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A comparative evaluation of groundwater suitability for drinking and irrigation purposes in Pugalur area, Karur district, Tamilnadu, India

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ABSTRACT

It is known that the groundwater quality is important as it is the main factor determining its suitability for drinking, domestic, agricultural and industrial purposes. In order to assess the groundwater quality, 16 groundwater samples have been collected from different places in cultivatedPugalur and uncultivatedPugalur during January 2012. The water samples collected in the stations were analyzed for Electrical Conductivity (EC), pH, Total Dissolved Solids(TDS), Total Hardness(TH), Total Alkalinity (TA), major cation like calcium, magnesium, sodium, potassium and anions like chloride, nitrate and sulphate in the laboratory using the standard methods given by the American Public Health Association (APHA, 2005). Water quality indices are generally used as a tool to convert a large data set into a much reduced and informative form. Water quality index (WQI) by weighing arithmetic index method is used to assess the suitability for drinking and irrigation purpose. The results were evaluated in accordance with the drinking water quality standards suggested by the World Health Organization and are presented. Chloride, alkalinity, hardness, EC and potassium were found excess in most of the samples.The results are analyzed in the light of USSL diagram and Piper trilinear plot using Aquachemsoftware.The Piper diagram showed that the groundwater was of mixed Ca-Mg-Cl type followed by Na-Cl and Ca-Cl type.

Key words: Water Quality Index, Irrigation water, Drinking water, Pugalur, Karur

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INTRODUCTION

In recent years, the competition for scarce water resources is intense both in India and in many places all over the world. Groundwater has long been considered as one of the purest forms of water available in nature and meets the overall demand of rural and semi-urban people. Apart from this, the most important are non availability of potable surface water and a general belief that groundwater is purer and safer than surface water due to the protective qualities of the soil cover [1]. On the other hand, the development of human societies and industry result in bioenvironmental problems; pollution puts the water, air and soil resources at risk [2]. Groundwater is important for human water supply and in Asia alone about 1.2 billion people are directly dependent upon these resources [3].

Urbanization and the unregulated growth of the population have altered the surface and sub-surface terrain of many areas. Changes in local topography and drainage system directly affect both quality and quantity of the groundwater [4]. Inadequate environmental protection measures in coal mining, waste dumps, thermal power plants, steel, sugar factory, fertilizers and cement plants have resulted in significant water pollution [5]. Groundwater quality depends on the quality of recharged water, atmospheric precipitation, inland surface water and sub-surface geochemical processes. Temporal changes in the origin and constitution of the recharged water, hydrological and human factors may cause periodic changes in groundwater quality [2, 6].

Water pollution not only affects water quality but also threats human health, economic development and social prosperity. The quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes [7, 8]. Groundwater chemistry in turn, depends on a number of factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources other than water interaction. Such factors and their interactions result in a complex groundwater quality [9].

The Water Quality Index (WQI) integrates complex data to generate a score that describes the status of water quality to the public as well as decision and policy makers [10-16]. Moreover, it may be used for comparing the quality of different water sources and in monitoring the temporal changes in the quality of water [14, 17]. It reflects the aggregate influence of various physical, chemical, and biological parameters of water quality conditions [18]. The results of the WQI allow the preliminary classification of river water for the purpose of various uses and provide a benchmark for evaluating management strategies [10, 19]. The WQI is a unitless number between 0 and 100 with the higher value indicating poor quality of water. Water quality indices have various approaches tostatistical integrating and interpreting variables and have been frequently utilized for the assessment of water quality [20, 21]. The results are compared with drinking water quality standards laid down by the World Health Organization [22] and Indian Council of Medicinal Research [23].

Sivakumar[24] quantified that groundwater quality at the Amaravathi River basin water parameters were crossed the permissible limits due to industrial and textile industrial activities. Similar results were reported by Raja [25], the groundwater in punnam village of Karur district is highly polluted due to the release of textile industries effluent, same observation was obtained by Rajamanickam[26] the groundwater quality in the Amaravathi River basin was severely affected by discharge of untreated or partially treated effluent from the bleaching and dyeing units in Karur. The aim of the study is to investigate the effects of the industrial activities and increase of human population on groundwater quality in the region since groundwater resources are widely used for drinking, agricultural and industrial purposes. The specific objectives of the study are (i) The preliminary investigation and interpretation of the groundwater quality of Pugalur area and (ii) Finding the suitability of groundwater for drinking and irrigation purposes.

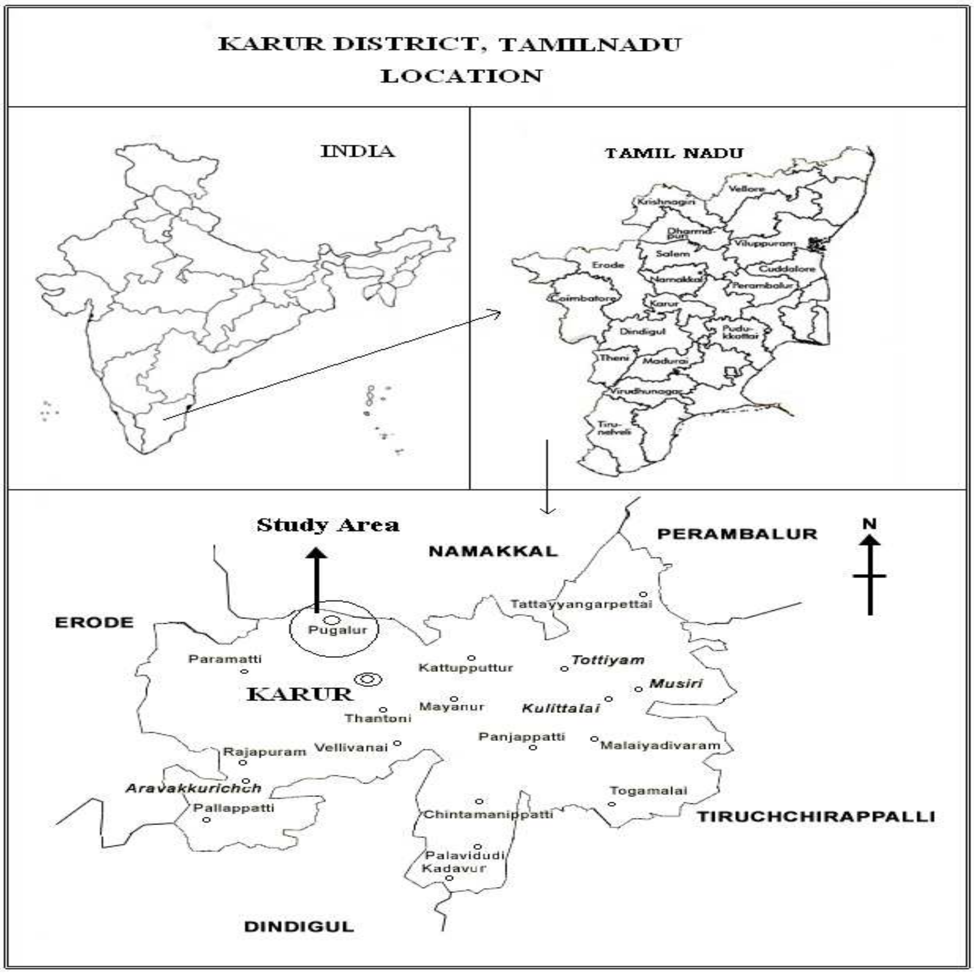

Fig. 1. Map of the Study Area

Details of the study area

Pugalur area (Fig. 1) lies between latitudes 11°5'N to 11.083°N and longitudes 78° 01' E to 78.017° E. The area covering lands both in cultivated and uncultivatedPugalur. The population of Pugalur is around 55,000.At present, Tamilnadu newsprint and papers limited (TNPL) and EID Parry India Private Limited is the major industries operating in this area. The temperature varies from 17° C to 38° C. The average annual rainfall is about 725 mm in cultivatedPugalur and 310 mm in uncultivatedPugalur. These areas get most of its seasonal rainfall from the northeast monsoon winds, from late September to mid November. The main dominant occupation of the people is agriculture and the main crops grown are sugarcane, paddy, plantain, yucca or manioc, groundnut, maize, millet and corn.

MATERIALS AND METHODS

SampleCollectionandAnalysis

Sixteen samples were collected for assessment of groundwater quality during the post monsoon season (January 2012) from the different deep bore hand pumps which are represented in Table 1. Hand pumps for sampling were selected on the basis of industrial unit as well as different land use patterns. Groundwater samples were collected in clean polyethylene bottles. At the time of sampling, bottles were thoroughly rinsed two or three times with groundwater to be sampled. The water samples were collected after flushingwaterfor 10-15 minutes to remove the stagnant water as per standard procedures [27].

Water temperature was measured on the site using a mercury thermometer while other parameters were determined in the laboratory within 48-72 h of the sampling following the standard methods [23, 28]. The samples were filtered using 0.45 µm Millipore filter paper and were stored in 4° C before analysis. Hydrogen ion concentration (pH), EC and TDS in water samples were analyzed with pH/EC/TDS Benchtop meter (Elico PE 138 Water quality analizer).TH, Calcium and Magnesium were measured by EDTA titrimetry.TA were determined using a titration with HCl. Chloride was titrated by silver nitrate, while sulphate and nitrate was obtained by spectrophotometric technique.Major cations like Na^+ and K^+ were determined using atomic absorption Spectrophotometer (Perkin ElmerAAnalyst 400 Spectrophotometer).

Table 1 Details of sampling location

Sampling code	Sampling station	Sampling code	Sampling station
S1	Kattur	S9	Velayudampalayam(W)
S2	Murugapalayam	S10	Moolimangalam
S3	Pugalur	S11	Sottaiyur
S4	Semmadaipalayam	S12	Nalliyampalayam
S5	Thottakurichi	S13	Semmadai
S6	Velayudampalayam(S)	S14	Thirukaduthurai
S7	Velayudampalayam(E)	S15	Gandhi Nagar
S8	Thavittupalayam	S16	Mullai Nagar TNPL

The reagents, including indicators and buffers, were of analytical grade (Merck). The aqueous solutions were prepared, using double distilled deionized water. The glassware employed in this study was of Borosil (India) grade. The standardization of reagents and solutions was in accordance with standard methods of water chemical analysis [29].

DataAnalysis

Water quality index (WQI) provides the overall water quality at a certain location and time, based on several water quality parameters. A water quality index based on some very important parameters can provide a simple indicator of water quality. To determine the suitability of the groundwater for drinking purposes, Water Quality Index [30] is computed by adopting the method which is formulated as

$$WQI = \Sigma^{n}_{i=1} (QiWi) / \Sigma^{n}_{i=1} (Wi) \quad (1)$$

Where, W_n, weightage = K/S_n and K, constant = $1/ [1/s_1 + 1/s_2 +.... 1/S_n]$ and S_n correspond to the WHO/ICMR standard value of the parameters. Quality rating (Q_i) is calculated as $Q_{ni} = [(V_{actual} – V_{ideal})/ (V_{standard} – V_{ideal})] *100$ where Q_{ni} = quality rating of 'i'th parameter for a total of 'n' water samples V_{actual} = value of the water quality parameter obtained from the analysis. $V_{standard}$ = value of the water quality parameters obtained from the standard tables. V_{ideal} for pH=7 and for the other parameters is equal to zero [31].

Correlationanalysismeasurestheclosenessoftherelationshipbetweenchoosingindependentanddependentvariables.This analysisattemptstoestablishthenatureoftherelationshipbetweenthevariablesandtherebyprovidesamechanismforpredicti on of forecasting.Inthisstudy,therelationshipofwaterqualityparametersoneachotherinthedataonwater analyzed was determined by calculating correlation coefficient using, r, by using the formula as given below,

$$r = [n\Sigma xy - (\Sigma x)(\Sigma y)] / [\sqrt{n(\Sigma x^2) - (\Sigma x)^2}\sqrt{n(\Sigma y^2) - (\Sigma y)^2}] \quad (2)$$

Where,x(x=valuesofx-variable)andy(y=valuesofx-variable)representstwo differentwaterqualityparameters and n=numberofdata points.

RESULTS AND DISCUSSION

Ground Water Chemistry

The results of various physico-chemical parameters are presented in Table 2 and their statistical measures such as minimum, maximum, average, median, mode are given in Table 3. The number and percentage of samples exceeding the allowable limits set by WHO [22] is given in Table 4.

The pH of all the groundwater samples was almost neutral, the range being 6.94 to 7.69. The EC is a valuable indicator of the amount of matter dissolved in water. The EC of water samples varied from 367µS/cm to 5652 µS/cm. EC of water is a direct function of its total dissolved solids [32]. Total dissolved solids ranged from 257 mg/L to 3956 mg/L. All the samples show high TDS level except S8. High TDS levels results in excessive staining of water pipes, water heaters and household appliances. Such scaling can shorten the service life of these appliances [33]. Hardness is an important factor for domestic as well as industrial purposes. Total hardness varied from 175 mg/L to 3184 mg/L. Water with hardness above 200 mg/L may cause scale deposition in the water distribution system and more soap consumption [34].

Table 2 Physicochemical parameters

Stations	pH	EC	TDS	TH	TA	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	NO_3^-	Na^+	K^+
S1	7.03	2527	1769	856	424	586	125	178	98	24	246	49
S2	7.26	1891	1324	647	440	354	94	154	63	19	171	23
S3	7.13	1585	1109	414	463	214	73	81	51	12	143	19
S4	7.31	2577	1804	886	412	475	188	186	101	19	27	56
S5	7.20	1330	931	310	372	198	65	67	35	11	133	21
S6	6.96	2567	1797	677	451	545	178	150	72	22	189	44
S7	7.13	2189	1532	846	352	465	173	162	72	25	196	31
S8	7.69	367	257	175	139	28	15	33	22	7	21	4
S9	6.94	1862	1304	414	400	331	54	86	48	14	177	43
S10	7.15	5652	3956	3184	376	1364	730	657	370	29	296	59
S11	7.14	2955	2069	1353	313	747	164	301	144	27	201	29
S12	7.43	1306	914	255	206	246	76	54	29	14	163	27
S13	7.19	2348	1644	706	681	323	95	150	79	20	171	33
S14	7.55	1220	854	402	341	170	67	86	45	16	113	21
S15	7.20	1826	1278	513	364	331	107	109	58	18	147	37
S16	7.44	1225	857	386	372	158	62	74	48	16	126	25

All the values are expressed in mg/L except pH and EC in µS/cm

Table 3 Statistical measures of groundwater samples

Water quality parameters	Units	Average	Maximum	Minimum	Median	Mode
pH	-	7.23	7.69	6.94	7.19	7.20
EC	µs/cm	2088	5652	367	1876.5	-
TDS	mg/L	1462	3956	257	1314	-
TH	mg/L	751	3184	175	580	414
TA	mg/L	378	681	139	374	372
Cl^-	mg/L	396	1364	28	331	331
SO_4^{2-}	mg/L	142	730	15	94.5	-
Ca^{2+}	mg/L	156	657	33	129.5	86
Mg^{2+}	mg/L	84	370	22	60.5	48
NO_3^-	mg/L	18	29	4	18.5	19
Na^+	mg/L	164	296	21	171	171
K^+	mg/L	31	59	4	30	21

Ionic Chemistry

Major anion and cation concentrations are shown in Table 2. Alkalinity is a total measure of substances in water that has acid neutralizing ability. Carbonate, bicarbonate and hydroxide compounds in rocks are the main sources of natural alkalinity [35]. TA values of all the samples were found to be greater than the standards except S8 and S12.

An excess of Cl^- in water is usually taken as an index of pollution and considered as tracers for groundwater contamination [36]. Chloride concentration was found in the range of 28 mg/L to 1364 mg/L. Cl^- greater than 100 mg/L affects the aesthetic property of water including taste and is classified as a zone of diffusion [37]. Concentration of sulphate ions varied from 15 mg/L to 730 mg/L. High concentration of sulphate has a laxative effect [38], which is enhanced when sulphate is consumed with magnesium.

Table 4 The number and % of samples exceeding the allowable limits set by WHO

Water quality parameters	Units	WHO (2005)		No. of samples exceeding allowable limits	Percentage of samples exceeding limits	Undesirable effects
		Desirable limits	Maximum limits			
pH	-	7-8.5	9.2	0	0	Taste
EC	µs/cm	1000	2000	7	43.75	Gastrointestinal irritation
TH	mg/L	300	500	9	56.25	Scale deposition
TA	mg/L	100	500	1	6.25	Unpleasant taste
Cl^-	mg/L	200	600	2	12.50	Salty taste
SO_4^{2-}	mg/L	200	400	1	6.25	Laxative effective
Ca^{2+}	mg/L	75	200	2	12.50	Scale formation
Mg^{2+}	mg/L	50	150	1	6.25	Encrustations in water supply structure
NO_3^-	mg/L	45	100	0	0	Blue baby disease
Na^+	mg/L	-	200	4	25.0	Salinity
K^+	mg/L	-	12	15	93.75	Bitter in taste
TDS	mg/L	500	1500	7	43.75	Gastrointestinal irritation

The cations of Ca^{2+} and Mg^{2+} are directly connected to pH value. The higher Ca^{2+} content, the less the negative impacts of Na^+ and Cl^-[39]. The concentration of Ca^{2+} varied from 33 mg/L to 657 mg/L. Mg^{2+} ranged from 22 mg/L to 370 mg/L. More Mg^{2+} present in the water will adversely affect the soil quality converting it to alkaline and decrease crop yields [40].

The concentration of nitrate ranges from 7 mg/L to 29 mg/L. WHO prescribed maximum permissible concentration for nitrate as 100 mg/L. The consumption of water with high nitrate concentration causes blue babies or methaemoglobinaemia disease in infants, gastric carcinomas, abnormal pain, central nervous system birth defects and diabetes [41]. Nitrate is less toxic to animal and human health than nitrite. Nitrates are extremely soluble in water and can more easily transfer through soil into the drinking water supply[42]. The fertilizers and domestic wastes are the main sources of nitrogen containing compounds and they are converted into nitrates in the soil. Na^+ and K^+ ranges from 21 mg/L to 296 mg/L and 4 mg/L to 59 mg/L respectively. Sodium is found in association with high concentration of chloride resulting in salinity. Na^+ and K^+ concentrations are also influenced by the cation exchange mechanism [43].

Drinking water quality

Water quality index

For computing WQI values, each of the 12 parameters has been assigned a weight (W_i) and water quality rating (Q_i) according to the guidelines laid down by the WHO[44]. The computed WQI value ranges from 46.83 to 206.39 are shown in Table 5. The high value of WQI at these stations has been found to be mainly from the higher values of EC, TDS, chloride, hardness and bicarbonates. Table 6 shows the percentage of water samples that falls under different quality from “excellent water” to “water unsuitable for drinking”. None of the samples are in excellent range, about 6.25 % of water samples are in good quality while 50% are in poor range. Eight samples are in very poor quality (31.25%) and 12.50% samples are unfit for drinking purpose. 95% of the groundwater samples are not suitable for drinking purposes.

Table 5 WQI value of groundwater samples

Sampling station	WQI Value	Sampling station	WQI Value
S1	79.67	S9	46.83
S2	76.89	S10	206.3
S3	57.03	S11	103.7
S4	94.72	S12	56.37
S5	51.39	S13	87.78
S6	68.01	S14	73.90
S7	79.61	S15	64.82
S8	55.70	S16	68.75

Table 6 Water quality classification based on WQI value

WQI value	Water quality	Sample station	% of water samples
0-24	Excellent	-	0
25-49	Good	S9	6.25
50-74	Poor	S3,S5-6,S8,S12,S14-16	50
75-100	Very poor	S1,S2,S4,S7,S13	31.25
>100	Unfit for drinking	S10,S11	12.50

Statistical analysis

Correlation analysis is a preliminary descriptive technique to estimate the degree of association among the variables involved [33]. The degree of a linear association between any two of the water quality parameters, as measured by the simple correlation coefficient (R), is presented in Table 7. Most of the parameters were found to bear a statistically significant correlation with each other indicating close association of these parameters with each other.

Table 7 Correlation coefficient matrix

Parameters	pH	EC	TDS	TH	TA	Cl^-	SO_4	Ca	Mg	NO_3	Na	K
pH	1.00	-0.51	-0.51	-0.29	-0.55	-0.48	-0.26	-0.30	-0.27	-0.51	-0.66	-0.60
EC		1.00	1.00	0.96	0.30	0.98	0.93	0.96	0.95	0.83	0.70	0.78
TDS			1.00	0.96	0.30	0.98	0.93	0.96	0.95	0.83	0.70	0.78
TH				1.00	0.12	0.96	0.97	1.00	1.00	0.76	0.63	0.62
TA					1.00	0.14	0.07	0.12	0.11	0.31	0.29	0.37
Cl						1.00	0.93	0.97	0.95	0.84	0.72	0.73
SO_4							1.00	0.96	0.97	0.67	0.59	0.64
Ca								1.00	0.99	0.77	0.64	0.62
Mg									1.00	0.71	0.61	0.63
NO_3										1.00	0.72	0.67
Na											1.00	0.48
K												1.00

EC and TDS (R = 0.98, 0.96) had a strong correlation with a number of parameters like TH, Cl^-, Ca^{2+}, SO_4^{2-}, Na^+ and K^+ indicating the high mobility of these ions. The high correlation between EC and chloride may be attributed to the fact that high conductance reflects the presence of high chloride content in the groundwater samples. Total hardness shows good correlation with Cl^-, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Na^+ and K^+. Calcium and Magnesium have good correlation with chloride and sulphate (R= 0.97 and 0.95 respectively) indicating that it is in the form of $CaCl_2$, $MgCl_2$, NaCl and $CaSO_4$, $MgSO_4$ respectively. This approves the abundance of calcium and magnesium rich minerals such as gypsum, limestone etc in the study area.

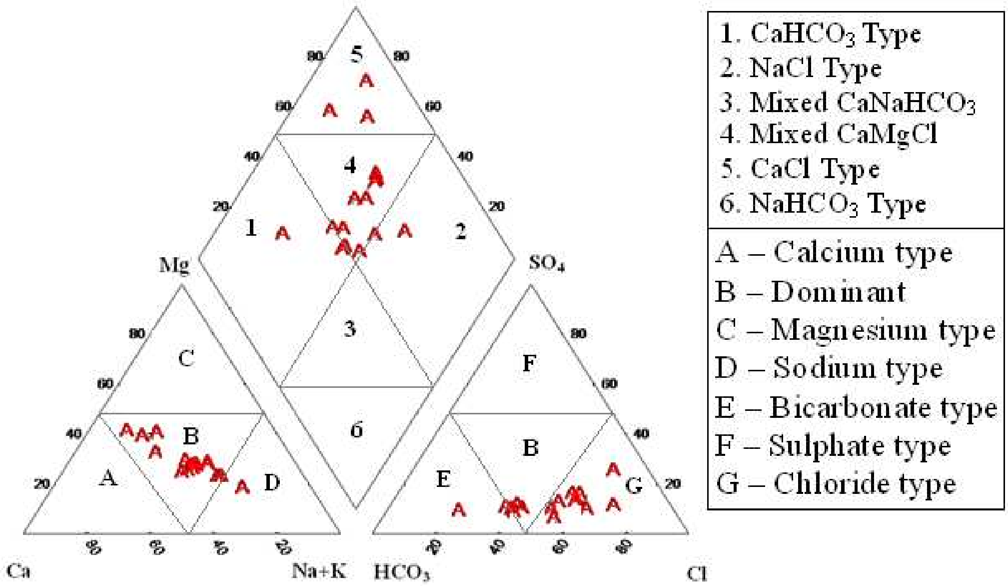

Fig. 2. Chemical facies of groundwater in Piper diagram

Graphical representation of hydro geochemical data

The term hydrochemicalfacies is used to describe the bodies of groundwater in an aquifer that different their chemical composition [45]. The facies are a function of the lithology, solution kinetics and flow patterns of the aquifer. Large tables of analytical data are usually difficult to interpret regarding the variations in water quality.

Graphs are useful for this purpose and several specialized types are in use. Piper diagram is one of them.Aquachem software was used for plotting the Piper diagram.

The values obtained from the groundwater samples analysis, and their plot on the Piper trilinear diagram reveal that the dominant cation is Ca^{2+} and Na^{+} and the anion is Cl^{-} and HCO_3^{-}. On the basis of chemical analysis, groundwater is divided into six facies (Fig. 2). The plot shows that the groundwater samples fall in the field of mixed Ca-Mg-Cl type. Some samples are also represented as Na-Cl, Ca-Cl and $Ca\text{-}HCO_3$ type. From the plot it is observed that the alkaline earths (Ca^{2+} and Mg^{2+}) exceed alkalis (Na^{+} and K^{+})and strong acids (Cl^{-} and SO_4^{2-}) exceed the weak acid (HCO_3^{-}).

Irrigation water quality

The excess amount of dissolved ions such as sodium, bicarbonate and carbonate in irrigation water effects plants and agricultural soil physically and chemically is thus reducing the productivity. The physical effects of their ions are to lower the osmotic pressure in the plant structural cells, thus preventing water from reaching the branches and leaves [46]. Excess salinity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil [47]. Salinity and indices such as, sodium adsorption ratio (SAR), sodium percentage (Na %), residual sodium carbonate (RSC), and permeability index (PI) are important parameters for determining the suitability of ground water for irrigation uses [9].

Table 8 Irrigation quality of groundwater based on several classifications

% Na	Classification	Sample station	Number of samples	% of samples
<20	Excellent	-	-	-
20-40	Good	S8, S10, S11	3	18.75
40-60	Permissible	S1-4, S6, S7, S13-16	10	62.50
60-80	Doubtful	S5, S9, S12	3	18.75
>80	Unsuitable	-	-	-
Based on alkalinity hazard (SAR) after Richards (1954)				
< 10	Excellent	S1-16	16	100
10-18	Good	-	-	-
18-26	Doubtful	-	-	-
>26	Unsuitable	-	-	-
Based on RSC after Richards (1954)				
<1.25	Good	S4, S7, S8, S10-12	6	37.50
1.25-2.50	Doubtful	S1-2, S6, S14-16	6	37.50
>2.50	Unsuitable	S3, S5, S9, S13	4	25

Sodium adsorption ratio (SAR)

Sodium adsorption ratio can indicate the degree to which irrigation water tends to enter into cation-exchange reactions in soil. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure and becomes compact and impervious. SAR is defined by Karanth[48] as

$$SAR = Na^{+} / \sqrt{(Ca^{2+} + Mg^{2+})/2} \quad (3)$$

Where all the Ionic concentrations are expressed in meq/L. The SAR values range from 1.415 to 8.945 and according to the SAR classification [49] 100 % of water samples (Table 8) fall in the excellent category of which can be used for irrigation on almost all soils. A more detailed analysis of the suitability of water for irrigation was made by plotting the data on US Salinity Laboratory diagram [50].

USSL diagram

The SAR v's EC values for groundwater samples of the study area were plotted in the USSL graphical diagram of irrigation water (Fig. 3). Based on USSL diagram, the water quality shows that the majority of the samples falls in the C4-S1 (very high salinity with low sodium), C3-S1 (high salinity with low sodium) categories, a single sample fall in the field of C2-S1 (medium salinity with low sodium), which can be used for irrigation on all types of soil without danger of exchangeable sodium.

Percent sodium (% Na)

Sodium concentration plays an important role in evaluating the groundwater quality for irrigation because sodium causes an increase in the hardness of the soil as well as a reduction in its permeability. The sodium percentage (Na %) is calculated using the formula given below,

$$Na\% = (Na^{+}+K^{+})*100/ (Ca^{2+}+Mg^{2+}+ Na^{+}+K^{+}) \quad (4)$$

Where, all the Ionic concentrations are expressed in meq/L. Na % in Table 8 indicates that the groundwater is found good only in three locations (18.25%). More than 62 (62.50) percentage of the groundwater samples is permitted for irrigation (Fig. 4) in almost all types of soils with little danger of exchangeable sodium. While the sample numbers S5, S9, S12 (Comprising 18.75%) are categorized under doubtful for irrigation.

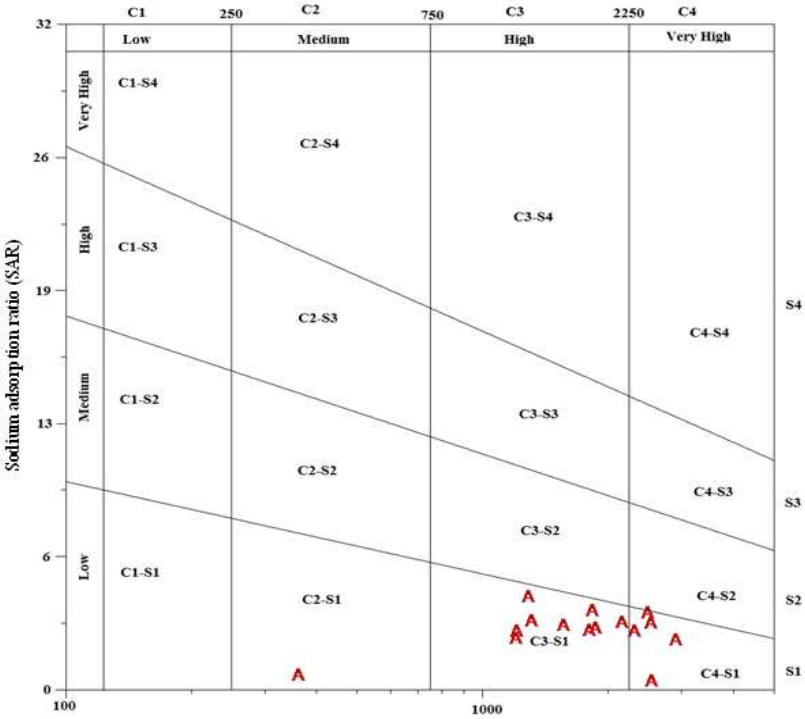

Fig. 3 USSL diagram for irrigation water quality classification (USSL 1954)

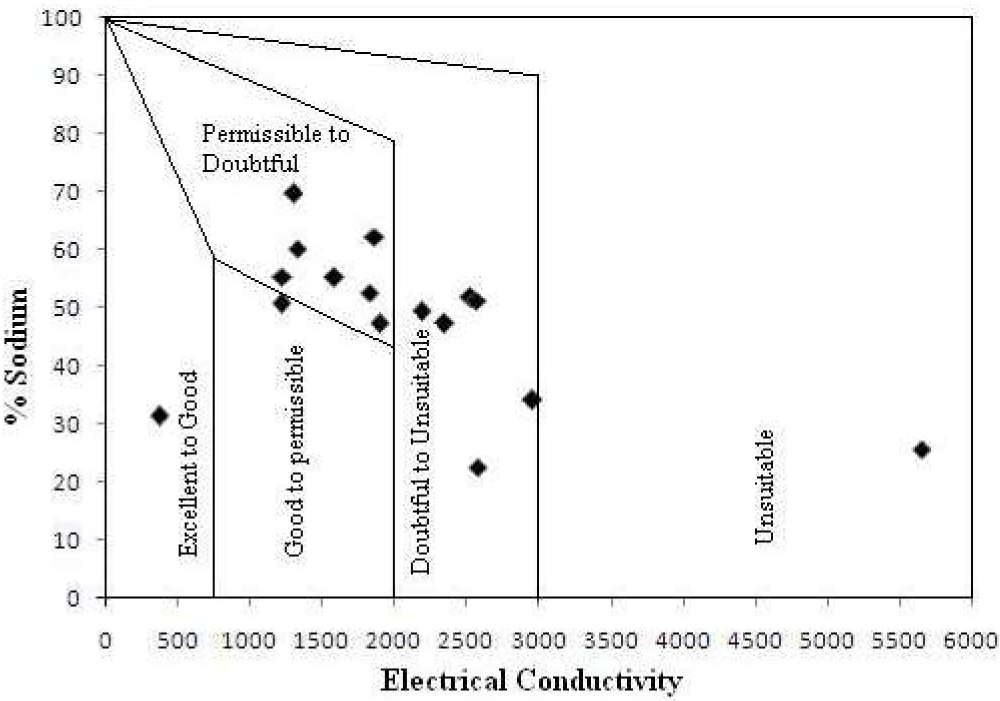

Fig. 4. Classification of irrigation water (after Wilcox 1955)

Residual sodium carbonate (RSC)

In addition to the SAR and % Na, the excess amount of carbonate and bicarbonate in groundwater over the sum of Ca^{2+} and Mg^{2+} also influences the suitability of groundwater for irrigation. An excess of sodium bicarbonate and carbonate is considered to be detrimental to the physical properties of soils as it causes dissolution of organic matter in the soil, which in turn leaves a black stain on the soil surface on drying. This excess amount is denoted by Residual Sodium Carbonate (RSC) and has been determined as follows [51]

$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$ (5)

Where, all the Ionic concentrations are expressed in meq/L. The classification of irrigation water according to the RSC values indicate that water containing more than 2.5 meq/L of the RSC is not suitable for irrigation, while those having 1.25 - 2.5 meq/L are doubtful and those with less than 1.25 meq/L are good for irrigation. The calculated value reveals that only 37.5 % samples are in the good category while 37.5 % of samples fall into doubtful category (Table 8) and the number of samples in unsuitable category is about 25 %. Poor agricultural returns in this area are partly due to this reason.

Permeability index (PI)
The soil permeability is affected by long-term irrigation influenced by Na^+, Ca^{2+}, Mg^{2+} and HCO_3 contents of the soil. The permeability index values also indicate the suitability of groundwater for irrigation. It is defined as

$PI = (Na^+ + \sqrt{HCO_3}) *100 / (Ca^{2+}+Mg^{2+}+ Na^++K^+)$ (6)

The concentrations are expressed in meq/L. The PI ranges from 23.1% to 69.1%. The average value was about 48.2%. WHO [44] uses a criterion for assessing the suitability of groundwater for irrigation based on permeability index. According to PI values, the groundwater in the study area can be designed as a class II (25 - 75%) that shows the groundwater in the study area is suitable for irrigation purposes.

Water quality management
Water quality management is related to broad concept of management of water resorurces for full and efficient utilization by man. It implies the utilization and development of water in a way that maintains its quality at optimum level for present and future users [52].

The present study area has moderate amount of rainfall. If the rainfall is used properly, it can be possible to reduce the concentrations of TDS, TH, calcium, sodium and potassium well below the safe limits for drinking and irrigation purposes, by simply following the water management techniques like rainwater harvesting.

Suggestions
Public awareness program on the consequences of inferior water quality on human health, agricultural fields and industrial sectors shall be made mandatory which is a key factor for successful water quality management for sustainable development. Policy makerers, planners, and administators must take the responsibility for implementing appropriate site-specific measures to improve the water quality.

CONCLUSION

The hydro geochemical analysis reveals that the groundwater in the study area is better for irrigation and unfit for drinking purposes except the station S9. High TDS, Na, K and TH at a number of areas clearly indicate the unsuitability of groundwater for drinking purposes. The alkaline earths (Ca^{2+} and Mg^{2+}) exceed the alkalis (Na^+ and K^+) and Cl^- exceeds other anions. This leads to a mixed Ca-Mg-Cltype of groundwater. However, few groundwater samples represent Na-Cl, Ca-Cland Ca-HCO_3 types. The water quality based on WQI revealed that only 6% (6.25) is fit for drinking and 50, 31.75 and 12.50 percentages of samples falls in poor, very poor and unfit for drinking purposes respectively. When WQI is greater than 100, it implies that the pollutants are above the standard limits. Similarly 0 < WQI > 100 reflects its unsuitability for human use. A high linear relationship between chloride and sulphate with calcium and magnesium indicating the hardness of water is permanent in nature. The occurrence of high EC values in the study area reflected the addition of some salts through the prevailing agricultural activities. About 18.75% samples are in good line and 62.50% samples are permissible for irrigation with little danger of exchangeable sodium. The stations S5, S9 & S12 are doubtful for irrigation purposes based on Na% values. However, SAR and PI values indicate that almost all the groundwater samples are suitable for irrigation.

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REFERENCES

[1] Shakeri, A., Moore, F., Mohammediz, and Raeisie, E. *World ApplSci J*, **2009,** 7: 522-530.
[2] Milovanovic, M. *Desalination*, **2007,** 213: 159-173.
[3] Foster, S.S.D. *Groundwater quality, 17th special Report*, Chapman and Hall, London United.**1995,**pp 1-3.

[4] Vasanthavigar, M., Srinivasamoorthy, K., Gandhi, R., Chidambaram, S., and Vasudevan, S.*Environ Monit Assess*, **2010,**171 (1-4): 595-609.
[5] Chatterjee, R., Goorab, T. and Paul, S. *Bull EngGeol Environ*,**2010,** 69: 137-141.
[6] Sreedevi, P. D.*J GeolSoc India*, **2004,** 64: 619-636.
[7] Schiavo, M. A., Havser, S., Gusimano, G., and Gatto, L.*Cont shelf Res*, **2006,** 26 (7): 826-834.
[8] Subramani, T., Elango, L., and Dhamodarasamy, S. R. *Environ Geo*,**2005,** 47: 1099-1110.
[9] NosratAghazadeh and AsgharAcghariMogaddam.*J Environ Prot*,**2010,** 1: 30-40.
[10] Bordalo, A.A., Nilsumranchit, W. and Chalermwat, K. *Water Res*,**2001,** 35(15): 3635-3642.
[11] Cude, C. G.*J Am Water Resour As*,**2001,** 37(1): 125–137.
[12] Nasirian, M.*J ApplSci*,**2007,** 7: 2977–2987.
[13] Simoes, F. S., Moreira, A. B., Bisinoti, M. C., Gimenez, S. M. N., and Yabe, M. J. S. *Ecol Indic*,**2008,** 8: 476–484.
[14] Fulazzaky, M. A., Seong, T., and Masirin, M. *Water Air Soil Pollut*,**2010,** 205: 63–77.
[15] Upadhyay, R., Dasgupta, N., Hasan, A., and Upadhyay, S. K.*PhysChem Earth*, **2010,** doi:10.1016/j.pce.2010.03.018
[16] Kalavathy, S., Rakesh Sharma, T. and Sureshkumar, P. *Arch Environ Sci*,**2011,** 5: 55-61.
[17] Sarkar, C., and Abbasi, S. A.*Environ Monit Assess*,**2006,** 119: 201–231.
[18] Liou, S., Lo, S., and Wang, S. *Environ Monit Assess*,**2004,** 96: 35–52.
[19] Debels, P., Figueroa, R., Urrutla, R., Barra, R., and Niell, X. *Environ Monit Assess*,**2005,** 110: 301–322.
[20] Said, A., Stevens, D. K., and Sehlke, G. *Environ Monit Assess*,**2004,** 34 (3): 406–414.
[21] Kannel, P., Lee, S., Lee, Y., Kanel, S., and Khan, S. P. *Environ Monit Assess*,**2007,** 132: 93–110.
[22] WHO, *International Standards for drinking water.*World Health Organization **(2005)**, Geneva.
[23] ICMR,*Manual of standards of drinking water supplies*,Indian Council of Medical Research,**1975,** No. 44, New Delhi.
[24] Sivakumar, K. K., Balamurugan, C., Ramakrishnan, D., and LeenaHebsibai, L. *Water R & D*,**2011,** 1(1): 36-39.
[25] Raja,G.,andVenkatesan, P.*E-J Chem*, **2010,** 7(2): 473-478.
[26] Rajamanickam, R., and Nagan, S. *Int J Environ Sci*,**2010,** 2(1): 91-108.
[27] BIS *Indian standards specification for drinking water 15:10500.*Bureau of Indian Standard,**2003,** New Delhi.
[28] Vogel, A. I.*A textbook of Quantitative inorganic analysis including elementary instrumental analysis*,**1978,** 4th edn, pp. 504-506.
[29] APHA, *Standard method for the examination of water and wastewater*,**2005,** 21st edn. American Public Health Association, Washington.
[30] Tiwari, T. N., and Mishra, M. A.*Indian J Environ Prot*,**1985,** 5: 276-279.
[31] RizwanReza, and Gurdeep sing. *World ApplSci J*,**2010,** 9 (12): 1392-1397.
[32] Harilar, C.C., Hashim, A., Arun, P.R. and Baji, S. *J Ecol Environ Conserv*,**2004,** 10 (2): 187-192.
[33] Aqueel Ashraf, M., JamilMaah, M. and IsmailYusoff.*E-J Chem*,**2010,** 7(51): 5245-5254.
[34] Maruthidevi, Ch., and UshaMadhur, T.*Nat Environ Poll Tech*,**2011,** 10 (3): 481-483.
[35] Patil, V. T. and Patil, P. R. *E-J Chem*,**2011,** 8 (1): 53-58.
[36] SumanMor, KhaiwalRavindra, Dahiya, R. P., and Chandra,A. *Environ Monit Assess*,**2006,** 118: 435-456.
[37] Majolagbe, Adeleke, A., Kasali., and LateefOhhaniyu. *AdvApplSci Res*,**2011,** 2(1): 289-298.
[38] Lorraine, C. B.*Crit Rev Clin Lab Sci*,**2003,** 37: 389-400.
[39] WaleedManasreh, Atef, S., Alzaydien, and Malahmeh, M.*E-J Chem*,**2009,** 6 (51): 5287-5303.
[40] Gowd, S.S. *India Environ Geo*,**2005,** 48: 702-712.
[41] Krishna Kumar, S., Rammohan, V., DajkumarSahayam J. and Jeevanandam, M.*Environ Monit Assess,* **2009,** 159: 341-351.
[42] Saba, S., Nalan, K., Umran, Y., Muserref, A., and Mithat, Y. *React FunctPolym*,**2006,** 66: 1206-1214.
[43] Elango, L., Lakshmanan, E., Kannan, K. and Senthilkumar, M.*India J Environ Geo Sci*,**2003,** 10 (4): 157-166.
[44] WHO, *Health guidelines for the use of wastewater in agriculture and aquaculture.***1989,** 778: pp. 74, Geneva.
[45] Aghazadeh, N. and Mogaddam, A. A. *Environ Monit Assess*,**2011,** 176: 183–195.
[46] Imran Ahamed Dar, Sankar, K. and MithasAhamed Dar.*Environ Monit Assess*,**2011,** 178: 437-447.
[47] Saleh, A., Al-Ruwih, F., and Shehata, M. *J Arid Environments*,**1999,** 42: 195-209.
[48] Karanth, K.R. *Groundwater assessment, development and management.***1987,**pp. 720, New Delhi.
[49] Richards, L. A. *Diagnosis and improvement of saline alkali soils: Agriculture.* Handbook, US department of Agriculture,**1954,** Vol. 160: pp 60,Washington DC.
[50] USSL,*Diagnosis and improvement of saline alkali soils: Agriculture.* USDA, Handbook, **1954,** Vol. 60: pp. 147.
[51] Ragunath, H. M. *Groundwater*,**1987,**pp. 563, Wiley Eastern, New Delhi.
[52] SubbaRao, N., Surya Rao, P., Venktram Reddy, G., Nagamani, M., Vidyasagar, G., and Satyanarayana, N. L. V. V. *Environ Monit Assess*,**2012,** 184: 5189-5214.

Kumar, M. (2004) An integrated hydro chemical and isotopic study of NCR-Delhi, India [in English]. M. Phil, Jawaharlal Nehru University.