Physico-Chemical Characterization of the Groundwater of Kotur Area Hyderabad, India

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Abstract
Significant increase in industries has been observed in Kotur industrial area. Improper disposal of industrial waste in the area has resulted in water quality deterioration. Water samples were collected from various locations within the area and analysed for physiochemical parameters using standard methods (APHA) and inductively coupled plasma–mass spectrometer (ICP-MS) respectively. High level of electrical conductivity, total dissolved solid, total hardness, calcium, sodium, chloride and magnesium were observed with relationships suggesting surface input. The concentrations of the cations range from 35 to 309mg/l for Ca, 13 to 106mg/l for Mg, 20 to 311 mg/l for Na and 2 to 8 mg/l for K. 87.5 % of the cations are in the order Ca > Na > Mg > K and Na > Ca > Mg > K respectively. The anions in the order Cl > HCO_3 > SO_4 > NO_3 were also observed. The high concentration of the physiochemical parameters reveal surface contamination originating from anthropogenic sources.
Keywords: Groundwater quality, physiochemical parameters, industrial waste, industrial area, contamination.

1. Introduction
Industrialization and unprecedented population increase have resulted in the generation of large volume of wastes that are poorly disposed and managed. The impact of indiscriminate waste disposal on the environment has raised concern in recent times. Improper disposal of chemicals from agricultural, industries, and mining activities have negative implications on aquatic life and water quality.

The main sources of water pollution include chemical fertilizers, pesticides, untreated sewage and industrial effluents into rivers, streams and groundwater (Shaik et al. 2012).

Past studies based on the monitoring and evaluation of groundwater sources for drinking and agricultural purposes (Al-Bassam & Al-Rumikhani 2003; Al-Futaisi et al. 2007; Elango et al. 2003; Jeevanandam et al. 2006; Pritchard et al. 2008; Subramani et al. 2005; Sujatha and Rajeshwara 2003, Ma et al. 2009) revealed the importance of groundwater quality assessment in order to protect the highly vulnerable resources. Factors such as lithology, groundwater flow, nature of geochemical reactions, residence time, solubility of salts, and human activities affects the concentrations of dissolved ions in groundwater (Bhatt & Saklani 1996; Karanth 1987; Nisi et al. 2008; Schot & Van der Wal 1992).

Standards are in place for the maximum desirable and permissible limits of most physiochemical parameters in both surface and groundwater resources for effective management of water quality. The physiochemical parameters such as pH, TDS and nitrate are important in determining the usage of water for a particular purpose. While water of low pH is acidic and unsuitable for drinking, high TDS in water renders it unfit for both drinking and agricultural purposes. The result of the present study indicates that the surface and groundwater resources of the area are affected by surface contaminants.

The objective of the study is to determine the relationships between water quality parameters and sources of contamination in Kotur industrial area. For this purpose, samples were collected from different locations chosen according to their proximity to industrial and agricultural activities. The samples were analyzed for components such as chloride, nitrate, potassium, sodium, magnesium, calcium, pH, TDS, Total hardness, TOC, and electrical conductivity (EC)

2. The study area
Kotur industrial area lacks appropriate solid waste disposal system therefore, evaluation of the water quality was essential. Irrigation farming for the production of tomatoes, pepper, ladies finger, corn, cotton etc abounds and requires sufficient water supply. The number of industries springing up within the area is on the increase and not without implication on available resources of fertile soil, surface water and groundwater of the area.

The area lies within Latitude $17^0$05'N to $17^0$10'N and Longitude $78^0$15'E to $78^0$20'E in the southern part of Hyderabad, India along the Banglore express way. The area is significant in abundant natural resources, fertile land for agriculture and hence location of an industrial area. It is characterized by an undulating topography with an elevation of 540 to 610m above msl. The industrial complex is rapidly expanding with attendant increase in population. The various industries located in the area include pharmaceutical and chemical factories, paper mills, oil, textiles, paints, battery, smelting factories etc. Due to the absence of waste disposal/management facilities, the solid wastes from these industries are indiscriminately disposed into the environment with consequent effect on available water supply sources. The geology of the area consist of granite (Archean) that are hard-massive to foliated and well- jointed, characterized by pink and grey colours. The groundwater occurs at a depth of about 30m in the soil of the weathered and decomposed granite and fractured bedrocks. The groundwater resources of the area are also significant for irrigation farming for food crops.

3.0 Materials and Methods

The groundwater samples were collected in February 2011 using 1 litre plastic bottles and labeled to avoid misidentification. Prior to sample collection, the wells were allowed to flow for 5 to 10min to remove stagnant water from the pipe and avoid contamination and also to ensure that the sample collected is the in-situ representative of the groundwater quality in the area. The containers were rinsed with the sample to be collected three to four times before collection to avoid the influence of external contamination. Fig.1 also shows the distribution of sample locations. 14 groundwater and 2 surface water samples were collected for the purpose of this study. The analysis for pH, EC, TDS, TOC, TH, Cl^-, HCO_3^{2-} NO_3^- and SO_4^{2-} was carried out in Environmental Geochemistry Laboratory of NGRI, India following standard methods (APHA, 1995). The pH and the EC were obtained using pH meter and conductivity meters respectively. The NO_3^- and SO_4^{2-} were analysed using the UV-VIS. Cl^- and HCO_3^{2-}were determined by volumetric method by titrating the water samples against standardized $AgNo_3$ and HCl respectively while TH was analysed by EDTA titration. The total organic carbon (TOC) present in the water samples were determined using Elementar vario TOC cube. $Ca^{2+,}$ Mg^{2+}, Na^+, and K^+ were obtained using ICP-MS and the results of the analysis are presented in Table1.

The pH of the water samples ranges from 6.8 to 7.5. pH value of 6.5 is slightly acidic and 8.5 slightly alkaline. The result suggests neutral water and the values fall within WHO, 2004 (World Health Organization) desirable limit for drinking water quality.

The EC values obtained from the study varies from 461 to 3430 μS/cm with an average value of 2039 μS/cm. 50% of the total sample have value above 2000 μS/cm indicating impacts from anthropogenic sources. EC in groundwater sample shows the presence of dissolved solids and can be used in the derivation of TDS in the laboratory using suitable multiplication factor. The values obtained for TDS ranges from 295 to 2195 with an average of 1253. Samples KGW-1, KGW-2, KGW-3, KGW-4, KGW-6, KGW-7, KGW-8, KGW-10, KGW-12, KSW-1 and KTGW-1 making up about 68.75% of the total samples have TDS values above WHO permissible limit. According to TDS classification Freeze and Cherry (1979), only 31.25% of the water samples with TDS <1000 can be grouped under fresh water type. The remaining samples fell into brackish water type.

Total hardness (TH) values for the water samples vary from 190 to 1400 with an average value of 804. The values exceed WHO permissible limit for drinking water except for samples KGW-5, and KGW-13. From the result of the field analysis, 81.25% of the water samples are classified as hard water and hardness attributed to the presence of the paper, textile and chemical industries in the study area.

Chloride concentration ranges from 28 to 1000 mg/l with an average of 453mg/l. The values for samples KGW-1, KGW-2, KGW-3, KGW-4, KGW-6 and KGW-12 are relatively high but still falls within WHO permissible limit. High value of chloride in groundwater is often associated with natural processes such as passage of water through natural salt formation or it may be an indication of pollution from industrial or domestic waste due to anthropogenic activities (Khan 2001; Rao et al. 2003). The high standard deviation of EC and chloride suggest that the water chemistry is regulated by external influence.

Nitrate concentration in the water samples varies from 6 to 49mg/l with an average concentration of 32mg/l. Only 25% of the samples made up of KGW-1, KGW-2, KGW-3 and KGW-9 samples have concentration above WHO maximum desirable value of 45mg/l. The high concentration of NO_3 and Cl^- suggest contamination from external sources such as agricultural activities that is prevalent in the area.

SO_4 concentration is below WHO desirable limit (200-400mg/l) for drinking water quality with values ranging from 3 to 201mg/l and an average of 108mg/l except for KGW-1. 43.75% of the samples have Ca^{2+} concentration above WHO desirable limit. The concentration of Ca^{2+} in the water samples varies from 35 to 309mg/l with an average value of 166mg/l and standard deviation of 86mg/l.

High values of Mg^{2+} ranging from 13 to 106 mg/l were also recorded from the analysis. Samples KGW-3, KGW-4 and KSW-1 have Na^+ concentration values of 235mg/l, 311mg/l and 223mg/l respectively which were above WHO maximum limit for drinking water quality. Although 81.25% of the total samples have concentration below WHO standard for permissible limit, Na^+ concentration of more than 50mg/l renders the water unsuitable for domestic purposes.

4.0 Statistical analysis of physico-chemical parameters

A bivariate correlation analysis was applied to describe the relationship between pairs of hydrochemical

parameters. A high correlation coefficient (r) with either positive or negative value means a good relationship between two variables and a value near zero depicts otherwise. In the present study, correlation analysis for the physicochemical parameters show strong correlation between EC and TDS with all the cations and anions except TOC, HCO_3, NO_3 and K with correlation coefficient of 0.07, 0.22, 0.35 and -0.16 (Table 2). Positive correlation was also observed between TH and all cations and anions except HCO_3 and K (correlation coefficient -0.03 and -0.32). Cl correlated strongly with SO_4, Ca, Mg and Na with a correlation coefficient of 0.70, 0.79, 0.85 and 0.82 respectively suggesting possible similar source of enrichment for the parameters. TOC showed very poor correlation with all the parameters except with pH, HCO_3 and K indicating the prevalence of a reducing environment. The poor and negative correlation of pH with EC and TH may likely suggest the lack of the influence of industrial activities on groundwater quality.
A scatter plot of the relationship existing between the physiochemical parameters are shown in Fig.1a-e. The r^2 = 0.68 in figure 2d indicates that the Total Organic Carbon may have influenced the presence of K in the groundwater. The TOC is most likely to emanate from the organic manure used in agricultural activities in the area. Similarly, the plot of Cl^- and EC shows a linear plot with r^2 = 0.97 suggesting the influence of Cl^- on EC. The scatter plot of SO_4, Ca^{2+} , Mg^{2+} and Na^+ against Cl^- revealed r^2 value equal to 0.54, 0.63, 0.76 and 0.68 respectively suggesting increased concentration from a common source.

5.0 Conclusion
Most of the physiochemical parameters have concentration above WHO maximum permissible level in the study area. High level of electrical conductivity, total dissolved solid, total hardness, Calcium, Sodium, Chloride and Magnesium were observed with relationships suggesting surface input. The concentration of the cations ranges from 35 to 309mg/l for Ca, 13 to 106mg/l for Mg, 20 to 311 mg/l for Na and 2 to 8 mg/l for K. 87.5 % of the cations are in the order Ca > Na > Mg > K and Na > Ca > Mg > K respectively while 68.75% of the anions occur in the order Cl > HCO_3 > SO_4 > NO_3. The high concentration of anions and cations in most of the samples are an indication of surface contamination possible from agricultural activities.

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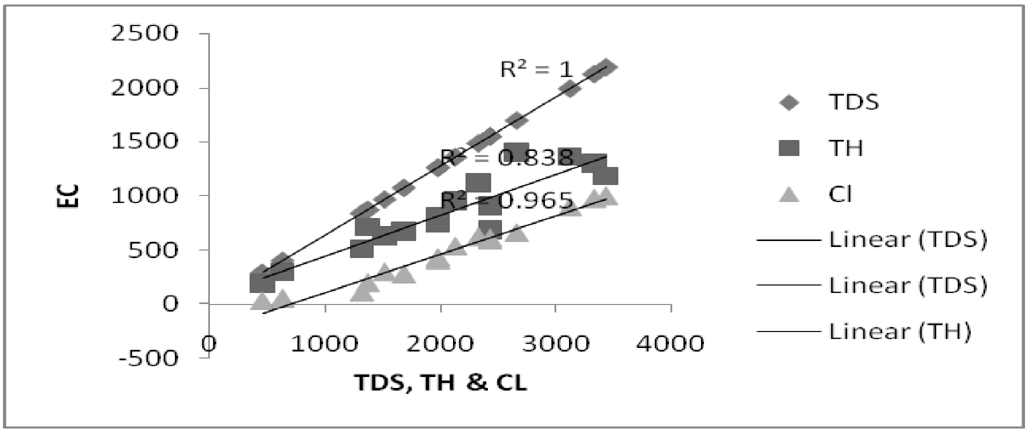
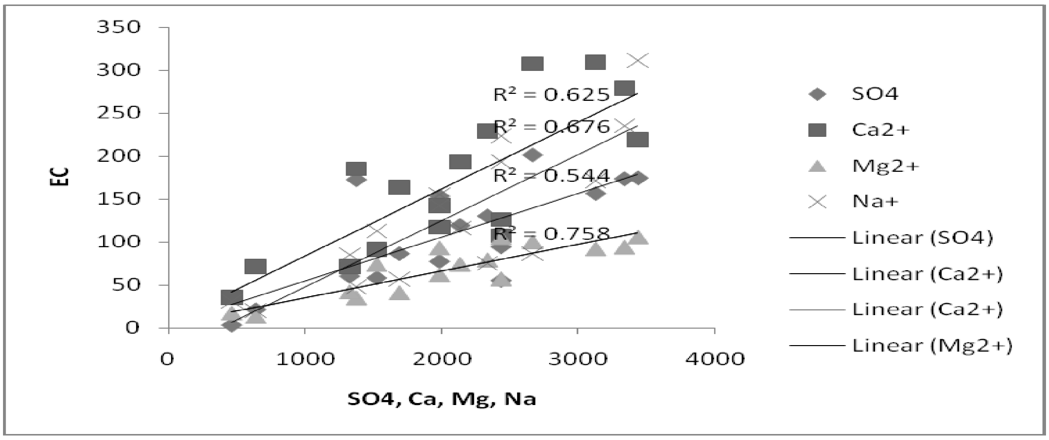
References
Al-Bassam, A.M. & Al-Rumikhani, Y.A. (2003), ‘‘Integrated hydrochemical method of water quality assessment for irrigation in arid areas: Application to the Jilh aquifer, Saudi Arabia’’, Journal of African Earth Sciences 36:345–356.
Al-Futaisi, A., Rajmohan, N. & Al-Touqi, S. (2007), ‘‘Groundwater quality monitoring in and around Barka dumping site, Sultanate of Oman’’, Proceedings of Second IASTED WRM conference.
APHA (1995), ‘‘Standard methods for the examination of water and wastewater’’, (19th edn). Washington: American Public Health Association’’.
Bhatt, K.B., Saklani, S. (1996), ‘‘Hydrogeochemistry of the Upper Ganges River, India’’, Journal of the Geological Society of India, 48:171–182.
Elango, L., Suresh Kumar. S., Rajmohan, N. (2003), ‘‘Hydrochemical studies of groundwater in Chengalpet region, South India’’, Indian Journal of Environmental Protection 23(6):624–632.
Freeze, R.A. & Cherry, J.A. (1979), ‘‘Groundwater’’, Englewood Cliffs: Prentice Hall.
Jeevanandam, M., Kannan, R., Srinivasalu, S. & Rammohan, V. (2006), ‘‘ Hydrogeochemistry and Groundwater Quality Assessment of Lower Part of the Ponnaiyar River Basin, Cuddalore District, South India’’, Environmental Monitoring and Assessment, 132(1–3):263–274.
Karanth, K.R. (1987), ‘‘Groundwater assessment, development and management’’, New Delhi Tata-McGraw-Hill.
Khan, M.A. (2001), ‘‘Pollution of water resources due to industrialization in arid zone of Rajasthan, India’’, Journal of Environmental Science (China) 13(2):218–223.
Ma, J., Ding, Z., Wei, G., Zhao, H. & Huang, T. (2009), ‘‘Sources of water pollution and evolution of water quality in the Wuwei basin of Shiyang River, Northwest China’’, Journal of Environmental Management 90:1168–1177.
Nisi, B., Buccianti, A., Vaselli, O., Perini, G., Tassi, F. & Minissale, A. (2008), ‘‘Hydrogeochemistry and strontium isotopes in the Arno River Basin (Tuscany,Italy): Constraints on natural controls by statistical modeling’’, Journal of Hydrology 360:166–183.

Pritchard, M., Mkandawire, T. & O'Neill, J.G. (2008), ''Assessment of groundwater quality in shallow wells within the southern districts of Malawi'', Physics and Chemistry of the Earth 33: 812–823.
Rao, M., Ranga, A. & Acharya, N.G. (2003), ''Effect of industrial effluent on properties of groundwater'', Journal of Environmental Biology, 24(2):187–192.
Schot, P.P. & Van der Wal, J. (1992),'' Human impact on regional groundwater composition through intervention in natural flow patterns and changes in land use'', Journal of Hydrology, 134: 297–313.
Shaik, R., Srikant, V.N.V., Rao, D.M. & Ramakrishna, C. (2012), '' Study of Ground Water Quality In Industrial Zone Of Visakhapatnam'', Appl. Sci. Res., 2012, 3(4):2463-2467.
Subramani, T., Elango, L. & Damodarasamy, S.R. (2005), '' Groundwater quality and its suitability for drinking and agricultural use in Chithar River Basin, Tamil Nadu, India'', Environmental Geology 47:1099– 1110.
Sujatha, D. & Rajeshwara Reddy, B. (2003), ''Quality characterization of groundwater in the south-eastern part of the Ranga Reddy district, Andhra Pradesh, India'', Environmental Geology, 44: 579–586.
WHO (2004),''Guidelines for drinking water quality'', 3rd edn. ISBN 9241546387. Retrieved August, 2011



a



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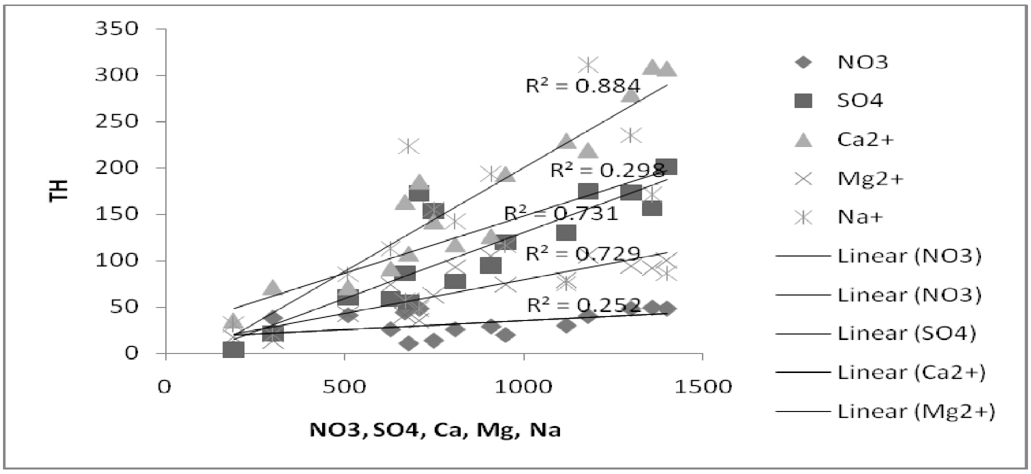

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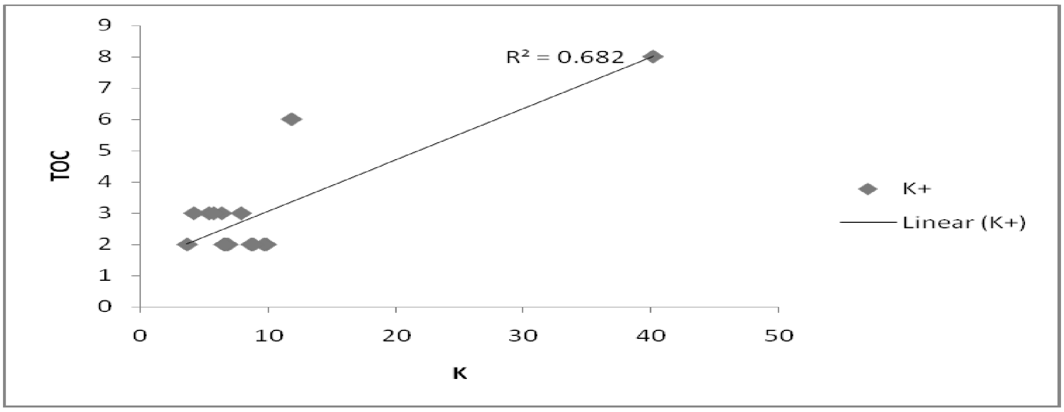

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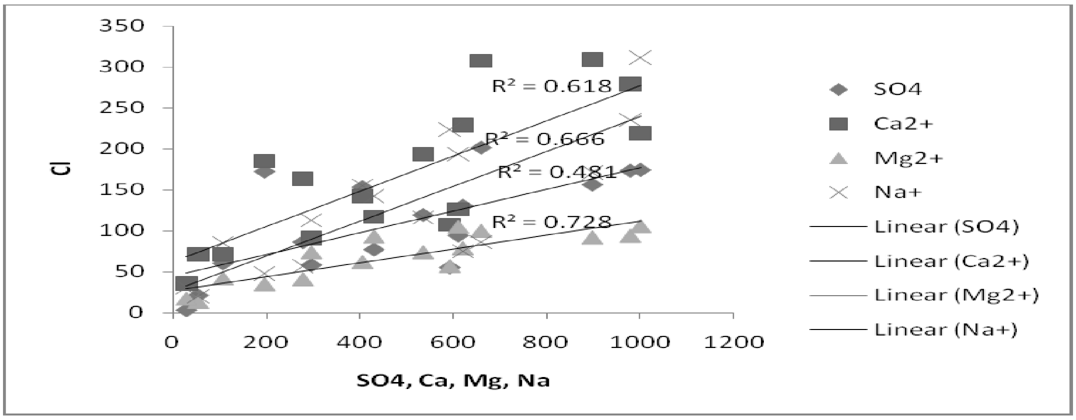

e

Fig. 2a-e Scatter plot of the physico-chemical parameters

Table 1 Result of physico-chemical analysis

Samples	Ph	EC	TDS	TOC	TH	Cl	HCO3	NO3	SO4	Ca2+	Mg2+	Na+	K+
KGW-1	6.8	2660	1702	5.32	1400	659	138	48	201	307	100	86	3
KGW-2	7.0	3120	1997	6.32	1360	897	180	49	156	309	92	171	3
KGW-3	7.0	3330	2131	6.49	1300	978	174	48	173	279	94	235	2
KGW-4	7.1	3430	2195	6.80	1180	1000	219	40	174	219	106	311	2
KGW-5	7.0	636	407	3.61	300	53	132	38	21	71	13	20	2
KGW-6	6.9	2330	1491	6.59	1120	620	183	30	130	229	79	75	2
KGW-7	7.0	2130	1363	6.57	950	535	213	20	119	193	74	116	2
KGW-8	7.0	1980	1267	7.84	750	404	258	14	153	142	62	155	3
KGW-9	7.0	1370	877	5.70	710	195	168	48	172	185	35	48	3
KGW-10	7.1	1980	1267	9.80	810	429	288	26	77	117	93	142	2
KGW-11	7.3	1520	973	8.62	630	295	219	26	58	91	74	113	2
KGW-12	7.1	2430	1555	9.61	910	610	294	29	94	126	105	193	2
KGW-13	7.3	1321	845	8.79	510	106	297	41	60	71	42	85	2
KSW-1	7.5	2430	1555	40.14	680	592	336	11	55	107	57	223	8
KTSW-1	7.5	461	295	11.78	190	28	117	6	3	35	17	31	6
KTGW-1	7.3	1687	1080	4.13	670	277	159	44	86	163	41	57	3
WHO STD	6.5-8.5		500-1000		300-600	250-1000		45-100	200-400	75-200	30-100	200	12
Min	6.8	461	295	3.61	190	28	117	6	3	35	13	20	2
Max	7.5	3430	2195	40.14	1400	1000	336	49	201	309	106	311	8
Average	7.1	2051	1313	9.26	842	480	211	32	108	165	68	129	3
STDEV	0.2	871	557	8.51	361	313	66	14	60	86	31	82	2

Table 2 Correlation analysis for the physicochemical parameters

	PH	EC	TDS	TOC	TH	Cl^-	HCO_3^-	NO_3^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
PH	1												
EC	-0.4	1											
TDS	-0.4	**1**	1										
TOC	**0.604**	0.067	0.067	1									
TH	-0.66	**0.915**	**0.915**	-0.19	1								
Cl^-	-0.41	**0.983**	**0.983**	0.053	**0.901**	1							
HCO_3^-	0.307	0.22	0.22	**0.587**	-0.03	0.124	1						
NO_3^-	-0.52	0.347	0.348	-0.54	**0.502**	0.299	-0.35	1					
SO_4^{2-}	-0.73	**0.738**	**0.738**	-0.33	**0.855**	**0.694**	-0.14	**0.55**	1				
Ca^{2+}	-0.7	**0.791**	**0.791**	-0.3	**0.941**	**0.787**	-0.3	**0.615**	**0.885**	1			
Mg^{2+}	-0.45	**0.871**	**0.871**	-0.07	**0.854**	**0.853**	0.296	0.228	**0.622**	**0.639**	1		
Na^+	0.005	**0.823**	**0.822**	0.329	**0.546**	**0.816**	**0.506**	0.009	0.401	0.34	**0.711**	1	
K^+	**0.641**	-0.16	-0.16	**0.826**	-0.32	-0.13	0.132	-0.53	-0.34	-0.27	-0.35	0.023	1