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RESEARCH ARTICLE

ASSESSMENT OF GROUNDWATER QUALITY WITH A SPECIAL EMPHASIS ON IRRIGATIONAL UTILITY IN CHINNAR WATERSHED, CAUVERY RIVER, TAMIL NADU

S. Venkateswaran

Hydrogeology Lab., Department of Geology, Periyar University, Salem, Tamil Nadu

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ABSTRACT

A holistic assessment of the quality of groundwater from the shallow unconfined aquifer of the Chinnar watershed, Cauvery River, Tamil Nadu. An investigation was carried out by collecting a total of 57 groundwater samples for two seasons to decipher hydrogeochemistry and groundwater quality for determining its suitability for agricultural purposes. The water is neutral to alkaline in nature with pH ranging from 6.50 to 8.27 with an average of 7.82. Higher Electrical Conductivity (EC) was noted in most of the study area. Higher $NO3^-$ was observed during premonsoon (PRM) due to the action of leaching and anthropogenic process. The piper plot reveals the dominance mixed $Ca^+Mg\ ^+Cl$ type in PRM samples and Ca^+Mg^+Cl, Ca^+HCO_3 type in post monsoon (POM) samples of hydrogeochemicalfacies. Residual Sodium Carbonate value indicates almost all the samples are suitable for irrigation purposes in both seasons. Sodium percentage is noted during PRM and POM samples in potable. USSL plot indicates most of the samples fell in C_3S_1 domain and it is suitable for irrigational purposes. The Doneen's Permeability Index plot samples fell in Class I and Class II category indicates water is good for irrigation purposes in both seasons. In general, groundwater in the study area influenced natural and anthropogenic activities.

INTRODUCTION

Water shortages have become an increasingly serious problem in India, especially in the arid and semi-arid regions of the country due to vagaries of monsoon and scarcity of surface water. Over the few decades, competition for economic development, associated with rapid growth in population and urbanization, has brought in significant changes in land use, resulting in more demand of water for agriculture, domestic and industrial activities. In India, groundwater constitutes about 53% of the total irrigation potential of the country (FAO 2003) and about 50% of the total irrigated area is dependent on groundwater irrigation (Central Water Commission 2006). Sixty percent of irrigated food production is from groundwater wells (Shah *et al.* 2000). All these lead to the overexploitation of this precious natural resource in several parts of the country resulting in declining groundwater level. Apart from water table decline, groundwater quality is also a major concern in many parts of the country. The monitoring of water quality is one of the important tools for sustainable development and provides important information for water management. The importance of water quality in human health has recently attracted a great deal of interest. In the developing world, 80% of all diseases are directly related to poor drinking water and unsanitary conditions (UNESCO 2006). Groundwater quality data gives important clues to the geologic history of rocks and indications of groundwater recharge, movement and storage (Walton 1970). Groundwater quality depletion by anthropogenic activities, such as urbanization and agricultural activities is a major problem in Chinnar watershed. Hence, evaluation of groundwater quality is a necessary and immediate task for present and future groundwater quality management.

Groundwater quality, 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-rock interaction (Domenico1972; Schuh *et al.* 1997). Such factors and their interactions result in a complex groundwater quality (Hussein 2004). Numerous publications have concentrated on groundwater quality monitoring and evaluation for domestic and industrial activities (Al-Futaisi *et al.* 2007; Jalali2005; Pritchard *et al.* 2008; Rivers *et al.* 1996; Vasanthavigar *et al.* 2010; Srinivasamoorthy *et al.* 2008). Srinivasamoorthy *et al.* (2009) identified lithological influence and dominance of anthropogenic impact on groundwater chemistry in Salem district of Tamilnadu, India. Ma *et al.* (2009) reported high salinity and nitrate in groundwater from Wuwei basin, northwest China. Identification of geochemical facies and demarcation of locations unfit for human consumption was attempted by Mohan *et al.* (2000) in Uttar Pradesh state of India. Demarcation of groundwater zones on the basis of quality was attempted by SubbaRao *et al.* (2002) in Guntur of Andhra Pradesh, India. Classification of groundwater was attempted by Ahmed *et al.* (2002) and Bathrellos *et al.* (2008) and suggested groundwater suitability for drinking and public health. Similar studies in different parts of The globe was also attempted by Anku *et al.* (2009), Jalali (2007), Kumar *et al.* (2009), Wen *et al.* (2008), Stamatis *et al.* (2006), Pachero *et al.* (2001), and Antoniou (2002). The concentrations of dissolved

* Corresponding author: **S. Venkateswaran**
Hydrogeology Lab., Department of Geology, Periyar University, Salem, Tamil Nadu

ions in groundwater are governed by lithology, groundwater flow, nature of geochemical reactions, residence time, solubility of salts, and human activities (Nisi *et al.* 2008). Moreover, the groundwater quality is mostly affected by either natural geochemical processes such as mineral weathering, dissolution/precipitation reactions, ion exchange, or various manmade activities such as agriculture, sewage disposal, mining and industrial wastes, etc. The surface runoff from the agricultural field is one of the main sources for nutrients and salinity in the groundwater (Stites and Kraft 2001). Agricultural contamination of groundwater usually results from routine applications of fertilizers on cropped fields and a process that accumulates the nutrients in groundwater. Several researchers evaluated the suitability of groundwater for irrigation quality Prasanna *et al.* 2010; Tyagi *et al.* 2009; Laluraj and Gopinath2006; Nagarajan *et al.* 2009, and Jeevanandam *et al.* 2006). Nitrate is one of the common contaminant identified due to agricultural activities. In humans, a condition called methemoglobinemia, also known as blue baby syndrome, results due to ingestion of high nitrate in inorganic form. Nitrate (>300 mg/l) poisoning may result in the death of livestock consuming water (Canter 1997). Nitrate contamination is strongly related to land use pattern (Rajmohan *et al.* 2009). Total dissolved solids (TDS) values are also considered as an important parameter in determining the usage of water, and groundwater with high TDS values are not suitable for both irrigation and drinking purposes (Freeze and Cherry 1979).

A detailed geochemical study was carried out to identify groundwater contamination processes in the Chinnar watershed, Tamilnadu, India. The study area being a hard rock terrain is generally precarious to get their supply during monsoon seasons, in nonmonsoonal seasons people depend on groundwater resources for their domestic, agricultural, and industrial activities. About 70% of the study area is dominated by human and agricultural activities. The trend analysis of historical ground water level data also indicates a long-term fall (CGWB 2008a, b). Based on the above factors, it is inferred that a major part of the district could be considered vulnerable to various environmental impacts of water quality degradation and water level depletion. Hence, an attempt has been made in this study to characterize the groundwater chemistry with reference to natural and manmade activities.

Hydrogeological Setting

The study area lies between North Latitudes 12°45′27’’and 12°04’36’’East Longitudes 77°36′14’’and 78°04′41’’with a total drainage of1, 592 km^2. The river originating on the NW slope of vattalaimalai (1195m AMSL) at Krishnagiri district and configures river Cauvery at Hogenakal Waterfalls in Dharmapuri district. (Fig.1). The mean temperature variesfrom 24°C to 40°C. The annual average rainfall over thestudy area is about 733 mm to1853 mm followed bynortheast, postmonsoon and summer. The geology of the study area is composed of rock types represent by Charnockite, Granitic gneiss, Pyroxene granulite, Syenite and Ultra basic. Hills, Undulating plains, plateaus, pediments and bazadas are the mixture of geomorphic units of the study area. Development of groundwater is through dug and bore wells. Groundwater occurs in the weathered residium under unconfined conditions as well as in the fractured rocks under semi confined conditions. The depth of weathering ranges from 2.2 to 50 m, while the fractures in rocks extend to 50 m depth. Most of the shallow wells are confined to the weathered zone, while the bore well extends up to fractured zone. Thickness of weathering in the rocks ranges varies from 5 to 15 m near hills and 3 to 30 m in the plain area. Groundwater fluctuation ranges from 3.52 m to 11.38 m below ground level (BGL). It reaches lowest level during summer (March-June) and after it starts rising till the end of monsoon season (August–January).

MATERIALS AND METHODS

Samples collection

A total of 57 groundwater samples were collected from bore wells ranging in depth between 20 and 120 m BGL for two different seasons, premonsoon (PRM) January 2008 and post monsoon (POM) May 2008 (Fig.2). Each sample was collected by acid-washed polyethylene 1,000 ml bottle. The bottle was completely filled with water taking care that no air bubble was trapped within the water sample.

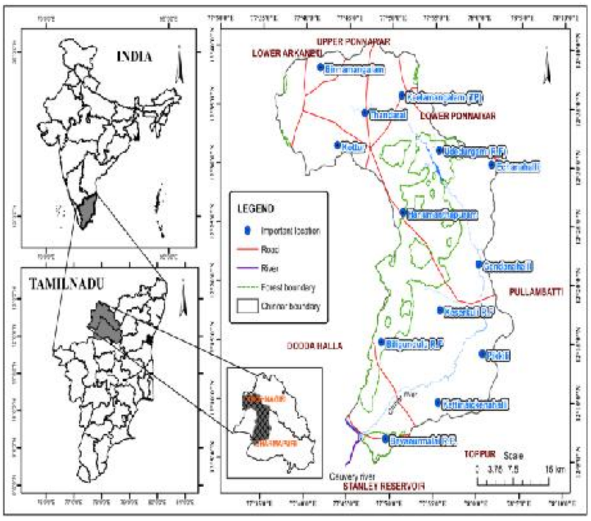


Fig.1 Study Area Map

Then to prevent evaporation, the double plastic caps of the bottles were sealed. Precaution was also taken to avoid sample agitation during transfer to the laboratory. The samples were immediately transferred to the laboratory and analysed for major ions by employing standard methods.

Laboratory measurements

Samples were analyzed in the laboratory for the major ions chemistry employing standard method (APHA 1995). Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were determined titrimetrically using standard EDTA. Chloride (Cl^-) by standard $AgNO_3$ titration, Bicarbonate (HCO_3^-) by titration with HCl, Sodium (Na^+) and Potassium (K^+) by flame photometry. EC, pH and TDS were measured insitu. Sulphate (SO_4^-) were determined by spectrophotometer CL 22D. Nitrate (NO_3^-), and Fluoride (F^-) by Consort Electrochemical Analyzer model C933.

The analytical precision for ions was determined by the ionic balances calculated as100× (cations−anions)/ (cations+anions), which is generally within ±5% (Srinivasamoorthy *et al.*2010).

Data treatment and classification methods

The parameters such as Sodium Adsorption Ratio (SAR), Percent Sodium (%Na), Residual Sodium Carbonate (RSC), Permeability Index (PI) and Kelly's Index (KI) were calculated to evaluate the suitability of the water quality for agricultural purposes. Further the results of the analyses were interpreted using graphical representations like Trilinear Piper's diagram and United States Salinity Laboratory (USSL) and Doneen's plots.

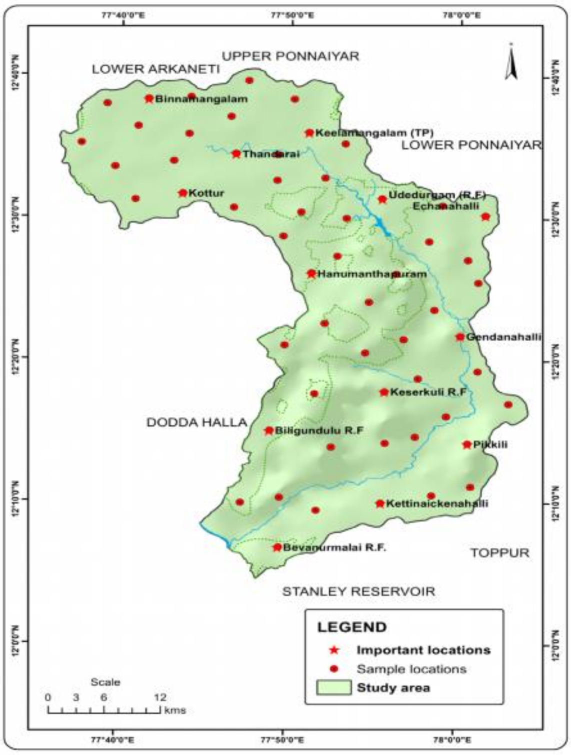


Fig.2 Water Sample Location Map

RESULTS AND DISCUSSIONS

Hydrogeochemical parameters of groundwater the physicochemical composition of the groundwater samples were statistically analyzed and the results such as maximum, minimum, average standard deviation parameters were discussed.

magnesium calcite, gypsum and/or dolomite from source rock (Garrels1967). During POM, bicarbonate is higher (612 mg/l) due to action of CO_2 which chemically reacts upon the minerals present in soil and granitic rock releases HCO_3 into the groundwater environment (Tyagi *et al.* 2009). Chloride is higher during POM (308 mg/l) due to industrial, domestic wastages and/or leaching from upper soil layers in dry climates (Srinivasamoorthy *et al.* 2008). Higher SO_4 is noted during PRM season (243.8 mg/l) due to action of sulphur gases from industries get oxidized and enter into the groundwater (Saxena2004). Fluoride is higher during PRM (1.61 mg/l) due to leaching from fluoride rich source rocks (Srinivasamoorthy *et al.* 2009), easier accessibility of rain water to weathered rock, long-term irrigation processes, semi-arid climate and long residence time of groundwater (Subbarao2006). Higher NO_3^- is noted in PRM (155 mg/l) indicating sources from plant nutrient leaching and application of nitrate fertilizers (Madison and Brunett1984).

Hill piper plot

Hydro chemical concepts can help to elucidate mechanisms of flow and transport in groundwater systems, and unlock an archive of pale environmental information (Pierre *et al.* 2005, and Hem 1991). The hydro chemical evolution of groundwater can be understood by plotting the major cations and anions in the Piper trilinear diagram (Piper 1994). This diagram reveals similarities and differences among water samples because those with similar qualities will tend to plot together as groups (Todd 2001). This diagram is useful in bringing out chemical relationships among water in more definite terms (Walton 1970). Major ions are plotted as cation and anion in percentages of milliequivalents in two base triangles. The total cations in meq/l and the total anions in meq/l are set equal to 100%. The data points in the two triangles are then projected onto the diamond grid (Fig.3). The projection reveals certain useful properties of the total ion relationships. Every sample is represented by three data points; one in each triangle and one in the diamond grid. The plot allows comparisons between a large numbers of samples like all trilinear plots it does not portray absolute ion concentrations.

Table1 Statistics of groundwater chemistry in both seasons (all values in mg/l except pH and EC)

Parameters	PRM				POM			
	Min.	Max.	Ave.	SD	Min.	Max.	Ave.	SD
Ca	33.5	104.5	69	50.20	29	154	91.5	88.39
Mg	14.5	106.95	39.50	65.37	13	93	34.35	56.57
Na	31.05	220.80	84.35	134.17	27	192	73.35	116.67
K	3.45	27.6	15.52	17.08	3	24	13.5	14.85
HCO_3	184	579	326.57	79.31	148	612	307.51	328.10
Cl	56	301.30	178.5	173.45	24	308	161	200.82
SO_4	4	243.8	120.5	169.56	11	130	70.5	84.15
NO_3	6	155	38.91	105.36	3	44	17.39	28.99
F	0.46	1.61	1.03	0.81	0.40	2	1.2	1.13
TDS	482	1150.80	816.4	472.91	301	1505	903	851.36
EC	689	1644	1101	675.29	430	2150	999.93	1216.22
pH	6.50	8.27	7.82	1.25	6.58	7.89	7.27	0.93

Note: Min.minimum, Max.maximum,Ave.average,SD.Standard Deviation PRM.preMonsoonPOM.Post Monsoon(All values in mg/l except pH and EC inμS/cm)

During PRM, Na^+ is ranged from 31.05 mg/l 220.80 mg/l indicating sources from weathering of feldspar (plagioclase) and over exploitation of groundwater (Hem 1985). Potassium is found to be higher during PRM (27.6 mg/l) due to weathering of K feldspars and clay minerals from aquifer matrix (Lakshmanan *et al.* 2003). During POM, Ca^{2+} is higher (154.1 mg/l), due to dissolution of $CaCO_3$ and CaMg $(CO_3)_2$ during recharge (Datta *et al.* 1996). During PRM, Mg^{2+} is higher (106.95 mg/l), indicating sources from dissolution of

The main purpose of this plot is to show clustering of samples. During PRM, majority of the groundwater samples irrespective of seasons fall in mixed Ca+Mg+Na type. During POM, change in the facies such asCa+Mg+Na and Na-$HCO_3$with minor representations were noted. From the plot it is inferred that increase of alkalis and alkaline earth is noted during PRM and POM, respectively Weak acid (HCO_3^-) exceeds strong acid ($Cl^-$and SO_4^-) in both the seasons. In general, calcite dissolution and reverse ion exchange process controls the water chemistry in thestudy area.

Spatial representation

The simplest way of representing groundwater quality information on a map is to contour the concentrations of a particular substance of interest. Hence, an attempt has been made to infer spatial variations of crucial ions determining the quality of groundwater.

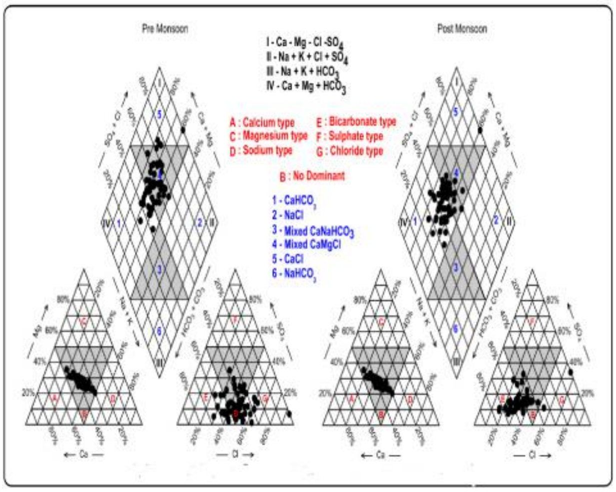


Fig. 3 Piper trilineardiagram of PRMand POMmonsoon seasons

EC is the most important parameter to demarcate salinity hazard and suitability of water for irrigation purpose. The EC varies from 689 to 1,644µS/cm and 430 to 2150µS/cm during PRM and POM, respectively. Higher was noted during POM when compared with PRM. The classification of groundwater on the basis of irrigation quality (WHO 2008) shows that 91.22% of PRM and (68.42%) of POM samples falls within the permissible limits. The PRM and POM season values are used to create the spatial distribution map for the study area (Fig. 4). Based on WHO standard the entire watershed has been delineated as i.Good (250-750), ii. Medium (750-2250) and iii.Very bad (>4000) good waters being as a pockets along upstream and boundaries of the study area. Domestic activities are confined to the upstream direction and agricultural activities area prominent along the downstream direction the study area.

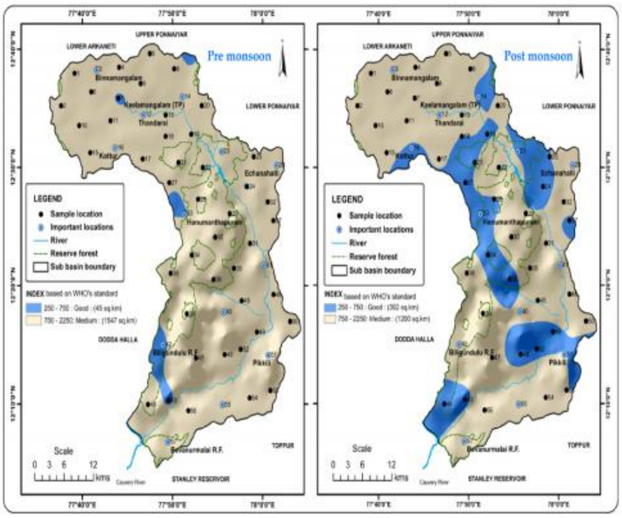


Fig.4 a, b Spatial distribution of EC (µS/cm) during *a* PRM and *b* POM monsoon seasons

Sodium

Sodium toxicity is recorded as a result of high sodium in water as Na% and SAR ratios. Typical toxicity symptoms to plants and trees are leaf burn and dead tissue along the outside edges of leaves. Symptoms appear first on the older leaves, starting at the outer edges and when the severity increases, move progressively inward between the veins toward the leaf centre. The maximum permissible limit of Na is 200 mg/l. The Na^+ ion ranges between 31.5 to 220.80 mg/l and 27 to 192 mg/l during PRM and POM season. Majority of water samples during both the seasons fall above the prescribed limit.(Fig. 5). The source of Na^+ into the groundwater is due to the weathering of feldspar and due to over exploitation of groundwater (Hem 1985).

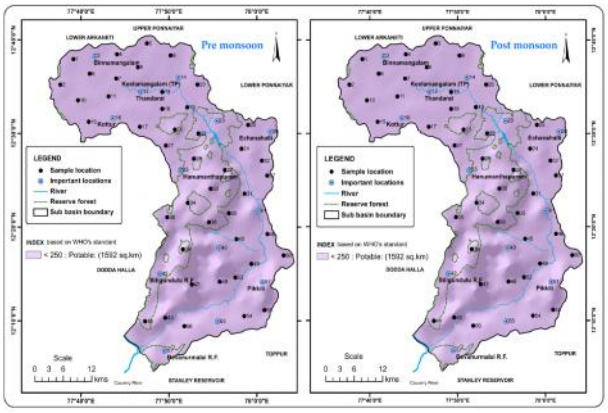


Fig.5 ***a, b*** Spatial distribution of Na during ***a***PRM and ***b***POM monsoon seasons

Chloride

The most common toxicity in water used for irrigation purpose is chloride. Chloride is not absorbed or held back by soils, therefore it moves readily with the soil-water gets adsorbed by crops, moves in the transpiration through stem, and accumulates in the leaves (Ayers and Westcot1994).Higher Cl−intake beyond the crop tolerance limit in plants develops symptoms like leaf burn and drying of leaf tissues.Excessive necrosis (dead tissue) is often accompanied byearly leaf drop or defoliation (Subbarao2006).The permissible limit of Cl^- in groundwater is 600 mg/l (WHO 2008).

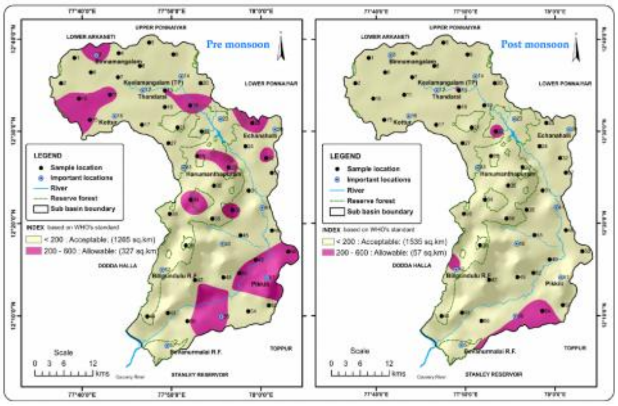


Fig.6 ***a,b*** Spatial distribution of Cl during ***a***PRM a nd ***b***POM monsoon seasons

Chloride is ranging from 56.35 to 301.30 and 24to 308 mg/l with an average of 178.5 and 161.0 mg/l during both the seasons. Table 2 shows that 29.82 % and 8% of the samples falls the allowable limit. Higher concentration was noted during PRM (301.30 mg/l) when compared with POM indicating the dominance domestic wastages and/or leaching from upper soil layers in dry climates (Srinivasamoorthy *et al.* 2008). The spatial distribution of Clinic concentration reveals that the acceptable limits of Cl (<200 mg/l) wider in the POM rather than PRM (Fig.6).

Nitrate

Nitrogen is a plant nutrient that stimulates crop growth, when applied in excess affects the crop by over stimulation of growth, delayed maturity and poor quality of crop yield. Sensitive crops may be affected by nitrogen concentrations above 5 mg/l. Most other crops are relatively unaffected until nitrogen exceeds 45 mg/l (Sundaray *et al.* 2009). Consumption of nitrogen above the permissible limit creates severe problem of blue baby disease/Methemoglobinemia in children and gastric carcinomas.

The NO_{3-} in the sample ranges from 6 to 155 and 3 to 44 mg/l with average of 38.91 and 17.39 mg/l during PRM and POM seasons. Higher NO_{3-} was noted during PRM along upstreamdirection of watershed where intensive irrigation practices area dominant (Fig.7).

soil alkalinity. Those samples would adversely affect the crop yield by making it more alkaline (Paliwal 1972).

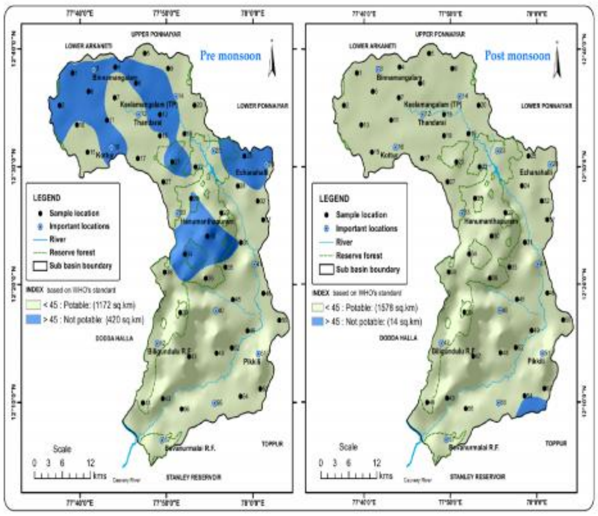


Fig.7 *a*, *b* spatial distribution of NO_3 during *a* PRM and *b* POM monsoon seasons

Table.2 Classification of groundwater quality based on suitability of water for Irrigation purposes

Parameters	Range	Class	No. of samples		Percentage of the samples	
			PRM	POM	PRM	POM
EC	<250	Excellent	-	-	-	-
	250-750	Good	5	18	8.77	31.57
	750-2000	Permissible	52	39	91.22	68.42
	2000-3000	Doubtful	-	-	-	-
	>3000	Unsuitable	-	-	-	-
Na%	200	Maximum allowable limit	57	57	100	100
	>200	Above allowable limit	-	-	-	-
NO3	<45	Potable	43	57	75.43	100
	>45	Not Potable	14	-	24.56	-
MR	<50	Suitable	57	57	100	100
	>50	Unsuitable	-	-	-	-
TH	<75	Soft	-	-	-	-
	75-150	Moderately	-	3	-	5.26
	150-300	Hard	24	22	42.10	38.59
	>300	Very hard	33	32	57.89	56.14
RSC	<1.25	Safe	51	56	89.47	98.24
	1.25-2.5	Marginally suitable	4	1	7.01	1.75
	>2.5	Not suitable	2	-	3.50	-
SAR	<20	Excellent	57	57	100	100
	20-40	Good	-	-	-	-
	40-60	Permissible	-	-	-	-
	60-80	Doubtful	-	-	-	-
	>80	Unsuitable	-	-	-	-
KI	<1	Suitable	57	57	100	100
	>1	Unsuitable	-	-	-	-

MagnesiumRatio

Generally Ca^{2+} and Mg^{2+} maintain a state of equilibrium in most groundwater (Hem 1985). During equilibrium more Mg^{2+} in groundwater will adversely affect the soil quality rendering it alkaline resulting in decrease of crop yield (Kumar *et al.* 2007). Paliwal (1972) developed an index for calculating the magnesium hazard Magnesium Ratio (MR).MR is calculated using the formula:

$$\text{Magnesium Ratio} = \frac{(Mg^{2+})\,x100}{(Ca^{2+} + Mg^{2+})} \qquad (1)$$

26.58 to 45.81 for PRM and POM season respectively. During PRM and POM all falls above the permissible limit of 50 mg/l indicating the unfavourable effect on crop yield and increase in

Total Hardness

Water hardness has no known adverse effects; however, some evidence indicates its role in heart disease (WHO 2008). Hard water is unsuitable for domestic use and it is a measure of the Ca^{2+} and Mg^{2+} content expressed in equivalent of calcium carbonate. Hardness of water (temporary and permanent) is by the inhibition of soap action in water due to the precipitation of Ca^{2+} and Mg^{2+} salts like carbonates, sulphates and chlorides. Temporary hardness is mainly due to the presence of calcium carbonate and gets removed when boiling water. Permanent hardness is caused by the presence of Ca^{2+} and Mg^{2+} which gets removed by ion exchange processes. Hardness of water limits its use for industrial purposes; causing scaling of pots, boilers and irrigation pipes may cause health problems to humans, such as kidney failure (WHO 2008). The total hardness in mg/l is determined by the following equation (Todd 1980).

Total Hardness mg/l = 2.497 Ca^{2+} + 4.115Mg^{2+} (2)

During PRM, total hardness (TH) ranges between196 to 592 mg/l with an average of 352.35 representing (57.87%) of the groundwater samples exceeding the permissible limit. During POM, TH ranges between 128 to 584 mg/l with an average of 334.66mg/l representing (56.14%) of the samples exceeding the permissible limit. It is inferred that, both the seasons records higher TH as permanent hardness. The sources of high TH in the study area is due to the location of dyeing and bleaching industries identified, discharges their effluents onto the barren land which gets infiltrated into the aquifers increases the TH.

Residual Sodium Carbonate

RSC is calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water used for agricultural activities (JanardhanaRaju2007) and it is determined by the formula:

$$RSC = (CO_3 + HCO_3) – (Ca + Mg) \quad (3)$$

Where, all ionic concentrations are expressed in meq/l. RSC ranges from 0to 2.02 meq/l and 0 to 2.01meq/l with an average of 1.2 and 1.4 during PRM and POM, respectively. From the observed values 3.50% of the samples are not suitable for irrigation purposes in PRM. Hence, continued usage of high RSC waters will affect the yields of crop.

Sodium Percentage

Sodium is an important ion used for the classification of irrigation water due to its reaction with soil, reduces its permeability. Sodium is usually expressed in terms of percent sodium or soluble-sodium percentage (%Na). Percentage of Na+ is widely used for assessing the suitability of water for irrigation purposes (Wilcox 1955). The Na% is computed with respect to relative proportion of cations present in water as

$$Na+\% = \left[\frac{Na^{+}+K^{+}}{(Ca^{2+}+Mg^{2+}+K^{+}+Na^{+})} X100 \right] \quad (4)$$

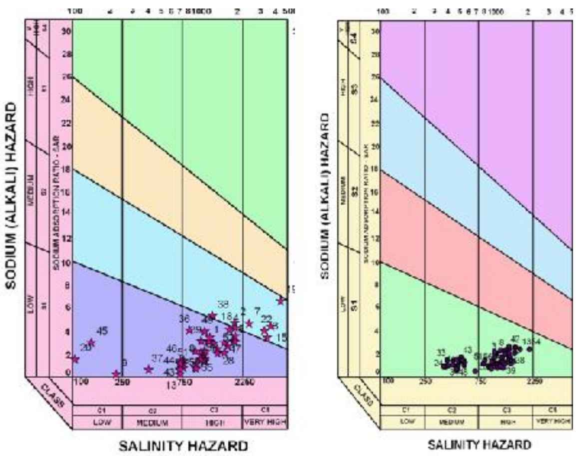
Where, all ionic concentrations are expressed in meq/l. The classification of samples is shown in Table 2. All samples are suitable for irrigation during PRM and POM seasons. Higher Na% is observed during PRM, indicating the dominance of ion exchange and weathering from litho units of the study area.

Sodium Adsorption Ratio

Total salt concentration and probable sodium hazard of the irrigation water are the two major constituents for determining SAR. Salinity hazard is based on EC measurements. If water used for irrigation is high in Na^{+} and low in Ca^{2+} the ion-exchange complex may become saturated with Na+ which destroys the soil structure, due to the dispersion of clay particles (Todd 1980) and reduces the plant growth. Excess salinity reduces the osmotic activity of plants (Subramani *et al.* 2005). The SAR is computed, using the formula (Hem 1991).

$$SAR = Na^{+}/\sqrt{(Ca + Mg)/2} \quad (5)$$

Concentrations of ions are expressed in meq/l. There is a close relationship between SAR values in irrigation water and the extent to which Na+ is absorbed (SubbaRao2006). The computed SAR values ranges from 0.78 to 3.72and 0.72 to 3.56indicating for all samples during PRM and POM are suitable for irrigation. SAR is found to be higher during POM season, indicating leaching and dissolution of salts during precipitation infiltrates into the aquifer matrix. In the USSL plot (Fig. 8 and 9) majority of water samples during PRM falls in C3S1, C3S2 and C4S2 zones and during POM samples clusters in C3S1, C2S1 zones. In PRM (68.42%) and POM (66.67%) samples fall sin C3S1 zone, indicating high salinity and low sodium water, which can be used for irrigation in almost all types of soil with little danger of exchangeable sodium (Kumar *et al.* 2007). Representations are also noted in C4S1 category indicating water suitable for plants having good salt tolerance but unsuitable for irrigation in soils with restricted drainage (Mohan *et al.* 2000). In PRM seasons 5.26 % of the samples fall in C3S2 category, indicating water having high salinity and medium sodicity. High salinity, medium sodicity water cannot be used on fine-grained soils with restricted drainage (Srinivasamoorthy *et al.* 2010). This is because restricted flow is likely to result in the accumulation of salts in the root zones of crops, leading to salinity and soil clogging crisis. Representations is also noted in C4S3 and C4S2 category indicating samples not suitable for irrigation purposes due to very high salinity and sodiumhazards which affects the plant growth.



Sodium(Alkali) hazards:S1:Low,S2:Medium,S3:High,S4:Very High
Salinity hazards:C1:Low,C2:Medium,C3:High,C4:Very High

Fig.8 a, b Suitability of irrigation water-USSL(1954) diagram for ***a***PRM and***b*** POM

Permeability Index

The permeability of soil is affected by long-term use of irrigation water and is influenced by sodium, calcium, magnesium and bicarbonate contents in soil. Doneen (1964) has evolved a criterion for assessing the suitability of water for irrigation based on PI. It is calculated by using the formula; where all the ions are expressed in meq/l.

$$PI = \frac{(Na^{+}+\sqrt{HCO3})}{Ca^{2+}Mg^{2+}+Na^{+}} x100 \quad (6)$$

PI ranging from 41 to 75meq/l and 43 to 68meq/l is noted during PRM and POM, respectively (Fig.9).

Kelly's Index

Kellys index is used for the classification of water for irrigation purposes. Sodium measured against calcium and magnesium is considered for calculate this parameter. A KI (>1) indicates an excess level of sodium in waters (Kelly 1940). Therefore, waters with a KI (<1) is suitable for irrigation, while those with greater ratio are unsuitable (Sundaray *et al.* 2009). KI is calculated by using the formula;where all the ions are expressed in meq/l.

Kelly's Index (KI) = Na/ (Ca + Mg) (7)

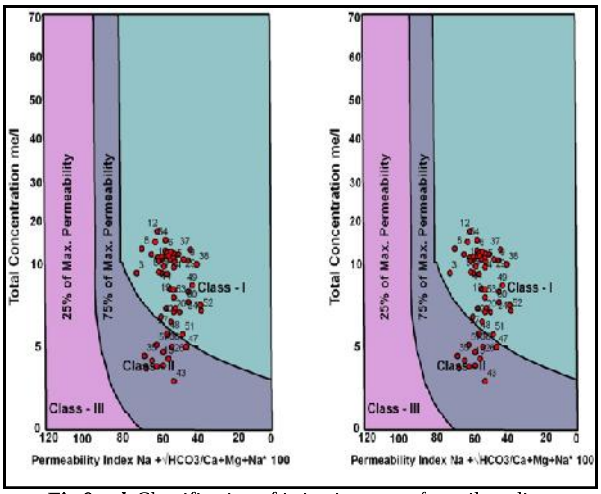


Fig.9.***a, b*** Classification of irrigation water for soil medium permeability diagram for for***a*** PRM and ***b*** POM

According to PI values, the groundwater samples fall in class I and class II during both the seasons indicating water is moderate to good for irrigation purposes (Arumugam and Elangovan2009).

Kelly's Index

Kellys index is used for the classification of water for irrigation purposes. Sodium measured against calcium and magnesium is considered for calculate this parameter. A KI (>1) indicates an excess level of sodium in waters (Kelly 1940). Therefore, waters with a KI (<1) is suitable for irrigation, while those with greater ratio are unsuitable (Sundaray *et al.* 2009). KI is calculated by using the formula;where all the ions are expressed in meq/l.

Kelly's Index (KI) = Na/ (Ca + Mg) (7)

KI in the present study varied between 0.28 to 0.98 and 0.37 to 0.96 during PRM and POM respectively. According to the classification is representing 100% (PRM) and (POM) falls insuitable limit.

CONCLUSION

The groundwater quality in Chinnar watershed has been evaluated for their chemical composition and suitability for domestic and agricultural uses. The piper plot indicates calcite dissolution and reverse ion exchange process controls the water chemistry in the study area. Higher EC valuesare confined along upstream, central and downstream indicating the dominance of domestic, industrial and agricultural activities. Higher sodium values are observed during PRM samples of the study area. Fluoride is higher during PRM indicating leaching from fluoride bearing minerals from source rocks and easier accessibility of rain water to weathered rock,long term irrigational processes, semi-arid climate and long residence time of groundwater. Higher NO_3 was observed during PRM is observed in areas where indicial irrigation practices dominant. Higher Na percentage is observed during POMindicating the dominance of ion exchange and weathering from the litho units of the study area. SAR is found to be higher during PRM season, indicating leaching and dissolution of salts during precipitation infiltrates into the aquifer matrix. The USSL plot shows that during PRM (68.42%) and POM (66.67%) samples falls in C_3S_1 zone, indicating high salinity and low sodium water, which can be used for irrigation in almost all types of soil with little danger of exchangeable sodium. PI values, the groundwater samples fall in class I and class II during both the seasons indicating water is moderate to good for irrigation purposes. The MR value indicate that all samples during both the seasons fells within the permissible limit of 50 mg/l indicating the favorable effect on crop yield.

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