg.L^{-1} in HW-27 (Byluvaddigere near Kakubaal).

The BIS permissible limit for calcium is 200 mg.L^{-1} . However, in the current work, 81% of the groundwater samples were within the permissible limit of drinking water guidelines of BIS. The remaining 18% of the groundwater samples in the pre-monsoon period and 17% of groundwater samples in the post-monsoon period are above the prescribed limit. The calcium content of 1% of water samples is below 75 mg.L^{-1} during three seasons (Fig. 3(a), 3(b), and 3(c)). In the present study, thematic maps of Mg^{++} of the study area showed that 67% of pre-monsoon

and 74% of post-monsoon seasons groundwater samples have magnesium concentration below 30 mg.L^{-1} . 19% of the groundwater samples have magnesium content above 50 mg.L^{-1} in both seasons. The remaining samples were in the range of 30 mg.L^{-1} to 50 mg.L^{-1} . This study revealed that during both seasons almost all the groundwater samples were within the permissible level and suitable for drinking purposes owing to low magnesium content. Mg^{++} content in the assessed groundwater samples (Fig. 4(c)) ranged from a minimum of 12.6 mg.L^{-1} in HW-17 (Ramasagara (Sugandi Renukamma House) to a maximum of 153 mg.L^{-1} in HW-27 (Byluvaddigere near Kakubaal) during post-monsoon season. In the monsoon period in Fig. 4(b), magnesium content ranged from a minimum of 7.0 mg.L^{-1} in HW-2 (Hosuru Near Railway gate) and a maximum of 68 mg.L^{-1} in HW-41 (M.M.Halli near Anjinappa home). In the pre-monsoon season (Fig. 4(a)), magnesium content ranged from a minimum of 11.4 mg.L^{-1} in HW-48 (Chilakanahatti near Thimmalapura) and a maximum of 78 mg.L^{-1} in HW-27 (Byluvaddigere near Kakubaal).

The spatial values in the map of the study area revealed that 1% of the groundwater samples in the pre-monsoon peri-

od and 6% of the groundwater samples in the post-monsoon period have SO_4^{2-} content less than 50 mg.L⁻¹. 87% of the groundwater samples in the pre-monsoon period and 81% of the groundwater samples in the post-monsoon period have sulfate content in the range of 50-100 mg.L⁻¹. 12% of the groundwater samples in the pre-monsoon period and 13% of the groundwater samples in the post-monsoon season have SO_4^{2-} content more than 100 mg.L⁻¹. Swarna Latha (2010) also found the same trend of SO_4^{2-} concentration in her studies.

In the present study, the SO_4^{2-} concentration varied between a minimum of 10.9 mg.L⁻¹ in HW-40 (Danapura near Iyyanahalli) to a maximum of 82 mg.L⁻¹ in HW-10 (Bukkasagara (76 Venkatapura Main road near Hanuman Temple) during the post-monsoon season (Fig. 5(c)). In the monsoon season (Fig. 5(b)), the SO_4^{2-} content in the groundwater samples ranged from a minimum of 9.3 mg.L⁻¹ in HW-40 (Danapura near Iyyanahalli) and a maximum of 84 mg.L⁻¹ in HW-10 (Bukkasagara (76 Venkatapura Main road near Hanuman Temple). In the post-monsoon period (Fig. 5(a)), the SO_4^{2-} content in the groundwater samples ranged

from a minimum of 8.9 mg.L⁻¹ in HW-40 (Danapura near Iyyanahalli) and a maximum of 83 mg.L⁻¹ in HW-10 (Bukkasagara (76 Venkatapura Main road near Hanuman Temple).

Agricultural Indices that were adopted in the present study are SH, MC, Na⁺, SAR, RSC and PI, Gibbs class I and II (anion and cation) ratio, which are relevant variables for assessing the suitability of groundwater for agricultural purposes. The irrigation indicators are adopted to categorize ground-water quality into excellent to unfit. Equations for the various hazards are adapted from Asante-Annor et al. (2018).

A salinity hazard is a major constituent of irrigation water quality that reflects crop growth and yields. The SAR values using the USSS diagram show that all the samples have less SAR value. Out of 50 samples, 03, 04, and 03 samples come under the C1-S1 category; 33, 35, and 25 samples come under the C2-S1 category in pre-monsoon, monsoon, and post-monsoon periods. Correspondingly 08, 06, and 04 samples come under the C1-S2 category; and 05, 06, and 12 samples come under the C2-S2 category (Fig. 3). The C3-S1 group in the USSS diagram (Fig. 6) is considered as a moderate water category for irrigation. These imply that

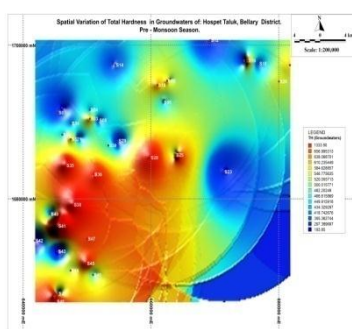


Fig. 2(a):

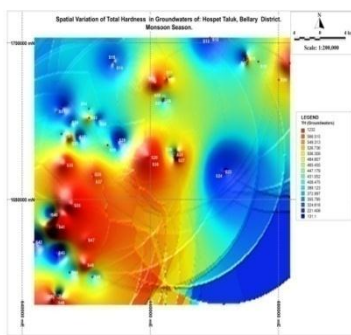


Fig. 2(a):

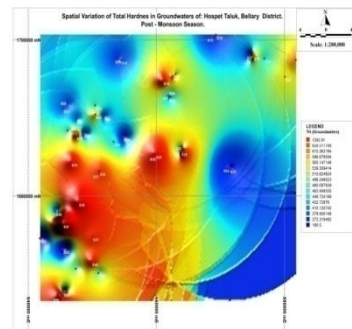


Fig. 2(a):

Average of three seasons level of TH (mg/L) at selected areas of Hospet Taluk.

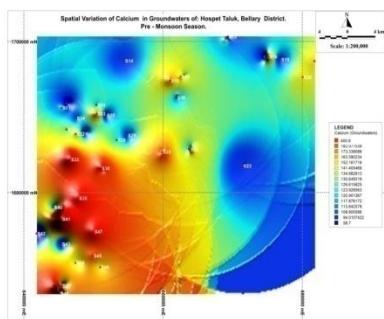


Fig. 3(a):

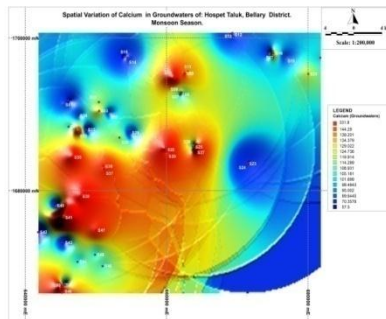


Fig. 3(a):

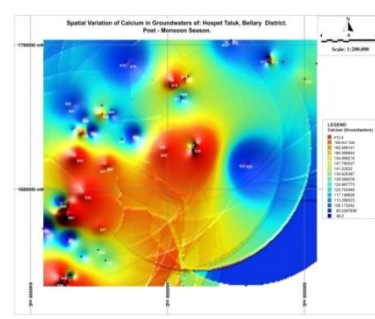


Fig. 3(a):

Average three seasons level of Ca++ (mg.L-1) at selected areas of Hospet Taluk.

no alkali hazard to the crops is expected. 41 Location (82%) samples come under the C3-S1 category and this category is fit for irrigational needs.

In the pre-monsoon and post-monsoon seasons, only 01 and 03 samples had the highest SAR. Irrigation water affects permeability on shrinking types in clay-type soils if the SAR is >6 to 9 (Karuppannan & Kawo 2018). Overall in the entire study period, SAR value percentage comes under C2-S1 during pre-monsoon (60%), monsoon (70%), and post-monsoon (50%) periods respectively. The source of salt in water can be introduced to the water either manually or by natural processes such as the weathering of rocks when the water permeates through them. EC or TDS are commonly used to calculate SH hazards. When the EC is increased, the amount of water available to the crops is reduced, leading to a deficit and low crop yield.

Sodium adsorption ratio (SAR) is a measure of the amount of sodium (Na^+) relative to calcium (Ca^{++}) and magnesium (Mg^{++}) in the water extract from saturated soil paste (Kesari et al. 2016). It gives the sodicity of the soil through quantitative chemical assessment of water in contact with it.

According to Richards (1954), categorization of SAR values is: < 10 (Low sodium in water, little danger), 10 to 18 (affects the texture of the soil as the soil is sensitive to Na^+), 18 to 26 (maximum Na^+ ; affects the entire soil), and > 26 (unsatisfactory and high sodium). As per the classification, SAR values in the study area varied from 4.86 meq.L^{-1} in HW-41 (M.M.Halli near Anjinappa home) to 48.82 meq.L^{-1} in HW-34 (Hosapete near Chittavadigeppa temple) during the post-monsoon period, and in the monsoon period, SAR values varied between 4.07 meq.L^{-1} in HW-41 (M.M.Halli near Anjinappa home) to 17.82 meq.L^{-1} in HW-2 (Hosuru Near Railway gate). During pre-monsoon season SAR values varied from 0.64 meq.L^{-1} in HW-35 (Kallahalli near Vysyanakeri Station) to 8.82 meq.L^{-1} in HW-05 (Kamalapura Opp to Vet. Hospital). SAR values of three periods were shown in decreasing order: pre-monsoon (48.82 meq.L^{-1}) > monsoon (17.82 meq.L^{-1}) > post-monsoon season (8.82 meq.L^{-1}). Seasonal distribution of values of groundwater samples predicts a relatively low minimum value of SAR in the post-monsoon period, and hence, the samples can be used for irrigation on almost any soil type and have only a slight risk of sodium permeating in the soil (Bozdog 2015 & Shammi et al. 2016).

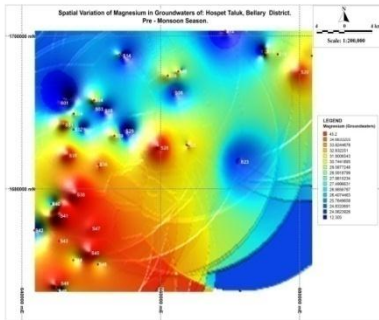


Fig. 4(a):

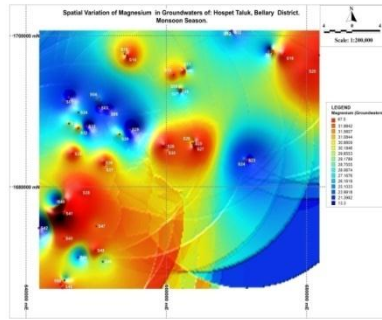


Fig. 4(a):

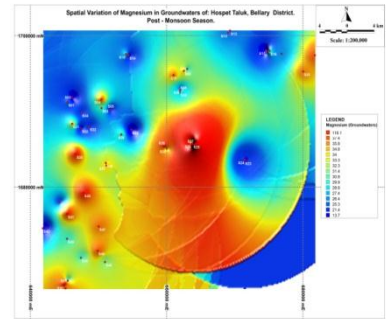


Fig. 4(a):

Average three seasons level of Mg^{++} (mg/L) at Selected Areas of Hospet Taluk.

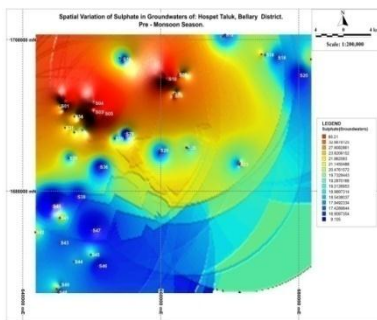


Fig. 5(a):

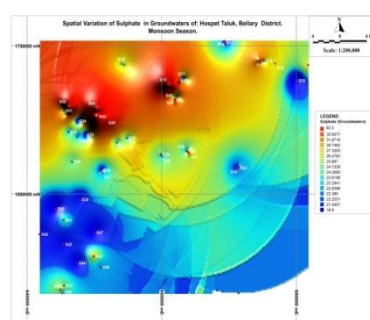


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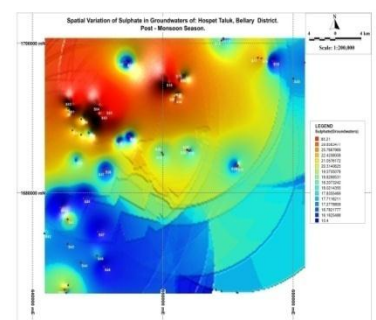


Fig. 5(a):

Average three season level of SO_4^{2-} (mg/L) at Selected Areas of Hospet Taluk.

According to SAR, the samples from the study area were classified as having a medium level of risk of sodium in the soil. If the SAR values are more than 10 and 26, the irrigation water permeability reduces in clayey soil, causing plant and soil degradation (Bozdag et al. 2015). The higher the SAR values in the water, the higher the sodium (Vasanthavigar et al. 2016).

Seasonal observation during the post-monsoon period shows that 18% of the groundwater samples fall under the good category, and 82% of groundwater samples fall under the excellent category. In the pre-monsoon period, all the samples fall under the excellent category. During the monsoon season, 8% of the groundwater samples fall under the good category, 92% of the groundwater samples fall under the excellent category. However, none of the groundwater samples are within the permissible, doubtful, and unsuitable categories. This may be because of agricultural activities. Based on Na% (Table 2 and 3), all the groundwater samples < 20 falls under the excellent to good Class-I irrigation

water. Table 3 shows the suitability of irrigation water based on Na⁺%.

Excess of Mg⁺⁺ in the soil effects easily the crop yield. In three periods Mg⁺⁺ value is more than the permissible limit except for one location. In the pre-monsoon period, the groundwater samples have a minimum value of 14.71 meq.L⁻¹ in HW-50 (Chilakanahatti near AjathaNagalinga Mata) and a maximum value of 40.25 meq.L⁻¹ in HW-48 (Chilakanahatti near Thimmalapura). During the monsoon season, the groundwater samples have a maximum value of 41.30 meq.L⁻¹ in HW-43 (D.N.Keri, Devalapura near Shayari Durugamma Temple) and a minimum value of 14.67 meq.L⁻¹ in HW-50 (Chilakanahatti near AjathaNagalinga Mata), and in the post-monsoon period, the groundwater samples have a maximum value of 43.41 meq.L⁻¹ in HW-43 (D.N.Keri, Devalapura near Shayari Durugamma Temple) and a minimum value of 16.60 meq.L⁻¹ in HW-50 (Chilakanahatti near AjathaNagalinga Mata). The spatial allocation of MH in groundwater shows that almost all the samples are within the

Table 2: SAR values for the selected groundwater samples in Hospet Taluk during three seasons.

	HW-1	HW-2	HW-3	HW-4	HW-5	HW-6	HW-7	HW-8	HW-9	H W - 10	HW-11	H W - 12	HW-13
Pre	2.396	1.821	6.399	1.491	8.820	1.453	7.155	7.177	5.103	5.195	6.772	4.918	4.691
Monsoon	12.612	17.179	5.495	5.952	6.406	12.200	15.897	8.560	7.012	6.151	8.905	15.517	7.171
Post	12.996	16.393	5.909	6.164	6.669	12.539	15.781	9.076	6.963	6.007	9.488	15.868	7.607
	HW-14	H W - 15	HW-16	HW-17	H W - 18	HW-19	HW-20	HW-21	HW-22	H W - 23	HW-24	H W - 25	HW-26
Pre	5.897	2.267	1.425	1.854	1.089	1.335	3.160	1.985	2.130	2.357	4.365	6.985	6.250
Monsoon	8.627	9.721	8.640	11.185	9.797	7.163	6.584	8.052	8.974	9.828	11.321	11.785	9.173
Post	9.104	9.889	8.605	13.140	9.501	7.387	7.077	8.178	8.814	10.449	12.421	12.452	9.482
	HW-27	H W - 28	HW-29	HW-30	H W - 31	HW-32	HW-33	HW-34	HW-35	H W - 36	HW-37	H W - 38	HW-39
Pre	4.328	1.729	1.799	1.469	1.058	0.806	1.747	1.942	0.644	1.138	1.350	0.801	1.663
Monsoon	8.547	7.010	9.332	5.081	6.687	5.950	7.205	11.328	9.090	6.511	6.929	12.100	8.851
Post	5.102	6.863	9.758	5.681	7.912	6.029	8.172	18.823	6.207	7.039	6.928	12.656	8.773
	H W - 40	HW-41	HW-42	H W - 43	HW-44	HW-45	HW-46	HW-47	H W - 48	HW-49	H W - 50		
Pre	4.838	2.559	8.042	5.634	3.711	1.296	3.086	4.057	1.013	0.940	4.838		
Monsoon	8.783	4.074	8.162	7.381	8.263	5.430	5.017	4.882	5.531	6.471	8.783		
Post	9.907	4.156	9.294	9.005	8.330	5.520	5.668	5.407	5.363	8.178	5.115		

Table 3: Suitability of irrigation water based on Na %.

Parameters	Range	Classifica- tion	Number of Samples		
			Pre-Monsoon	Monsoon	Post- Monsoon
%Na ⁺ Wil- cox 1955	< 20	Excellent	All most all the groundwater loca- tions	HW-1, HW-3, HW-10, HW-11, HW-13, HW-14, HW-15, HW-16, HW-18, HW-19, HW-20, HW-21, HW-22, HW-23, HW-24, HW-25, HW-26, HW-27, HW-28, HW-29, HW-30, HW-31, HW-32, HW-33, HW-34, HW-35, HW-36, HW-37, HW-38, HW-39, HW-40, HW-41, HW-42, HW-43, HW-44, HW-45, HW-46, HW-47, HW-48, HW-49, HW-50	HW-3, HW-4, HW-5, HW-6, HW-8, HW-9, HW-10, HW-11, HW-13, HW-14, HW-15, HW-16, HW-18, HW-19, HW-20, HW-21, HW-22, HW-23, HW-26, HW-27, HW-28, HW-29, HW-30, HW-31, HW-32, HW-33, HW-35, HW-36, HW-37, HW-38, HW-39, HW-40, HW-41, HW-43, HW-44, HW-45, HW-46, HW-47, HW-48, HW-49, HW-50
	20 – 40	Good	-	HW-2, HW-7, HW-12, HW-17	HW-1, HW-2, HW-7, HW-12, HW-17, HW-24, HW-25, HW-34, HW-42
	40 – 60	Permissible	-	-	-
	60 – 80	Doubtful	-	-	-
	> 80	Unsuitable	-	-	-

range of 50 meq.L⁻¹ and are fit for irrigation. The maximum magnesium ratio value of the observed samples is 43.41 meq.L⁻¹ in HW-43 at D.N.Keri, Devalapura near Shayari Durugamma Temple) on magnesium ratio.

The MH values of the study area range from 14.67 at HW-50 (Chilakanahatti near Ajatha Nagalinga Mata) to 43.41 meq.L⁻¹ at HW-43 (D.N.Keri, Devalapura near Shayari

Durugamma Temple) with a mean value of 32.06). Almost all the groundwater samples (100%) are within magnesium hazard of 50 which are considered beneficial and fit for irrigation use. In the present work, Gibbs ratio I (Anion) values in the pre-monsoon period vary from 0.05 to 0.40, in the monsoon period varies from 0.05 to 0.42, and in the post-monsoon period varies from 0.06 to 0.42. Gibbs ratio

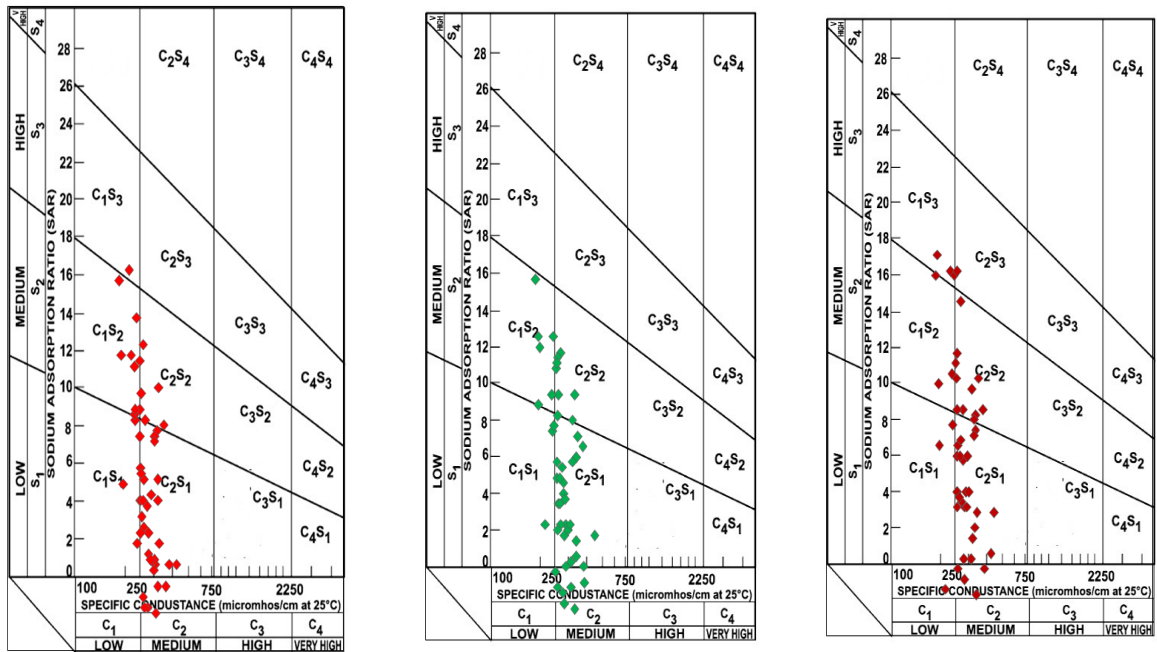


Fig. 6: SH classification of the groundwater locations according to the USSL diagram for pre- and post-monsoon and monsoon seasons.

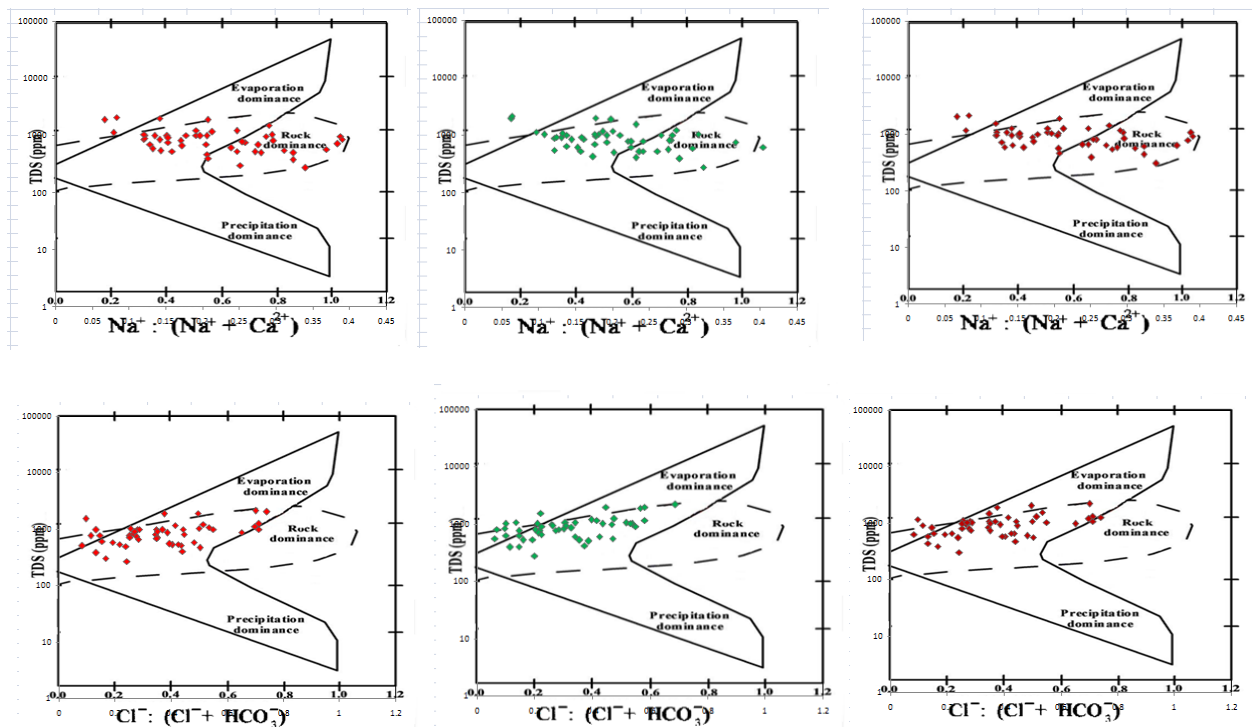


Fig. 7: Seasonal variations in mechanism controlling the quality of groundwater.

II (Cation) values vary from 0.12 to 0.78, 0.11 to 0.72, and 0.21 to 0.81 during three seasons respectively. According to Fig. 7, the samples in the study area fall into the rock dominance area, indicating rocks in the groundwater in the aquifers. This affects the hydrochemistry of groundwater in alluvial plains and rock–water contact (Wu et al. 2015).

CONCLUSION

Most of the selected locations had TH content within the permissible limit. The results showed the order of $\text{Cl}^- > \text{SO}_4^{2-} > \text{HCO}_3^-$ with water types Na-Cl^- and Cl^- , and the order of $\text{Na}^+ > \text{Mg}^{++} > \text{Ca}^{++} > \text{K}^+$ with Na^+ and Mg^{++} as the dominant anions and cations, correspondingly. As per the Wilcox diagram no-alkali exposure to the crops is expected. Forty one samples (82%) fit within the C3–S1 group; this category is fit for irrigational needs. Only 01 and 03 samples showed maximum SAR during two seasons like pre-monsoon and post-monsoon periods. The GIS maps of the respective variables indicated that groundwater are usually of higher quality, whereas the presence of dolomite indicates a reduction in water quality.

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