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Groundwater quality characterization around Jawaharnagar open dumpsite, Telangana State

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Abstract In the present work groundwater samples were collected from ten different data points in and around Jawaharnagar municipal dumpsite, Telangana State Hyderabad city from May 2015 to May 2016 on monthly basis for groundwater quality characterization. Pearson's correlation coefficient (r) value was determined using correlation matrix to identify the highly correlated and interrelated water quality standards issued by Bureau of Indian Standard (IS-10500:2012). It is found that most of the groundwater samples are above acceptable limits and are not potable. The chemical analysis results revealed that pH range from 7.2 to 7.8, TA 222 to 427 mg/l, TDS 512 to 854 mg/l, TH 420 to 584 mg/l, Calcium 115 to 140 mg/l, Magnesium 55 to 115 mg/l, Chlorides 202 to 290 mg/l, Sulphates 170 to 250 mg/l, Nitrates 6.5 to 11.3 mg/l, and Fluoride 0.9 to 1.7 mg/l. All samples showed higher range of physicochemical parameters except nitrate content which was lower than permissible limit. Highly positive correlation was observed between pH–TH ($r = 0.5063$), TA–Cl$^-$ ($r = 0.5896$), TDS–SO$_4^-$ ($r = 0.5125$), Mg^{2+}–NO$_3^-$ ($r = 0.5543$) and Cl$^-$–F$^-$ ($r = 0.7786$). The groundwater samples in and around Jawaharnagar municipal dumpsite implies that groundwater samples were contaminated by municipal leachate migration from open dumpsite. The results revealed that the systematic calculations of correlation coefficient between water parameters and regression analysis provide qualitative and rapid monitoring of groundwater quality.

Keywords Groundwater · Dumpsite · Solid waste · Pearson correlation · Regression equation · Leachate

Introduction

The solid waste generation has become a burning environmental and public health problem everywhere in the world (Akoteyon et al. 2011). Disposing of solid waste in open dumps is the oldest and common way. The common danger reported to human health is using groundwater that has been polluted by municipal leachate (Kanmani and Gandhimathi 2013).

Open landfills are located wherever land is available, without regard to esthetical degradation, safety and health hazard (Sabahi et al. 2009). From these open landfills the commonly reported danger to the human health is by consuming the groundwater contaminated by leachate (Jhamnani and Singh 2009). The leachate generated from dumpsite contain elements like ammonia, nitrogen, potassium, calcium and magnesium, trace metals like lead, nickel, chromium, manganese, iron copper and organic compounds like chloroform, toluene, acetone, benzene, phenols, hydrocarbons, etc. (Freeze and Cherry 1979).

The solid waste placed in open dumps is subjected to infiltration from precipitation, or underflow. During rainfall, the solid waste dumped in open landfills release water and the by-products of its decomposition. The liquid containing inorganic and organic compounds is called "leachate" which accumulates at the bottom of the landfill and percolates through the soil and reaches the groundwater (Mor et al. 2006). The areas near open dumps or landfills

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have a greater possibility of groundwater contamination because of the potential pollution source of leachate (Saarela 2003). Such type of contamination of groundwater results in a substantial risk to local groundwater resource user and to the environment (Moo-Young et al. 2004).

Leachate is produced when moisture enters the refuse in a landfill (Lo 1996). When moisture enters the refuse in a landfill, it extracts the pollutants into liquid phase, which initiates a liquid flow called as leachate. Groundwater is an important drinking water source for humankind. Leachate percolation from open dumps release pollutants which pose a high contamination of groundwater (Ahmed and Sulaiman 2001). The present study aims to understand, correlate and characterize the groundwater quality in the Jawaharnagar open dumpsite and the adjacent areas through bore wells.

Study area

Telangana and Andhra Pradesh is the sixth largest city in India as Hyderabad as its capital city. Jawaharnagar is an open dumpsite which was established in 2002. Jawaharnagar is a village located in Ranga Reddy district, Telangana State, India. The Jawaharnagar dumpsite in Greater Hyderabad Municipal Corporation (GHMC) is located in Jawahar Mandal village over an area of approximately 350 acres and about 4500 metric tons of waste generation. It is located between 7030′01″N–17,032′03″N latitude and 78,034′13″E–78,037′47″E longitude. The groundwater level in the Jawaharnagar area is observed about 40 m below ground level. The annual mean temperature is 26 °C, where as summers are hot with maximum temperatures of 40 °C and winter has varying temperatures from 14.7 to 28.6 °C. Ranga Reddy with most of its annual rainfall of 812.5 mm (32 in). The height of the dump is around 4–5 m above ground level. The waste is disposed here without segregation and compaction. The stinking garbage pile at the Jawaharnagar dumping yard is not capped in a scientific method by which the garbage releases leachate which infiltrates into ground and further contaminates groundwater which is causing diseases like cholera and dysentery when consumed. This situation is reported frequently in the surrounding areas of Jawaharnagar.

Methodology

Groundwater sample collection

Ten groundwater samples were collected during dry and wet period from May 2015 to May 2016 around the dumpsite. The groundwater samples details are Malkaram (GW 1), Haridaspally (GW 2), Balajinagar (GW 3),

Ahmedguda (GW 4), Cheeryal (GW 5), Kundanpally (GW 6), Rampally (GW 7), Dammaiguda (GW 8), E C Nagar (GW 9) and Vasavinagar (GW 10). Groundwater samples were collected in 1L pre-cleaned high-density polyethylene bottle (HDPE). Geographic locations of the groundwater sampling points were collected using GARMIN 78S TRIMBLE GPS, USA. The study area and groundwater sampling locations are depicted in Fig. 1.

Analytical methods

The groundwater characterization has been carried out for the parameters like pH, alkalinity, total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), sulphate (SO_4^-), nitrate (NO_3^-) and fluoride (F^-) by following the standard methods prescribed as per Bureau of Indian Standard 10500 (BIS 2012). The physicochemical parameters for characterization were selected based on their relative importance in municipal landfill leachates composition and their pollution on groundwater (Bagchi 2004).

The various analytical methodologies followed for analyzing physicochemical parameters are represented in Table 1. Each of the analysis in the study was repeated twice until concordant values were obtained, and all the tests were carried out according to the standard methods (APHA 1998).

Statistical analysis

Linear regression model: The mathematical model used to estimate water quality requires two parameters to describe water situations. Correlation analysis measures the closeness of the relationship between chosen independent and dependent variables (Nair et al. 2005, 2006). If the correlation coefficient is nearer to +1 or −1, it shows the probability of linear relationship which is between the variables x and y.

The parameters are characterised as strong, moderate and weak based on correlation. The parameter is strong, when it is in the range of +0.8 to 1.0 and −0.8 to −1.0, the parameter is moderate when it is having value in the range of +0.5 to 0.8 and −0.5 to −0.8, the parameter is weak when it is in the range of +0.0 to 0.5 and −0.0 to −0.5 (Nair et al. 2005). The correlation analysis attempts to establish the nature of the relationship between the variables which is based on correlation analysis which provides a mechanism for forecasting and prediction (Kumar and Sinha 2010a, b). In the present study, the Pearson correlation coefficient was used which is a helpful statistical formula that measures the strength between variables and relationships which is referred as Pearson R test. This coefficient correlation value is useful to determine how strong that relationship is between those two variables:
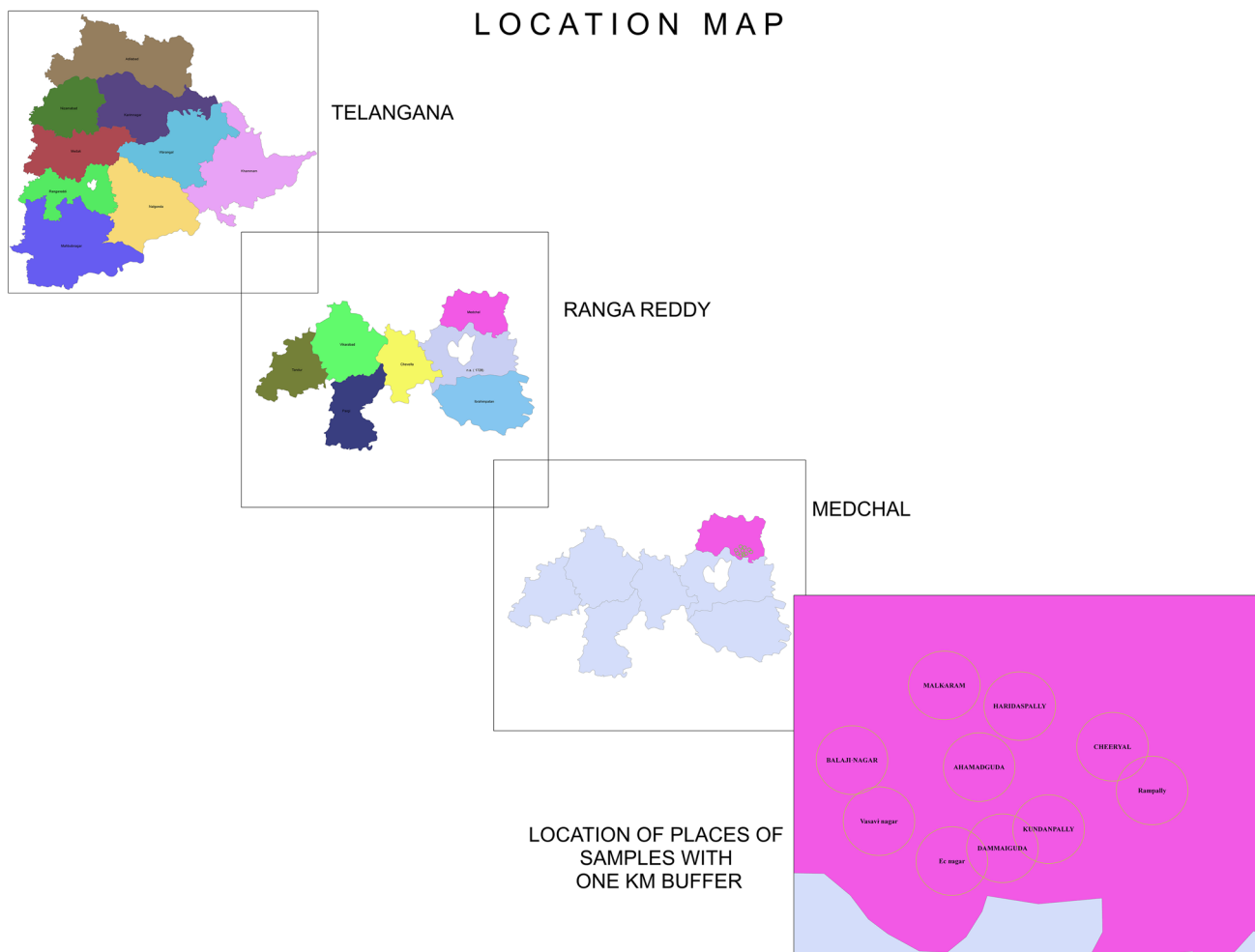
LOCATION MAP

TELANGANA

RANGA REDDY

MEDCHAL

LOCATION OF PLACES OF
SAMPLES WITH
ONE KM BUFFER

Fig. 1 The study area and groundwater sampling locations

Table 1 Analytical methodology for various analyzed physico-chemical parameters

S. no.	Parameters	Analytical Methodology
1	pH	Electro-metric method (pH meter-HANNA Italy) calibrated with buffers 4.0 and 7.0
2	Total alkalinity (TA)	Titrimetric method
3	total dissolved solids (TDS)	Sensor based (Model-HM Digital Aqua Pro Tolexo, USA)
4	Total hardness (TH)	EDTA titrimetric method
5	Magnesium (Mg^{2+})	EDTA titrimetric method
6	Calcium (Ca^{2+})	Titrimetric method
7	Chloride (Cl^-)	Titrimetric method
8	Nitrate (NO_3^-)	Ion-selective electrode (Orion 4 star)
9	Sulphate (SO_4^-)	Spectrophotometer (Model-UV–VIS Systronics 118).
10	Flouride (F^-)	Photometric method (Thermofisher scientific, USA Benchtop)

$$R = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}} \tag{1}$$

where, x (x = values of x-variable, $\bar{x}$ = average values x) and Y (y = values of y-variable, $\bar{y}$ = average values y) represents two different water quality parameters. If the values of correlation coefficient 'R' between two variables X and Y are fairly large, it implies that these two variables are highly correlated. To determine the straight linear regression, following equation of straight line serve as a guide:

$$y = a + bx \qquad (2)$$

where y and x are the dependent and independent variable, respectively, a is the slope of line, b is intercept on y axis. The value of empirical parameters 'a' and 'b' are calculated with the help of the following equation:

$$b = \frac{\sum xy - \bar{x} \sum y}{\sum x^2 - \bar{x} \sum y} \qquad (3)$$

$$a = \bar{y} - b\bar{x} \qquad (4)$$

The correlation is a broad class of statistical relationship between two or more variables in statistics. The correlation study is useful to find a predictable relationship which can be exploited in practical. It is used for the measurement of the strength and statistical significance of the relation between two or more water quality parameters (Mehta 2010). To study the correlation between various water quality parameters, the regression analysis was carried out using IBM-SPSS version-20 software.

Results and discussion

Leachate

The physicochemical characteristics in the leachate sample depend upon the waste composition and moisture content of solid waste (Denutsui et al. 2012). The characteristics of leachate sample from Jawaharnagar open dump site is presented in Table 2.

The pH value of the dry season was observed in the range of 7.6 and in wet season it was 8.3 which indicate it is alkaline in nature. This may attribute to the decrease in the free volatile acids concentrations due to anaerobic decomposition (El-Fadel et al. 2002). The TDS (34000 mg/l) concentration also fluctuated widely. The inorganic contaminants trends to decrease TDS concentration with increasing leachate age and stability (Calli et al. 2005). The parameters analyzed such as Ca^{2+}, Mg^{2+}, Cl^-, NO_3^- and SO_4^- were found to be in higher

Table 2 Typical range of leachate characteristics

S. no.	Parameters	Dry	Wet
1	pH	7.6	8.3
2	TDS	34,000	3559
3	Ca^{2+}	13	5
4	Mg^{2+}	400	250
5	NO_3^-	410	290
6	SO_4^-	390	150
7	Cl^-	46,000	13,016

All parameters are in mg/l, except pH

concentration during dry season when compared to wet season. The presence of magnesium is due to construction disposal (Al-Yaqout 2003) and chloride concentration due to kitchen waste from hotels, households, and restaurants (Fatta et al. 1999).

Groundwater assessment

The groundwater physicochemical characterization is considered as important principle in the quality, identification of nature and type of water (Abdo 2005). Ten physicochemical parameters for estimation of suitability for drinking purpose characteristics adopted are pH, total alkalinity (TA), total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), sulphate (SO_4^-), nitrate (NO_3^-) and fluoride (F^-) using standard techniques. The statistical results with respect to mean and standard deviation (SD) values for groundwater quality with IS-10500 standards parameters are summarized in Table 3. The collected groundwater samples in and around Jawaharnagar municipal dumping site were free from colour and odour for all locations. The groundwater of the studied area is used for drinking and domestic purpose. Table 3 shows the acceptable and minimum permissible limit of individual parameters for drinking water recommended by Bureau of Indian Standards (BIS 2012) and World Health Organization (WHO 2002).

The physicochemical concentrations of collected groundwater samples for the various parameters are shown in Table 4. The pH values of all groundwater samples are within the range of WHO and BIS standards. pH values greater than 8.5 are considered to be too alkaline for human consumption, where as pH lower than 6.5 are considered too acidic which can cause acidosis (Duncan et al. 2014). The TDS concentrations in all samples were above the permissible limits, which indicate the saline behaviour of groundwater samples. According to Rabinove et al. (1958) samples range from 512 to 831 mg/l are above standards. The high concentrations of TDS may be due to leaching of various contaminants into groundwater. Groundwater TDS was classified according to Todd (1980) into very fresh (0–250 mg/l), fresh (250–1000 mg/l), brakish (1000–10,000 mg/l) and saline (10,000–100,000 mg/l). According to this classification all the groundwater samples fell under the fresh water type and slowly reached to brackish water. Total hardness was above the standards in all samples, which is primarily caused by the presence of cations such as magnesium and calcium and anions such as sulphate, chloride and bicarbonate (Ravikumar et al. 2010). Calcium and magnesium concentration was above the acceptable limits. The multivalent, mainly magnesium and calcium, are often present at significant concentration in natural water (Durfor and Becker's 1964). Calcium in

Table 3 Drinking water quality standards as per BIS and WHO

S. no.	Parameters	BIS standards (BIS 10500:2012)		World Health Organization (WHO) (2002)
		Desirable limit	Permissible limit	
1	pH	6.5–8.5	No relaxation	6.5–9.2
2	Total alkalinity	200	600	500
3	Total dissolved solids	500	2000	250
4	Total hardness	200	600	300
5	Calcium	75	200	150
6	Magnesium	30	100	200
7	Chloride	250	1000	200
8	Sulphate	200	400	50
9	Nitrate	45	No relaxation	0.5
10	Fluoride	1.0	1.5	1.0

All values are in mg/l, except pH

Table 4 Physicochemical and statistical analysis of groundwater samples at Jawaharnagar dumpsite

S. no.	Parameter	BIS 10500:2012	Groundwater sampling points										Mean	SD
			GW1	GW 2	GW 3	GW 4	GW 5	GW 6	GW 7	GW 8	GW 9	GW 10		
1	pH	6.5	7.8	7.5	7.2	7.5	7.4	7.2	7.5	7.4	7.6	7.3	7.44	0.1743
2	Total alkalinity	200	298	323	410	305	422	222	301	394	427	390	349.2	65.180
3	TDS	500	760	831	765	652	512	680	752	768	854	824	739.8	96.754
4	TH	200	584	460	420	475	545	490	530	550	495	530	507.9	46.375
5	Calcium	75	115	125	120	128	123	120	128	140	135	140	127.4	8.1510
6	Magnesium	30	55	72	87	109	68	85	98	115	93	65	84.7	18.626
7	Chlorides	250	230	202	260	238	275	250	255	263	290	255	251.8	22.493
8	Sulphates	200	200	240	190	170	210	215	205	230	250	220	213.0	22.494
9	Nitrates	45	6.5	10	7.2	11.3	9.5	12	11	10.3	11	9.8	9.86	1.6722
10	Fluoride	1.0	1.0	0.9	1.2	1.1	1.6	1.3	1.7	1.6	1.5	1.2	1.31	0.2624

All values are in mg/l, except pH

excess amount can lead to the formation of gallbladder stones (Stringer et al. 2007). The concentration of total alkalinity was higher than the acceptable limit of 200 mg/l as $CaCO_3$ in all groundwater samples. The high concentration of TA imparts an unpleasant taste and hazardous to human health (Pawar 1993). The concentration of chloride in samples were above the acceptable limits except GW-1, GW-2, GW-4 described by BIS 10500:2012. Cl^- imparts a salty taste in water, which might be due to dissolution of rocks and anthropogenic pollution, which can cause osteoporosis, renal stone and hypertension (McCarthy 2004).

The concentration of sulphate in all locations except GW-3, GW-4 exceeds the permissible level by BIS. Similarly, the concentration of nitrate was within the acceptable limit in all samples. The concentration of sulphate in groundwater might be due to leachate from landfills, domestic sewage and agriculture runoff (Jalali 2005). The "Blue baby syndrome" is caused by NO_3^- in higher concentration which particularly affects infants (Kapil et al.

2009). The fluoride concentration in all locations except GW-2 exceeds the acceptable limits of 1.0 mg/l. The alkaline groundwater generally tends to solubilise fluoride minerals like fluoride, appatite and cryolite (Lee et al. 2003). The lesser concentration of fluoride has beneficial effect in preventing dental caries and higher concentration has increased risk of dental fluorosis and even higher concentration that of 1.5 mg/l could lead to skeletal fluorosis (Vyas and Sawant 2008).

The statistical results indicates that regression equation have the same correlation coefficients. Interrelationship studies between different variables helps in promoting research and opening new frontiers of knowledge. The correlation study reduces the range of uncertainty associated with decision making (Shyamala et al. 2011). Ultimately it can be concluded that the correlation studies of the groundwater quality parameters have great significance in the study of water resources. From the present study results, in most part of the Jawaharnagar dumpsite area,

these parameters values have exceeded the prescribed limit of BIS 10500:2012.

Correlation analysis for groundwater quality parameters

The correlation coefficient for the systematic calculation between water quality variables and regression analysis indicates indirect means for water quality monitoring. The degree of association that exists between two variables is measured by correlation coefficient, one taken as dependent variable (Chatterjee 2010). The greater the value of regression coefficient, the better and more useful the regression variables (Patil and Patil 2011). In the present study, the numerical values of correlation coefficient, R for the ten water quality parameters are tabulated in Table 4. From Table 5 it is revealed that highly positive correlation is observed between Cl^- and F^- ($R = 0.778$) (Fig. 2), TA and Cl^- ($R = 0.589$), Mg^{2+} and NO_3^- ($R = 0.554$), TDS and SO_4^- ($R = 0.512$) and TH and pH ($R = 0.506$).

No significant correlation among most of the parameters was obtained in the groundwater quality of Jawaharnagar dumpsite area (Kumar and Sinha 2010a, b). However, some of the parameters having correlation coefficients with $R < 0.05$ are tabulated in Table 6. The linear regression analysis have been carried out for the groundwater quality parameters which are found to have better and high level of significance in their correlation coefficient ($R > 0.50$) (Mulla et al. 2007), which is depicted in Table 6.

The various dependent characteristics of groundwater quality were calculated using the regression equation and the values where substituted for the independent parameters in the equations (Shah et al. 2007). These correlations revealed that the physicochemical parameters independently of anions and major cations in the Jawaharnagar area and some cations, anions and physical parameters were found interrelated (Sharma et al. 2009). Ca^{2+}, Cl^-, SO_4^-, NO_3^- are positively correlated with majority of water parameters. pH is negatively correlated with most of the water parameters. Highly negative correlation coefficient is found between TDS and F^{-2} ($R = -0.268$) and TH and Mg^{2+} ($R = -0.260$). The results indicate that regression relations have the same correlation coefficients (Jothivenkatachalam et al. 2010) and (Fatta et al. 1999).

Conclusion

The moderately high concentration of TDS, TA, TH, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^-, F^- of groundwater in Jawaharnagar indicates contamination and above the permissible limits of drinking water standards. A study was carried out on groundwater characterization using the correlation coefficient and regression method for analyzing Jawaharnagar groundwater quality. The results when compared with the drinking water quality standards issued by BIS-10500, the groundwater samples were found to be not potable. The statistical analysis of the experimentally estimated groundwater quality parameters on water samples yielded the range of the variation, mean, standard deviation and coefficient of variation. Since the correlation coefficient gives the interrelationship between the parameters, correlation coefficients were calculated. A linear regression analysis technique has been proven to be a very useful tool for monitoring drinking water and has a good accuracy. From the correlation regression study, it can be concluded that most of the parameters are more or less correlated with each other. The present study showed that all the physicochemical parameters for groundwater in Jawaharnagar dumpsite are more or less correlated with each other. The present study provides a baseline for the groundwater quality in Jawaharnagar dumpsite, which will help the allied agencies and policy makers to focus on the specific contaminants sources and its mitigation.

Table 5 Pearson's correlation coefficient among various groundwater quality parameters

Parameters	pH	TA	TDS	TH	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^-	No_3^-	F^-
pH	1.0000	−0.0666	0.1836	0.5063	−0.1308	−0.1933	−0.2160	0.0841	−0.2517	0.0892
TA		1.0000	0.0952	−0.0276	0.4673	0.0184	0.5896	0.2932	−0.2792	0.3277
TDS			1.0000	−0.1714	0.3839	0.0143	−0.1676	0.5125	−0.0884	−0.2680
TH				1.0000	0.1310	−0.2605	0.1371	0.1172	−0.1288	0.3245
Ca^{2+}					1.0000	0.4427	0.3740	0.4461	0.4530	0.3860
Mg^{2+}						1.000	0.2808	−0.1016	0.5543	0.4484
Cl^-							1.0000	0.1672	0.1661	0.7786
SO_4^-								1.0000	0.2451	0.1981
NO_3^-									1.0000	0.3745
F^-										1.0000

Fig. 2 Strong positive correlation between fluoride and chloride ($r = 0.7786$)
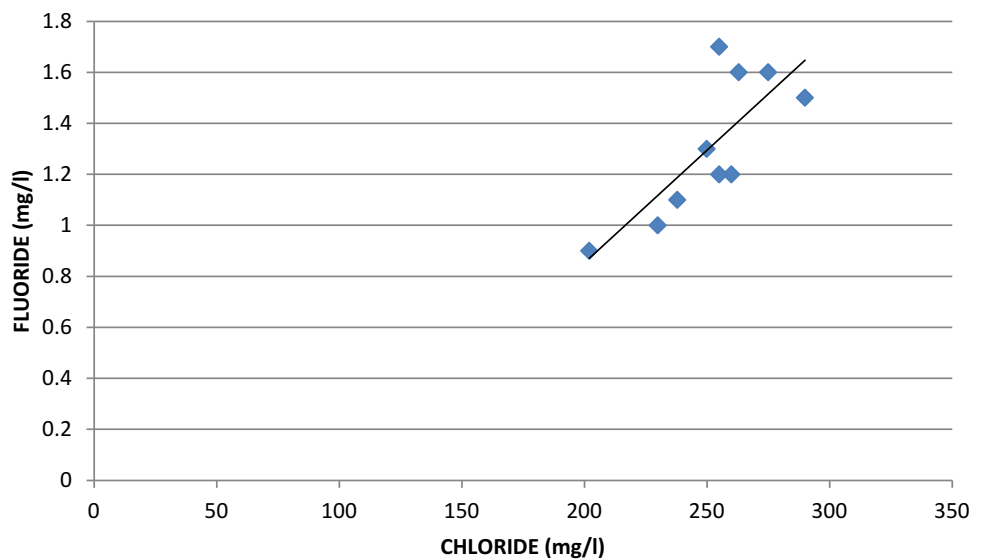
Table 6 Linear correlation coefficient R and regression equation for parameters which have significant value of correlation

S. no.	Parameters	R value	Correlation coefficient		Regression equation
			a	b	
1	pH–TH	0.5063	−494.053	134.671	TH = −494.053 (pH) + 134.671
2	TA–Ca^{2+}	0.4673	106.99	0.058	Ca^{2+} = 106.99 (TA) + 0.058
3	TA–Cl$^-$	0.5896	178.67	0.209	Cl$^-$ = 178.67 (TA) + 0.209
4	TA–SO$_4^-$	0.2932	177.665	0.101	SO$_4^-$ = 177.665 (TA) + 0.101
5	TA–F$^-$	0.3277	0.849	0.001	F$^-$ = 0.849 (TA) + 0.001
6	TDS–SO$_4^-$	0.5125	124.838	0.119	SO$_4^-$ = 124.838 (TDS) + 0.119
7	TH–F$^-$	0.3245	0.377	0.002	F$^-$ = 0.377 (TH) + 0.002
8	Ca^{2+}–Mg^{2+}	0.4427	−44.196	1.012	Mg^{2+} = −44.196 (Ca^{2+}) + 1.012
9	Ca^{2+}–Cl$^-$	0.3740	116.461	1.062	Cl$^-$ = 116.461 (Ca^{2+}) + 1.062
10	Ca^{2+}–SO$_4^-$	0.4461	56.147	1.231	SO$_4^-$ = 56.147 (Ca^{2+}) + 1.231
11	Ca^{2+}–NO$_3^-$	0.4530	−1.983	0.093	NO$_3^-$ = −1.983 (Ca^{2+}) + 0.093
12	Ca^{2+}–F$^-$	0.3860	−0.274	0.012	F$^-$ = −0.274 (Ca^{2+}) + 0.012
13	Mg^{2+}–Cl$^-$	0.2808	222.232	0.349	Cl$^-$ = 222.232 (Mg^{2+}) + 0.349
14	Mg^{2+}–NO$_3^-$	0.5543	5.645	0.05	NO$_3^-$ = 5.645 (Mg^{2+}) + 0.05
15	Mg^{2+}–F$^-$	0.4484	0.775	0.006	F$^-$ = 0.775 (Mg^{2+}) + 0.006
16	Cl$^-$–F$^-$	0.7786	−0.913	0.009	F$^-$ = −0.913 (Cl$^-$) + 0.009
17	SO$_4^-$–NO$_3^-$	0.2451	5.979	0.018	NO$_3^-$ = 5.979 (SO$_4^-$) + 0.018
18	NO$_3^-$–F$^-$	0.3745	0.73	0.059	F$^-$ = 0.73 (NO$_3^-$) + 0.059

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