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Appraisal of Ground Water Quality of Hospet Taluk, Karnataka, India – Cation, anion and Multivariate Techniques

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Abstract
The present work is to assess the contamination using hydro-chemistry by adopting multivariate statistical techniques. The water quality data collected during Sept 2019- Aug 2020 from twenty five sampling locations distributed in and around the Hospet Taluk. Total dissolved solid indicates deviation from 355 mg/L to 918 mg/L with maximum values noticed, as EC, in the selected ground water samples. The relative richness of cations in ground-water during the study period is Ca^{++}>Mg^{++}>Na^{+}>K^{+}. Maximum sulphate content is captured in the selected ground water samples with values exceeding the permissible limit of WHO. Sulphate is suspected of devising an anthropogenic source. The relative richness of anions in and around ground water samples of Hospet Taluk is in the following order: HCO_3^-> $SO^{-2}{}_4{}^{--}$> Cl^-> NO_3^-. Author recommended the appraisal and monitoring the water quality during repair of pipes particularly in the area which is limit un-wanted infiltration. Authors also recommend for management of anthropogenic activities in and around the Hospet Taluk. USSL graphs predicts most of the ground water samples falls in C2-S1 class, which representing its suitable condition for drinking and irrigation needs. Piper trilinear graph confirms that the bore-wells were categorized as secondary alkalinity during the study period.

Keywords: Cation, Anion, Piper trileaner diagram, USSL diagram

Introduction

Groundwater is the most useful water resources around the world. Less than 1.9% of world water is deposited inside the rocks as mineral constitutive in the form of groundwater. Urbanization is a collective demand for water of tolerable quality, complemented by the refusal of large consistent volumes of waste-water [14]. The major task is to safeguard urban ground-water resources, it means that is remains obtainable to the future people. The total of ground-water using yearly is around at about 21% of global water usage [30]. Irrigated irrigation is accountable for 92.5% of the total water claim in all most all the irrigation practicing cities. Irrigated agriculture is the principal driver for confirming food security and economic development of rural and urban areas. Yet, the irrigated agriculture in Hospet Taluk is also stated to have negative influences on ground-water quality for occasion observed maximum nitrate content of groundwater in the Hospet taluk region and described this content by an increasing agricultural practices.

Due to disturbance of unscientific human activity, the water is still a distance dream form any people. Hence, present need to create awareness among the community of our country about the importance of water for present and future [19]. Groundwater is the second purest water on the earth, which is used for daily needs and industrial water supply and irrigation all over the world. Currently, the multivariate statistical method converts general for a better water quality and biological prominence; due to treat more quantity of data from diversity in selected locations. In the scientific works, various statistical tools, contains a CA, FA and PCA are used to analyze and understand the quality of ground water [17], [21] and [25]. In view of the work conducted, it proves that water quality appraisal in Karnataka particularly in Bellary district is insufficient. Hence, the current work has been identified to appraise the water quality of Hospet taluk in Karnataka.

Materials and Methods
Study Area
Hospet taluk is the major city of Ballary district. It lies amongst 14^0 58 to 15^0 25' latitude and 76^0 18` $76^0$ 27` longitude. It covers an area 933.9 sq km. The Taluk has population 3,99,516 as per 2011 census. The average yearly rain fall of the study region is 593.9 mm. The average yearly temperature ranges between 27^0C to 40^0C. The study area is enclosed by grano-diorite, granite and meta-basalt. The major part of the city consists of grano-diorite and granite related with iron and manganese ore groups. The rock formations are combined and are crossed by doleritic Dykes. Enduring in hard rocks is restricted to 5.5 meters from lower level, where as in schist and phyllite spreads upto 22 meters. Secondary weathered zone, joints hard fresh rock, gives place for ground-water storage.

Experimental Work
The work gives a detailed account of the hydro-chemical variables of groundwater. Twenty five typical samples collected during Sept 2019- Aug 2020 and analyzed for Ca^{++}, Mg^{++}, Na^+, K^+, Cl^-, bicarbonate, SO^{-2}_4, NO^-_3 and TDS, pH, and electrical conductance (EC). Further the sodium adsorption ratio (SAR), %Na and RSC were tabulated. The tools and methods adopted for sampling, preservation and appraisal including interpretation is adopted [4], [7] & [11]. The chemical quality values are given in Table-1. Various methods used are given in tables.

Result and Discussion
The summary of the range, average, standard deviation of used variables in the selected at 25 ground water locations for the one year 2019-2020, and the WHO quality standards [30] are given in Tables 1, 2, respectively. Pearson's correlation coefficient (r) predicts an idea and possible relations between physico-chemical variables. The value of r value ($p < 0.01$) for two variables at selected 25 sampling locations is given in Table 3. Standard deviation gives the data is broadly spread, due to the occurrence of temporal dissimilarity triggered likely by natural and manmade polluting agents.

Maximum (above 1000 µS/cm) EC was observed in HSW-10, HSW-11, HSW-13, HSW-14, HSW-15, HSW-17 and HSW-18 locations of Hospet Taluk, and ranged between 490 and 1260 µS/cm (Table 1). It's due to considerable amount of salts dissolved in during rainy season through soil filtration. The average EC values were 827.2 µS/cm during the study period. All the selected ground water samples had EC less than the value mentioned by the WHO [30].

The major cause of Mg^{++} in ground-water is may be due to ion interchange of minerals in rocks and soils through water flow. The results of the analysis predict the Ca^{++} and Mg^{++} values range from 72.0 to 284 mg/L and 20 to 85.4 mg/L (Table1). This indicates that the values not exceeded the desirable limits set by WHO [30] standards except the locations HSW-8, HSW-13, HSW-15, HSW-17, HSW-20, HSW-22 and HSW-23, but No one sample values of magnesium not exceeded. The results indicates that the sodium and potassium range from 2.7 to 67 mg/L and 1.0 to 10.5 mg/L not exceeded the desirable limits set by WHO [30] standards.

Chloride content shown lower than the permissible value of 250 mg/L in all most all sampling sites. An additional of chloride in water is frequently used as an index of pollutants and measured as tracer for ground-water contamination [18]. According to Walker, [29], Cl^- ion content in the ground-water generally rises from sources like solubility behavior of chloride, evaporation deposits and anthropogenic agents. The results of the analysis showed that the chloride values ranged from 12.30 to 108.0 mg/L. This indicates that the results are well within the permissible limits set by WHO [30] standards.

The pH of water ranged between 7.1 and 7.9. The pH signifies the strength of acidity or alkalinity, measures the content of hydrogen in water. The interval values of pH suggested by the WHO are 6.5 to 8.5. pH of analyzed ground water was in all the cases medium level recommended by the WHO [30], which predicts the slightly neutral character of selected ground water samples. pH may be accredited to the acidic lateritic and moisture lithosphere of the area [20], [24]. However, the current study usually agrees with those described [15] of Ghana and [4] in Nyamebekyere.

The content of bicarbonate ranged between 254 and 468 mg/L. Bicarbonate is accountable for the alkalinity of ground-water. The bicarbonates are possibly achieved from weathering of silicate, dissolution of carbonate precipitate, atmospheric and soil CO_2 gas [13] & [16].

The sulphate contents ranged from 65.0 mg/L to 801 mg/L, with mean value of 321 mg/L. The sulphate content in selected ground water samples is within the allowable limit of 250 mg/L of WHO [30], except in HSW-7, HSW-8. HSW-13, HSW-14, HSW-16, HSW-17, HSW-18, HSW-20, HSW-22, HSW-23, HSW-24 and HSW-25. Maximum content of sulphate in groundwater may be accredited to contamination of un-treated industrial and domestic wastes [6], [12].

Nitrate content in selected ground water samples exceeds the drinking water standards suggested by the WHO [30]. Observed values place between 6.5 and 41.20 mg/L. This is in agreement with the work done [26] analyzed the nitrate quality of the aquifer in the central part of Morocco, observed nitrite contents limits. Nitrites occur as an inter-mediate product converts ammonia to nitrate also in the nitrification process [8].

The net growth in conductivity level at station HSW-10, HSW-11, HSW-13, HSW-14, HSW-15, HSW-17 and HSW-18, may be due to irrigation and domestic human activity at these locations. According the WHO values [30], measurements also showed that the major sampling locations ranked as moderate to slightly contaminated class in terms of water quality. EC displayed significant positively associated with SO^{-2}_4, NO_3 and Bicarbonates. In the present most of the ground water samples are showing low EC, Thus, a lower value of EC specifies the occurrence of a low content of dissolved ions, such as in-organic salt and organic matter in water [30] and [22]. Results were found to be similar with work [3] Nyamebekyere. The levels were lower than work conducted [1], Brong-Ahafo Region, Ghana. According to Todd [27], water in TDS classification, all the groundwater samples falls under the very fresh water class, current study also agreement with the researchers. Water hardness is chiefly caused by the presence of cations such as Ca^{++} and Mg^{++}; and of anions such as bicarbonate, Cl^-, and SO^{-2}_4 in the water [23].

Principal component (PC)
Principal components analysis (PCA) was useful for data,

to appraise the continuity and overlap of clusters including similarities in the data and adopted to determine the sources of difference between variables [9]. FA relates to PCA in water quality appraisal works, where various variables are analyzed for specifically causes to change in the water quality [10], [24] & [30]. Results of factor analysis including factor-loading matrix, total, cumulative difference and societies values are presented in Table 4. From the PCA, eight factors were extracted that identified for 86 % of the total variance. The factors are suggest that EC, TDS, Na^+ and K^+ variable component communalities for PC1, describes 38.63%, TDS 0.915, -0.188, 0.078, -0.060, -0.141, -0.207, -0.042 and 0.045, EC 0.877, -0.263, 0.117, -0.033, -0.148, -0.221, -0.046 and 0.105, Na^+ 0.680, 0.540, -0.254, 0.036, -0.149, -0.081, 0.108 and 0.158, K^+ 0.525, 0.260, -0.182, 0.071, -0.180, 0.345, -0.192 and 0.279, have maximum positive factor loadings in factor 1 and this may be attributed to enduring and leaching of main rocks.

For Factor PC2, describes 16.70% of the total variance Ca 0.415, 0.738, -0.189, 0.364, -0.086, 0.00, 0.072, -0.016, Na 0.680, 0.540, -0.254, 0.036, -0.149, -0.081, 0.108 and 0.158, SO4 0.115, 0.697, -0.259, 0.616, -0.026, 0.062, 0.030 and -0.085, have high positive loading for Ca^{++}, Na^+ and SO_4^-.hence this factors and reflecting and influencing the anthropogenic activity. pH, and Bicarbonates have a high positive factor loading in factor 7 and Factor 3 respectively, whereas SO_4^- has maximum positive loading factor 4. Sulphate is thought to be unconfined from the percolating of upper agricultural soil layer which flow water and other chemicals from agricultural activity.

Correlation among parameters

The chemical structure of groundwater is characterized by major cations and anions. The relationship of the physico-chemical variables is given in Table 1. From the association matrix, most of the variables were found to bear statistically important correlation with each other representing close relation with these variables with each other.

The high content of $SO^{-2}_4$is reported for the dissolution of gypsum ($CaSO_4$), But in some samples (HSW-7, HSW-8. HSW-13, HSW-14, HSW-16, HSW-17, HSW-18, HSW-20, HSW-22, HSW-23, HSW-24 and HSW-25) predicted the content of Sulphate is more than 500 mg/L which is reported possibly due to release of domestic seepage from non-point sources directly into a composite system of natural and manmade hollows. Groundwater pollution in urban areas is may be to leakage sewage, septic tanks, soiled land, infiltration, land-fills and fertilizers used in parks [28]. In Hospet taluk, there are several ground water well residents directly from the domestic sewage. This leads to direct infilteration of pollutants to reach quickly to saturated zone. The diagram in Figure 6 represents the attendance of a positive association with the ions (HCO_3^-, Na^+, K^+, Cl^- NO_3^- and the TDS, representing the contribution of these ions in the attainment of the total dissolved load.

According to a method formulated by the US Salinity Laboratory, when the Na^+ hazards ratio and EC of water are identified, the classification of water for irrigation is suitable by plotting these results on the graph. In the present study, according to USSL classification (Figure 4), 25 ground water samples are falls into C2S1 (medium salinity with low sodium). Hence all the ground water samples can be used for irrigation and drinking needs.

The results of the global Moran's I diagram of eight variables of the three sessions are given in Figure 5. TDS fits to the first class with strong auto-correlation and a large maximum-maximum spatial cluster identified during the study period and the minimum -minimum spatial cluster in the border road. K shows average auto-correlation with decrease in the number of sampling locations belonging to the maximum-maximum and minimum -minimum cluster and enhancing the number of the non-significant sampling locations high-high cluster was located. The number of samples with significant auto-correlation was very less; SO_4 is the best variable to demonstrate the third class demonstrating recording the lowest more auto-correlation. In order to clarify the auto-correlation of the PC as bunched above, we use an empirical Bayes standardization submitted [5] and revised [2] for bivariate spatial correlation of PC1 and PC2.

Table 1: Hydro-chemical data of groundwater sampling sites (EC in µs/c and TDS in ppm; major elements: mg/L).

Sl.No	EC	pH	TDS	Cations				Anions				Agricultural Indicator		
				Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3	SO^{-2}_4	NO^-_3	Cl^-	%Na	SAR	RSC
HSW-1	860	7.5	490	72.1	67	2.9	1	450	65	19.5	12.3	2.03	0.35	−1.81
HSW-2	650	7.2	470	76.3	67.96	18	1.9	445	125	15.8	37.7	10.96	2.12	−2.18
HSW-3	680	7.6	490	81	69.97	22.3	2.1	395	179	23.5	45.1	12.72	2.57	−3.41
HSW-4	560	7.7	405	79.6	50.16	18.1	1.8	254	167	6.2	37.9	12.09	2.25	−4.00
HSW-5	530	7.7	385	81.8	42.75	19.2	1.9	350	89	32.2	39.7	13.18	2.43	−1.91
HSW-6	580	7.5	425	121	55.4	19.8	2	374	215	35	40.5	9.99	2.11	−4.54
HSW-7	730	7.5	526	194.2	62.5	31.5	2.5	316	502	23.1	35.4	10.84	2.78	−9.74
HSW-8	850	7.2	619	201	51.2	45.3	8.4	322	489	22	70.1	14.81	4.03	−9.04
HSW-9	970	7.7	704	161	54.1	43.1	8.5	440	181	35	90.1	16.16	4.16	−5.35
HSW-10	1110	7.2	814	153	60.1	25.4	3	446	123	41.2	67.7	10.52	2.46	−5.35
HSW-11	1260	7.1	918	157	41.5	30	4.1	401	111	25.2	70.3	12.9	3.01	−4.73
HSW-12	830	7.5	599	148.5	50.2	32	2.5	380	183	21.5	60.4	13.72	3.21	−5.38
HSW-13	1040	7.5	753	207.6	57.12	59.8	2.7	384	412	18.3	108	18.28	5.2	−8.84
HSW-14	1080	7.4	786	193.3	73.81	56	4.9	410	385	30.5	101.6	17.07	4.85	−9.09
HSW-15	1010	7.6	732	200.1	52.4	57.5	2.4	407	233	28.2	100.4	18.41	5.12	−7.70
HSW-16	810	7.7	587	195	85.4	58.5	10.5	354	654	22.5	78.2	16.74	4.94	−11.06
HSW-17	1000	7.2	728	205	62.26	54.5	3.7	457	412	35.7	97.1	16.75	4.71	−7.95
HSW-18	1080	7.4	785	190	77	54.1	2.8	402	502	29	92.1	16.7	4.68	−9.33
HSW-19	770	7.4	552	152.2	41.86	33.4	2.9	468	102	27.1	63.6	14.5	3.39	−3.43

HSW-20	810	7.3	625	268	78	67	7.5	406	801	17	54	15.93	5.09	−13.24
HSW-21	490	7.9	355	125	20	29	2.3	301	142	32	48	16.45	3.41	−2.98
HSW-22	800	7.3	576	284	74	41.5	3.5	415	769	6.2	54	10.3	3.1	−13.56
HSW-23	810	7.4	593	205	65	43	3.6	407	562	16.5	45.5	13.58	3.7	−8.99
HSW-24	790	7.4	570	166.1	37.81	47.8	3.3	421	256	21	87.8	18.74	4.73	−4.55
HSW-25	580	7.8	414	175	38	35.5	2.5	403	366	19	50.3	14.14	3.44	−5.31

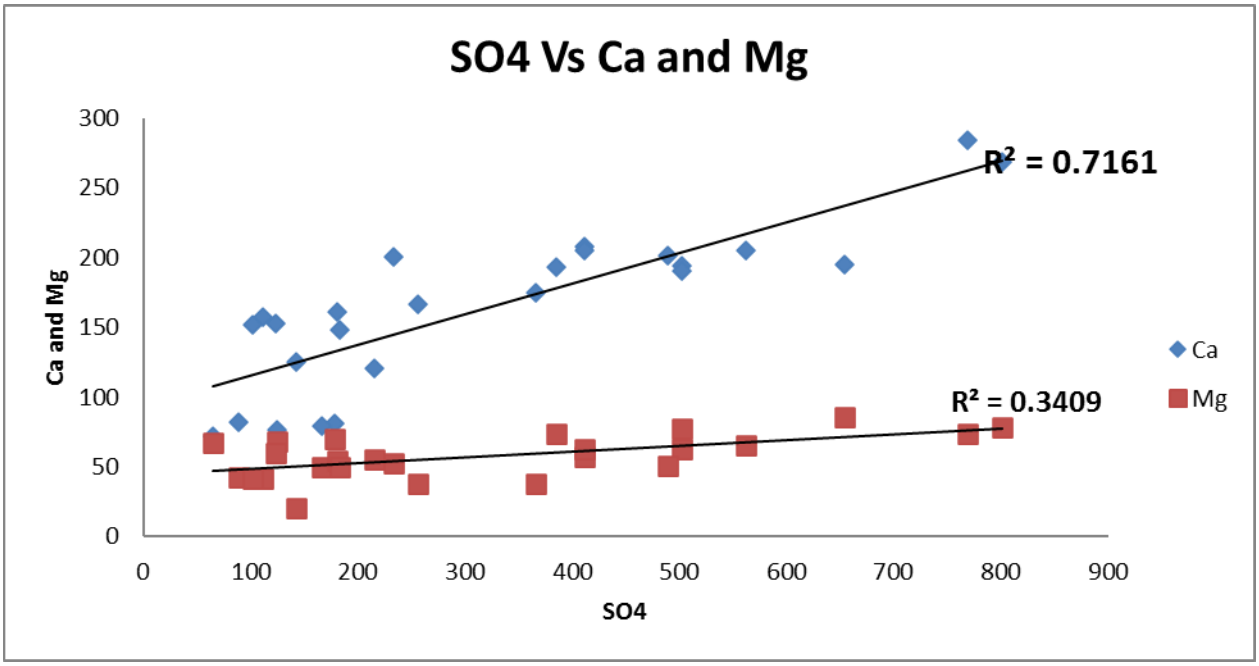

Fig 1: Scatter graphs of SO4 (mg/L) vs. Ca (mg/L) and Mg (mg/L).

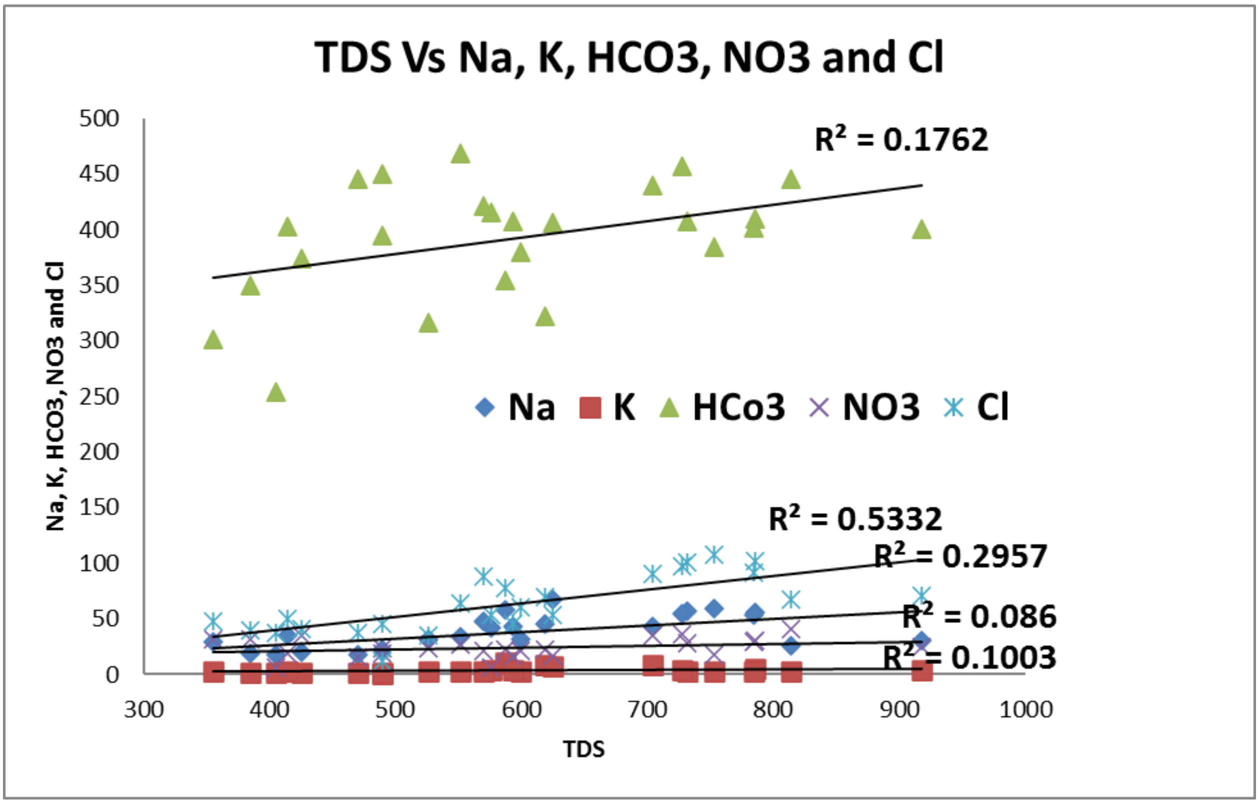

Fig 2: Scatter graphs of TDS (mg/L) vs. Na, K, HCO_3, NO_3 and Cl^- (mg/L).

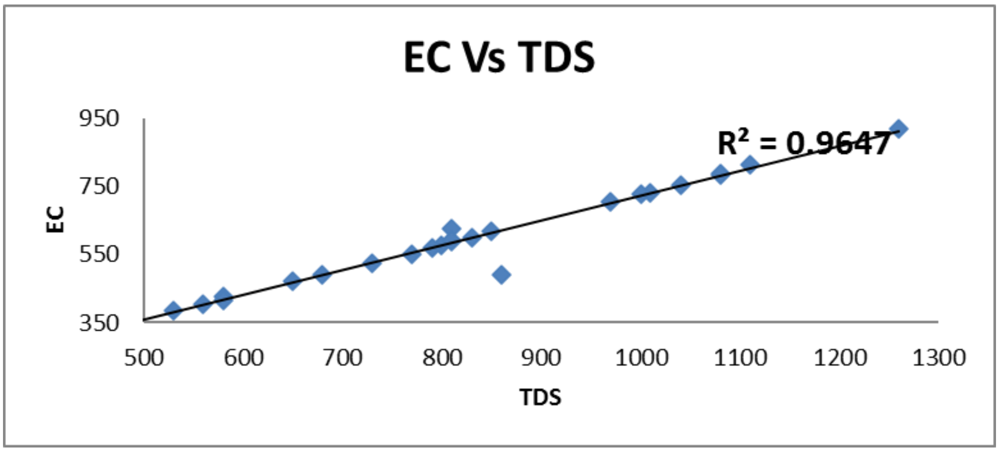

Fig 3: Scatter graphs of TDS (mg/L) vs. EC (µs/c).

Table 2: Drinking water quality standards (BIS and WHO)

Sl. No.	Parameters	BIS (1998)		WHO (1993)		ISI	
		A	E	A	E	A	E
Physical parameters							
1	pH	6.5	9.2	7.0-8.5	6.5-9.2	6.5-8.5	No Relaxation
2	Electrical conductivity	-	2000	-	-	-	-
3	Total dissolved solids	500	1000	500	1500	500	1000
Chemical parameters							
4	Ca^{2+}	75	200	75	200	75	200
5	Mg^{2+}	30	100	50	150	30	100
6	Chloride	250	1000	200	600	250	1000
7	SO^{-2}_4	200	400	200	400	150	400
8	NO^-_3	45	45	-	50-100	45	100
9	Sodium	-	-	200	-	-	200
10	Potassium	-	-	-	-	-	-
11	Bicarbonate	200	600	500	1000	-	-

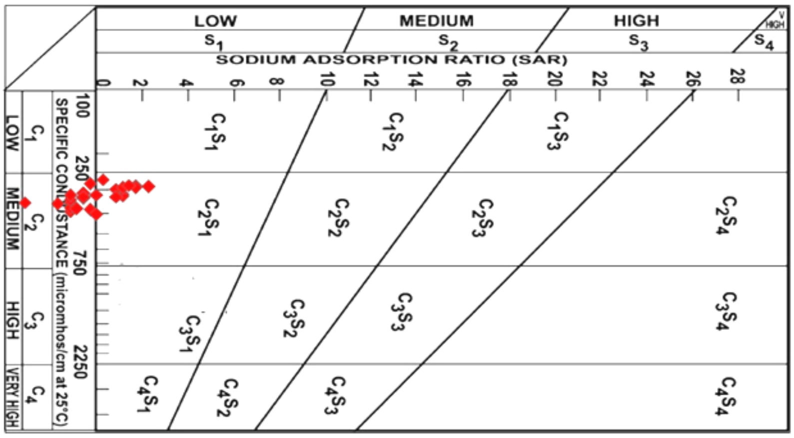

Fig 4: USSL Plot of selected ground water samples.

Table 3: Person Correlation of Hydro-chemical variables.

	EC	pH	TDS	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3	SO^{-2}_4	NO^-_3	Cl^-
EC	1										
pH	-0.5747	1									
TDS	0.9822	-0.5858	1								
Ca	0.4163	-0.3127	0.4860	1							
Mg	0.3032	-0.3228	0.2916	0.3281	1						
Na	0.4567	-0.1424	0.5437	0.8247	0.3072	1					
K	0.2611	-0.0882	0.3167	0.4882	0.3320	0.5835	1				
HCo3	0.4666	-0.4611	0.4197	0.1440	0.2423	0.1182	-0.0275	1			
SO4	0.1103	-0.1831	0.1730	0.8462	0.5839	0.6938	0.5185	-0.0833	1		
NO3	0.2762	0.0140	0.2932	-0.1425	-0.1940	0.0226	0.0565	0.2531	-0.3768	1	
Cl	0.6705	-0.1702	0.7302	0.5050	0.0716	0.7908	0.3812	0.2503	0.2027	0.3319	1

Table 4: Loadings of analytical variables (10) on principal components for the whole datasets

Variables	Principal Component Factors								Varimax Rotation Factors		Median Cluster Values		
	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**	**PC8**	**VF1**	**VF2**	**C1**	**C2**	**C3**
EC	**0.876**	−0.262	0.118	−0.034	−0.147	−0.220	−0.045	0.106	**0.821**	0.401	701.10	694.06	1047.82
pH	−0.352	0.150	−0.318	−0.156	0.162	0.280	**0.553**	0.188	−0.345	−0.124	7.53	7.50	7.41
TDS	**0.914**	−0.186	0.075	−0.059	−0.140	−0.213	−0.040	0.042	**0.801**	0.479	496.70	512.00	762.36
Ca^{2+}	0.418	**0.736**	−0.182	0.359	−0.072	0.000	0.070	−0.015	−0.186	**0.826**	131.70	221.27	172.19
Mg^{2+}	0.442	0.011	0.019	0.762	0.072	0.049	0.083	−0.156	0.321	0.318	42.29	61.21	59.52
Na^{+}	**0.680**	**0.540**	−0.254	0.036	−0.149	−0.081	0.108	0.158	0.133	**0.858**	30.16	42.85	51.56
K^{+}	**0.519**	0.218	−0.176	0.069	−0.119	0.329	−0.126	0.281	0.219	**0.548**	2.72	4.12	3.72
HCO_3	0.452	−0.242	**0.682**	−0.059	0.021	0.018	0.016	0.082	**0.521**	0.132	349.21	326.35	415.73
SO^{-2}_4	0.118	**0.689**	−0.246	**0.613**	−0.125	0.079	0.043	−0.084	−0.386	**0.579**	182.00	592.06	312.64
NO_3	0.346	−0.382	0.210	−0.438	0.130	0.049	0.286	−0.221	**0.542**	−0.018	23.16	19.19	29.32
Cl−	**0.820**	0.041	−0.111	−0.361	−0.091	−0.171	0.152	0.172	**0.581**	**0.5894**	52.75	51.91	96.10

Bold values indicate strong loadings (>0.50).

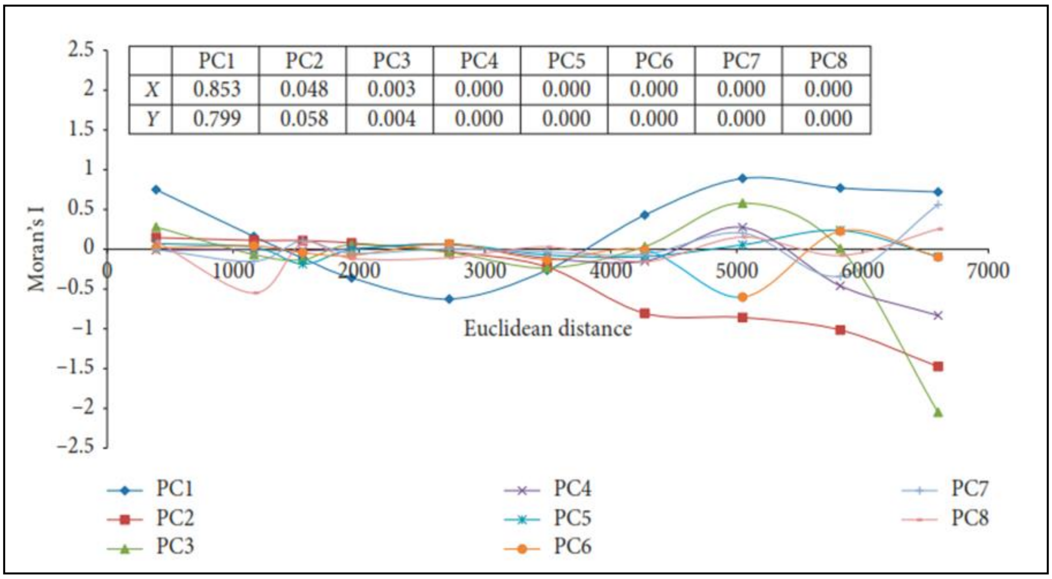

Fig 5: Spatial auto correlation of PC with correlation coefficient between components and space.

Conclusions

In this study, an effort was made to clarify variations of ground-water hydro-chemistry structure of cation and anion water-rocks communication and urban activities in and around Hospet Taluk. Summary as flows with conclusions:

- TDS shows large difference from 355 mg/L to 918 mg/L with maximum values recorded, as EC, in the study area.
- The relative richness of cations in ground-water in the study area is in the order is: Ca^{++}> Mg^{++}> Na^{+}> K^{+}
- High SO_4^- content is interrupted also in the selected ground water samples with values exceeding the permissible limit of WHO. SO_4^- ions are often assumed of having an anthropogenic source.
- The relative richness of anions in and around ground water samples of Hospet Taluk is in the following order: HCO_3^-> $SO^{-2}_4{}^{--}$> Cl^-> NO_3^-
- The first two factors PC1 and PC2 explained about the total increasing variance, responsible for 38.63% and 16.70% of the variance respectively. The factor PC1 is typically correlated with EC, TDS, sodium and potassium.
- By applying spatial auto-correlation, we conclude that ground-water variables diverse another way allowing to the direction.

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