Hydro Chemical Characteristics and Groundwater Quality Assessment in Parts of Pambar River Basin, Tamil Nadu, India

S. Venkateswaran, S. Karuppannan, S. Vijay prabhu, R. Kannan, S. Malar, P. Prabu

Abstract: ***Understanding geochemical characteristics of groundwater is vital for the support of habitat and for maintaining the quality of base flow to rivers, while its quality assessment is essential to ensure sustainable safe use of the resources for drinking, agricultural, and industrial purposes. Twenty seven sample sites were selected systematically and samples were taken for a reference line study to understand the geochemistry of the groundwater and to assess the overall physicochemical faces for pre and post monsoon. Sampling was carried out using pre-cleaned polyethylene containers. The physical and chemical parameters of the analytical results of groundwater were compared with the standard guideline values recommended by the World Health Organization for drinking and public health standards. Thematic maps pertaining to TDS, EC, TH, Cl, NO3, SO4, F , SAR, Na, Na % and RSC were generated using ArcGIS platform. To find out the distribution pattern of the concentration of different elements and to demarcate the higher concentration zones, the spatial maps for various elements were also generated, discussed, and presented.***

Keyword: Geochemistry; Spatial Analysis; Water quality; Pambar

I. INTRODUCTION

Groundwater is a dynamic natural resource. It is projected that approximately one third of the world's population use groundwater for drinking (Nickson et al. 2005). Groundwater is the major source of water supply for domestic purposes in urban as well as rural parts of India. Among the various causes, 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 (Mishra et al. 2005). Burston et al. (1993) argued that the quality of groundwater is often assessed by reference to drinking water standards. Rural people mostly trusted on groundwater for domestic purposes.

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The following are the reasons why groundwater is attractive for most domestic uses: the resource is generally sheltered from most surface polluting activities and does not need bacteriological treatment prior to consumption; aquifers underlie most of the rural communities and can be tapped at relatively shallow depths; surface water resources are virtually nonexistent in most of these communities and where surface water resources exist, they are often so much polluted that the cost of tapping groundwater is modest compared to the fee of treating surface water resources before usage. In addition to meeting the domestic water needs of the rural population, it has been envisaged that groundwater has the potential of being phased in sufficient quantities to meet irrigation needs to raise the standard of living of the communities.

Groundwater is the primary source of water for domestic, agricultural and industrial purposes in many countries. India accounts for 2.2% of the global land and 4% of the world water resources and has 16% of the world's population. It is projected that nearly one third of the world's population uses groundwater for drinking (Nickson et al. 2005). Therefore, water quality problems and its management opportunities need to be given greater consideration in developing countries. Intensive agricultural activities have enhanced the demand on groundwater resources in India. Groundwater quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices. Once undesirable elements enter the ground, it is difficult to control their dissolution. The chemical characteristics of groundwater play a vital role in classifying and assessing water quality. Spatial analysis of geochemical studies of groundwater provides a better understanding of possible changes in quality. The objective of this study is to determine the groundwater quality in part of Pambar basin and to delineate regions where groundwater is suitable or unsuitable for drinking and irrigation purpose.

II. STUDY AREA

The study area, parts of Pambar basin, located in the districts of Krishnagiri and Vellore districts of Tamilnadu, India. The study area lies between12^{0}18' 49" N and 12^{0}30' 15" N to 78^{0}22' 47'' E and 78^{0}38' 15" E and it covers an area of 588km^{2}. The contribution of southwest monsoon ranges from 45 to 52 percent, whereas it ranges from 30 to 43 percent due to northeast monsoon. The basin experiences a moderately Tropical climate. The area in and around of basin forms a part of the Archaean Peninsular complex having intensive high grade regional metamorphism with folding, faulting and shearing structures. The major rock

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types of the area are hornblende biotite gneiss, charnockite and epidote hornblende gneiss, granitic gneiss, calc granulites, syenites and ultra-basics.

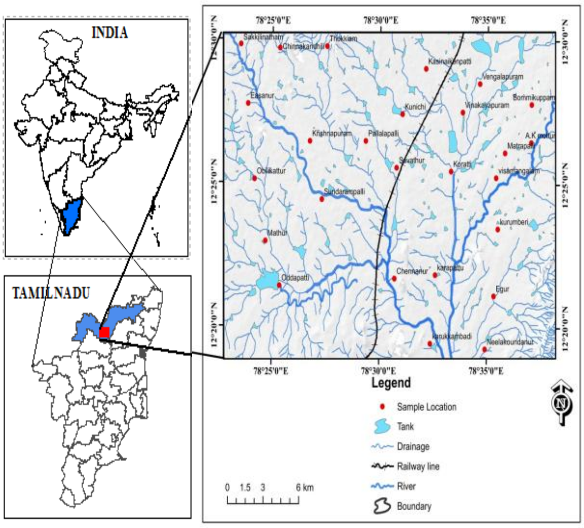

Figure 1 Study area and location of sampling wells

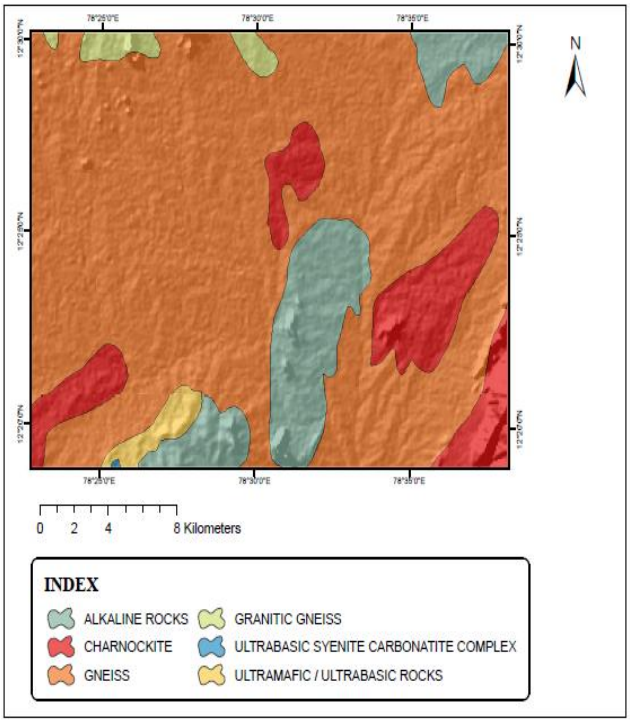

Figure 2 Geology of the study area

III. MATERIALS AND METHODS

Altogether 26water samples for chemical analysis were obtained in July (2012), as pre monsoon (PRM) and in December, as post monsoon (POM) from the 26 wells shown in Figure 1. Samples were collected in polyethylene bottles. These bottles had been rinsed with distilled water before sampling. These samples were collected after a pumping time of about 30 min. The samples were adequately labeled and preserved in the refrigerator until they were taken to the laboratory for measurement. Samples were analyzed in the laboratory for the major ions. Sampling, preservation and analysis of water samples were carried out following the method recommended byAPHA (1992). The pH and EC were measured using pH and EC meters.

IV. RESULTS AND DISCUSSION GROUND WATER CHEMISTRY

Quality of groundwater controls its fitness for different purposes depending upon the specific criterions. The water used for drinking should be soft, low in dissolved salts and free from toxic constituents. Deciphering the groundwater quality is important as it is the main factor determining its suitability for drinking, domestic, agricultural and industrial purposes (Subramanian et al. 2005). Geochemical parameters including statistical measures such as minimum, maximum, mean, median and standard deviation are given in Table 1.The EC values ranges from 692µ /cm to 3100 µ/cm with an average value of 1419µ/cm for pre monsoon and for post monsoon it varies from591 µ /cm to 3480 µ/cm with an average value of 1562. The pH value of groundwater ranges from 7.01 to 7.73 with an average value of 7.70 for pre monsoon season. For post monsoon season, it ranges from 1.30 to 7.43 with an average value of 6.82. TDS values ranges from 484 to 2170 mg/l with an average value of 1008 mg/l for pre monsoon, whereas it varies from 413 to 2640 mg/l with an average value of 1065 mg/l is summarized in Table 1.

V. HYDRO-CHEMICAL FACIES

The geochemical evolution of groundwater can be understood by plotting the concentrations of major cations (Ca, Mg, Na, and K) and anions (CO_2, HCO_3, SO_4, and Cl) in milliequivalents per liter to evaluate the geochemical evolution/ hydrochemistry of groundwater in the study area in the Piper (1944) trilinear diagram (Fig.3). On the basis of chemical analysis, groundwater is divided into six facies. The plot shows that the groundwater samples fall in the field of CaHCO3, mixed CaMgCl types, NaCl, mixed CaNaHCO3 and NaHCO3 respectively for pre monsoon season, according to their order of their dominance. For post monsoon season, the plot shows that, CaHCO3, Mixed CaMgCl types, Mixed CaNaHCO3 types, and NaCl types respectively, as per their order of domination. The hydrochemical facies of groundwater is summarized in Tab2.

VI. DRINKING WATER QUALITY

The physical and chemical parameters of the analytical results of groundwater were compared with the standard recommendation values stated by the World Health Organization (WHO 1993) for drinking and public health standards (Table 3).The table shows the most desirable limits and maximum allowable limits of various parameters.

VII. TOTAL DISSOLVED SOLIDS

The TDS is a measure of the solid materials dissolved in the groundwater. This contains salts, some organic materials, and a host of other materials stretching from nutrients to toxic materials. To ascertain the suitability of groundwater of any purposes, it is important to classify the groundwater depending upon their hydrochemical properties based on their TDS values (Davis and DeWiest 1966) which are represented in Table 4. The spatial representation of TDS in the

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groundwater samples prepared (Fig.4).

Parameters	Pre monsoon					Post monsoon				
	Min	Max	Mean	Median	S.D	Min	Max	Mean	Median	S.D
pH	1.35	7.43	6.83	7.05	1.13	1.35	7.43	6.83	7.05	1.13
EC	591.00	3480.00	1562.15	1254.00	885.14	591.00	3480.00	1562.15	1254.00	885.14
TDS	413.00	2640.00	1065.00	840.00	630.38	413.00	2640.00	1065.00	840.00	630.38
Cl	24.00	820.00	198.77	102.00	221.87	24.00	820.00	198.77	102.00	221.87
Ca	51.00	224.00	104.31	84.00	47.76	51.00	224.00	104.31	84.00	47.76
Mg	25.00	101.00	49.12	39.50	21.39	25.00	101.00	49.12	39.50	21.39
Na	10.00	448.00	135.65	107.00	121.17	10.00	448.00	135.65	107.00	121.17
K	3.00	63.00	17.23	13.00	14.76	3.00	63.00	17.23	13.00	14.76
SO4	4.00	140.00	46.46	38.00	33.62	4.00	140.00	46.46	38.00	33.62
TH	232.00	980.00	468.77	378.00	205.86	232.00	980.00	468.77	378.00	205.86
HCO3	268.00	664.00	427.85	408.00	115.77	268.00	664.00	427.85	408.00	115.77
NO3	5.00	92.00	31.92	25.50	25.01	5.00	92.00	31.92	25.50	25.01
F	0.40	4.80	1.69	1.50	0.99	0.40	4.80	1.69	1.50	0.99

Note: Min – Minimum; Max – Maximum; S.D – Standard deviation

Table 1 Statistics of chemical parameters (all in mg/l and EC in µS/cm) in groundwater for PRM and POM seasons, respectively

Types	Season	Sample numbers	Percentage of samples
CaHCO3	A	4,6,10,12,13,16,17,22,26,	34.62
	B	1-5,8,9,13-15,19,23,24	50.00
NaCl	A	2,3,18,21,23	19.23
	B	6,21	7.69
Mixed CaNaHCO3	A	8,15,19,20	15.38
	B	14,17,19,23	15.38
Mixed CaMgCl	A	1,5,9,7,11,14,25	26.92
	B	11,12,16,18,22,26,25	26.92
CaCl	A	Nil	Nil
	B	Nil	Nil
NaHCO3	A	24	3.85
	B	Nil	Nil
Note : A – Pre monsoon, B – Post monsoon			

Table 2 Hydrochemical facies of groundwater

Groundwater samples of the study area exceeding the permissible limits prescribed by WHO for domestic purposes					
Water quality	WHO (1993)		Numbers of samples exceeding allowable limits		Undesirable Effects
parameters	Most desirable limits	Maximum Allowable limits	Pre monsoon	Post monsoon	
pH	6.5-8.5	9.2	Nil	Nil	Taste
TDS (mg/l)	500	1,500	10	3	Gastrointestinal irritation
Ca^{2+} (mg/l)	75	200	1	Nil	Scale formation
Mg^{2+} (mg/l)	50	150	Nil	Nil	
K+ (mg/l)	-	12	14	17	Bitter taste
Na+ (mg/l)	-	200	4	3	
Cl^- (mg/l)	200	600	3	1	Salty taste
NO_3^-(mg/l)	45	-	5	7	Blue baby
$SO4^{2-}$(mg/l)	200	400	Nil	Nil	Laxative effective

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F^- (mg/l)	-	1.5	13	6	Fluorosis

Table 3 Groundwater samples of the study area exceeding the permissible limits prescribed by WHO for domestic purposes

TDS	Classification	Season	Sample numbers	Percentage of samples
< 500	Desirable for drinking	A	4,9,15	11.54
		B	4	3.85
500 - 1000	Permissible for Drinking	A	1,2,3,5,7,10,13,14,16,17,20,24	46.15
		B	1,3,6,8,12,13,15,16,17,19,20,24	46.15
1000 - 1300	Useful for Irrigation	A	6,8,18,19,23,26	23.08
		B	2,5,7,9,14,21,22,26,25	34.62
> 1300	Unfit for drinking and Irrigation	A	11,12,18,21,25	19.23
		B	10,11,18,23	15.38
Note : A – Pre monsoon, B – Post monsoon				

Table 4 Groundwater classification of all ground waters (Davis and DeWiest 1966)

Ec	Classification	Season	Sample numbers	Percentage of samples
< 1500	Permissible	A	1-5,7,9,10,14,16,20,22,24	50.00
		B	2,7,8,9,10,16,17,18,22,23,26	42.31
1500 - 3000	Not permissible	A	6,8,11,13,15,17,19,23,25,26	38.46
		B	1,3,4,5,6,12,13,14,15,19,20,21,24,25	53.85
> 3000	Hazardous	A	12,18,21	11.54
		B	11	3.85
Note : A – Pre monsoon, B – Post monsoon				

Table 5 Groundwater classification based on electrical conductivity

TH	Classification	Season	Sample numbers	Percentage of samples
>75	Soft	A	Nil	Nil
		B	Nil	Nil
75-150	Moderately high	A	Nil	Nil
		B	13	3.85
150-300	Hard	A	5,9,14	11.54
		B	1,4,6,12,15,16,24	26.92
<300	Very Hard	A	1-4,6-8,10-13,15-26	88.46
		B	2,3,5,7-11,14,17-26	69.23
Note : A – Pre monsoon, B – Post monsoon				

Table 6 Groundwater classification based on hardness (Sawyer and McMcartly 1967)

NA %	Classification	Season	Sample numbers	Percentage of samples
< 20	Excellent	A	4,5,9,15,16	19.23
		B	4,6,7,13,16,22,25	26.92
20 - 40	Good	A	1-3,7-8,13,22,20,24,26,	38.46
		B	1-3,5,8-12,14-15,17,20,21,23,26	61.54
40 - 60	Permissible	A	6,10-12,14,17-19,21,23-25	42.31
		B	18,19,24	11.54
> 60	Doubtful	A	Nil	Nil
		B	Nil	Nil
Note : A – Pre monsoon, B – Post monsoon				

Table 7 Irrigation quality of groundwater based on sodium percentage

Classification	Season	Sample numbers	Percentage of samples
Excellent to Good	A	1,2,4,5,7,9,14,16,20,22,24,	42.31
	B	1,4,6,8,12,13,15-16,19,24	38.46
Good to Permissible	A	2,3,8,10,11,15,17	26.92
	B	2,3,5,7,9-10,14,17,20,21,22,25,26	50.00
Permissible to Doubtful	A	6,19,23	11.54
	B	18	3.85
Doubtful to Unsuitable	A	25	3.85
	B	23	3.85
Unsuitable	A	12,18,21	11.54
	B	11	3.85
Note : A – Pre monsoon, B – Post monsoon			

Table 8 Classification of groundwater (Wilcox)

Classification	SAR/EC	Season	Sample numbers	Percentage of samples
C4 - S1	"SAR low EC high"	A	12,18,21	11.54
		B	11,23	7.69
C4 - S2	"SAR medium EC high"	A	25	3.85
		B	NIL	NIL
C3 - S1	"SAR low EC medium–high"	A	1-3,5-8,10-11,13-17,19-20,22-24,26	76.92
		B	1-10,12-17,19-22,25-26	80.77
C3 - S2	"SAR medium EC medium–high"	A	NIL	NIL
		B	18,24	7.69
C2 - S1	"SAR low EC moderate"	A	4,9	7.69
		B	4	3.85
Note : A – Pre monsoon, B – Post monsoon				

Table 9 Salinity and alkalinity hazard of irrigation water in US salinity diagram

RSC	Classification	Season	Sample numbers	Percentage of samples
< 1.25	Safe	A	1-9,11-13,15-16,18,20-26	84.62
		B	1-14,16-18,21-23,25	80.77
1.25-2.5	Marginally suitable	A	10,14,17,19	15.38
		B	20,15,19	11.54
2.5	Unsuitable	A	Nil	Nil
		B	24,26	7.69
Note : A – Pre monsoon, B – Post monsoon				

Table 10 Irrigation quality of groundwater based on residual sodium carbonate

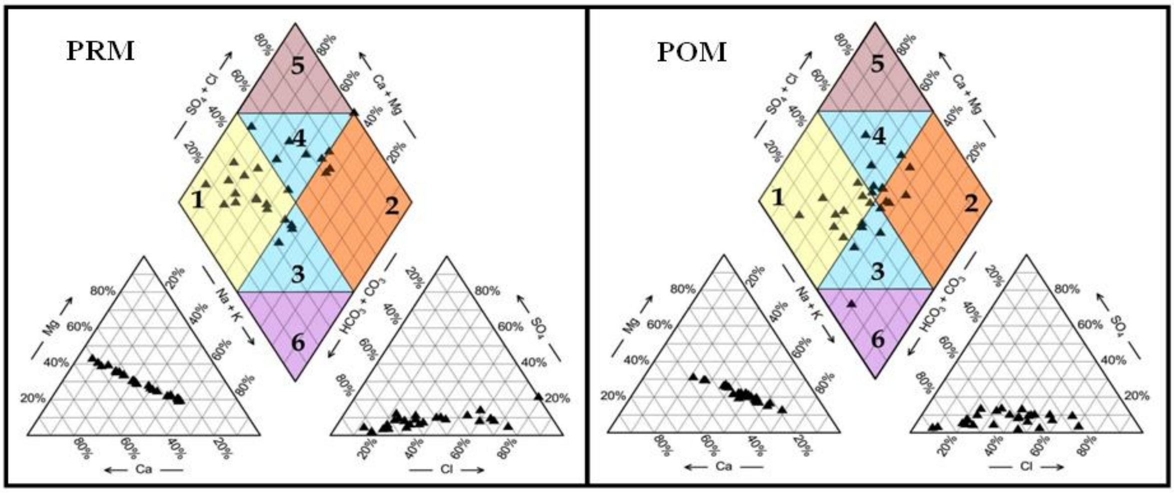

Figure 3 Piper classification diagram

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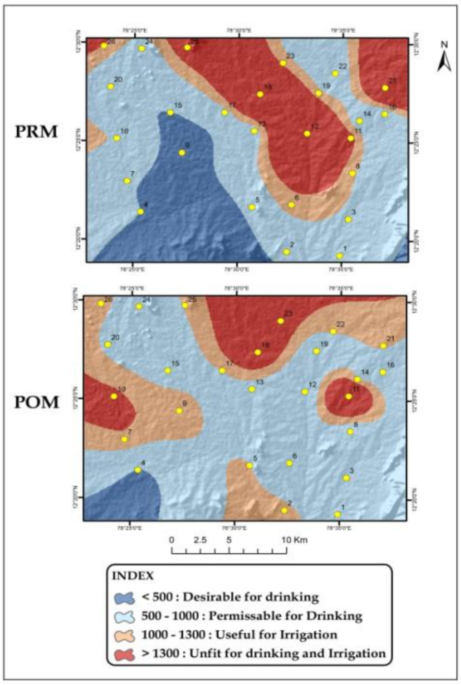

Figure 4 Spatial distribution of TDS

VIII. ELECTRICAL CONDUCTIVITY

Electrical conductivity in water is due to ionization of dissolved inorganic solids and becomes a measure of TDSs. It is used as a basic index to select the suitability of water for agricultural purposes. Electrical conductivity of groundwater in parts of Pambar river basin is given in Table 5. It is found that in pre monsoon, 50 % of the samples found within permissible limit, 38.46 % of the samples falls in not permissible limit and 3 samples (11.54 %) are fall in hazardous limit. In post monsoon, 42.31%, 53.85 %, 3.85 %, of the samples found in permissible, not permissible, and hazardous limit respectively. The interpolated electrical conductivity map (pre monsoon and post monsoon) is season shown in Fig 5.

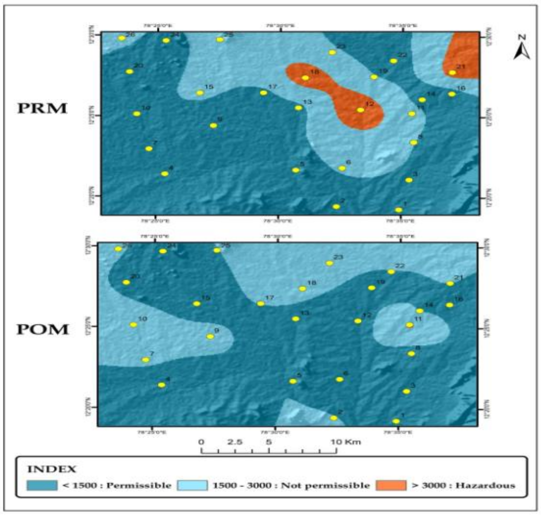

Figure 5 Spatial distribution of Ec

IX. TOTAL HARDNESS

Total hardness is determined as CaCO3 in milligrams per liter. Mainly, TH is caused due to cations of calcium, magnesium, iron, and strontium.TH of thegroundwater was calculated using the formula given below(Sawyer et al.2003).
TH (as $CaCO_3$) mg/l = (Ca^{2+} + Mg^{2+}) meq/l × 50
In this study, for pre monsoon, it ranges from 156 mg/L as minimum and 810 mg/l as maximum, with an average value of 369 mg/l. In post monsoon period, the TH ranges from 232 mg/l to 980 mg/l, with an average value of 468 mg/l. The TH map (pre monsoon and post monsoon) is shown in Fig.6. The total hardness of groundwater sample is summarized in Table 6.

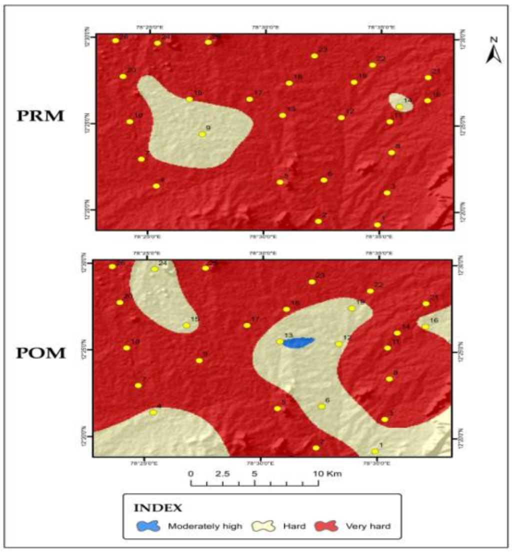

Figure 6 Spatial distribution of TH

X. CHLORIDE

The chloride concentration in groundwater samples varies from 18 mg/l to 710 mg/l, with an average value of 180 mg/l in pre monsoon. In post monsoon period, it ranges from 24 mg/l to 820 mg/l, with an average value of 198.7 mg/l. The spatial distribution of chloride concentration in groundwater of the study area is illustrated in Fig.7.

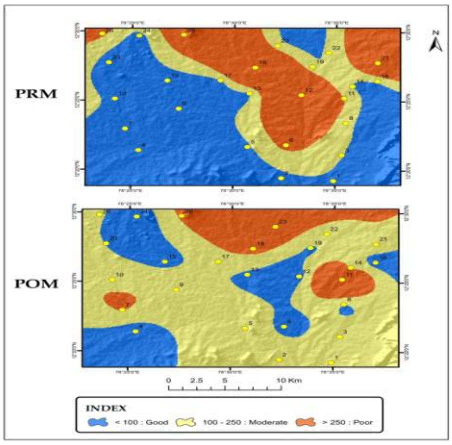

Figure 7 Spatial distribution of Chloride

XI. NITRATE

The nitrate ion concentration ranges from 6 mg/l to 88 mg/l, with an average value of 38 mg/l, in pre monsoon. In post monsoon season, it ranges from 5 mg/l to 92 mg/l, with an average value of 31.92 mg/l. Nitrogen is originally fixed from the atmosphere and then mineralized by soil bacteria into ammonium.In pre monsoon; seven samples (26.92 %) whereas in post monsoon, five samples (19.23 %) exceed the desirable limit of 45 mg/l, as per WHO standard. The high concentration of nitrate in drinking water is toxic and causes blue baby disease/methaemoglobinaemia in children and gastric carcinomas (Comly 1945; Gilly et al. 1984). The spatial variation of nitrate in groundwater of the study area is illustrated in Fig.8.

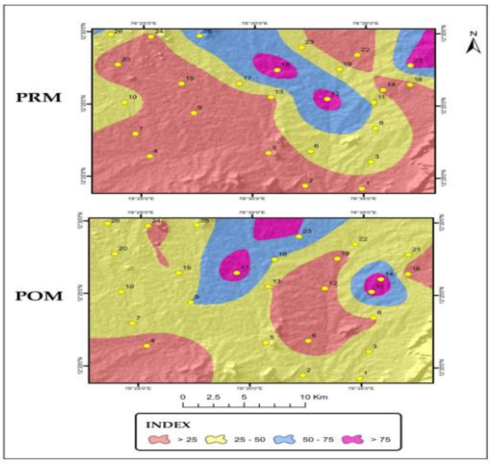

Figure 8 Spatial distribution of Nitrate

SULPHATE

The concentration of sulphate is close to react with human organs if the value exceeds the maximum allowable limit of 400 mg/l and causes a laxative effect on human system with the excess magnesium in groundwater. Still, thesulphate concentration in groundwater of the study area is within the maximum allowable limit in all the sample locations. The spatial variation of sulphate ion concentration is shown in Fig.9. The maximum, minimum, mean, median and standard deviation of sulphate ion is shown in table 1.

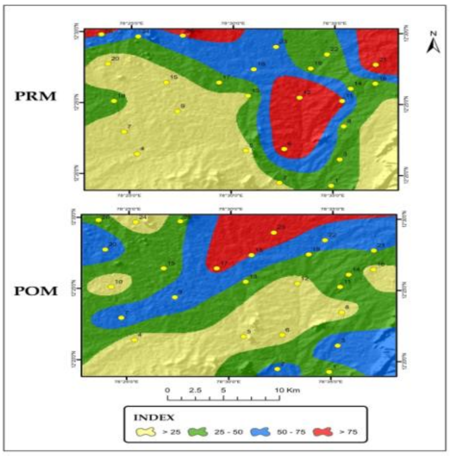

Figure 9 Spatial distribution of Sulphate

FLUORIDE

The fluoride content in the groundwater shows a range of 0.60 to 3.20 mg/l for pre monsoon period. In post monsoon period, it ranges from 0.40 to 4.80 mg/l. Fluoride may be an essential element for humans (WHO 2004). Deficit or low concentration in drinking water (<0.5 mg/l; therefore, low intake dose) leads to dental caries (Edmunds and Smedley 1996). High intake of fluoride (over 1.5 mg/l) consequences in physiological disorders, skeletal and dental fluorosis, thyroxine changes and kidney damages (Latha et al. 1999; ISI 1983). Bedrock comprising fluoride minerals is generally accountable for high concentration of this ion in ground water (Handa 1975). The maximum allowable limit of fluoride is 1.5 mg/l according to WHO (1993). The concentration is higher than 1.5 mg/l in thirteen (50 %) locations in pre monsoon period and six (23.07 %) locations in post monsoon period. The spatial distribution of fluoride ion concentration in groundwater is illustrated in the Fig.10.

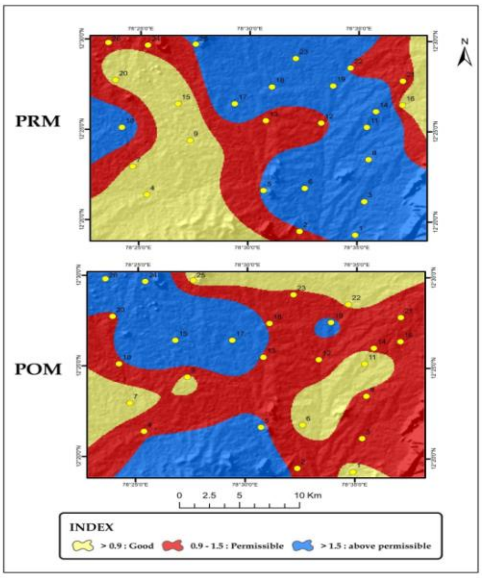

Figure 10 Spatial distribution of Fluoride

IRRIGATION WATER QUALITY

Excessive amount of dissolved ion such as sodium, bicarbonate and carbonate in irrigation water affect plants and agricultural soil physically and chemically, thus reducing the productivity (Arumugam and Elangovan 2009).The suitability of groundwater for irrigation purposes depends upon the effect of mineral constituents of water on both plants and soils. Water quality criteria can be used as guidelines by farmers for selecting suitable management practice to overcome potential salinity hazard, if the quality of available water would pose any problem for irrigation to sustain existing soil productivity with the advantage of high crop yield under irrigation.

a) Alkali and salinity hazard (SAR)

SAR is an important parameter for defining the suitability of groundwater for irrigation because it is a measure of alkali/sodium hazard to crops. SAR is computed by the following formula (where the concentrations of all ions are in meq/l),

$$SAR = Na^{+} / (Ca^{2} + Mg^{2})^{0.5} / 2$$

The computed sodium adsorption ratio for the study area (pre and post monsoon period) is presented in Table.7. The spatial distribution of SAR in groundwater is illustrated in the Fig.11.

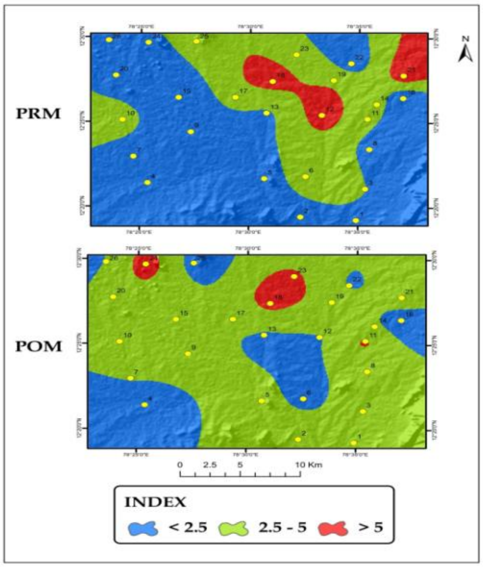

Figure 11 Spatial distribution of SAR

SODIUMPERCENTAGE (Na %)

When the concentration of sodium ion is high in irrigation water, Na+ tends to be absorbed by clay particles, displacing magnesium and calcium ions, reducing the soil permeability, and eventually resulting in soil with poor internal drainage (Ravikumar et al 2010). The sodium in irrigation waters is usually denoted as percent sodium, which is calculated using the equation

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

The classification of groundwater samples with respect to the Na+ % is shown in Table.8.

The NA % is ranging from 21.43 % as minimum and 68.83 % as maximum with an average value of 46.74 %. The spatial distribution of sodium percentage in groundwater is illustrated in the Fig.12.

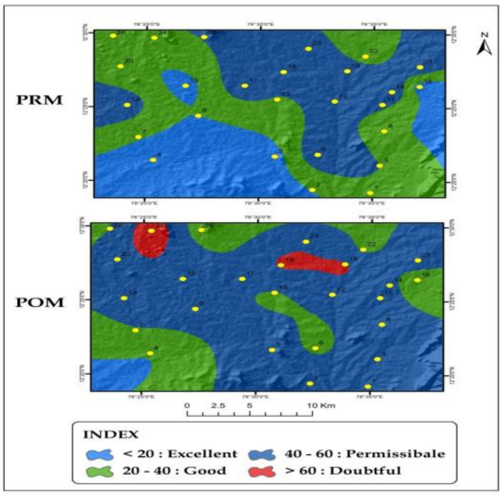

Figure 12 Spatial distribution of Sodium percentage

Table 1 Irrigation quality of groundwater based on sodium percentage

WILCOX DIAGRAM

Wilcox (1948, 1995) classified groundwater for irrigation purposes (Table 8) by correlating percent sodium and electrical conductivity, which illustrates that 42.31 %, 26.92 %, 11.54 % , 3.85 %, 11.54 % of the samples fall in the field of excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable, and unsuitable for irrigation respectively (pre monsoon). In post monsoon period, it shows that 38.46 %, 50.00 %, 3.85 %, 3.85 %, and 3.85 % of the samples fall in the field of excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable, and unsuitable for irrigation respectively (Fig.13).

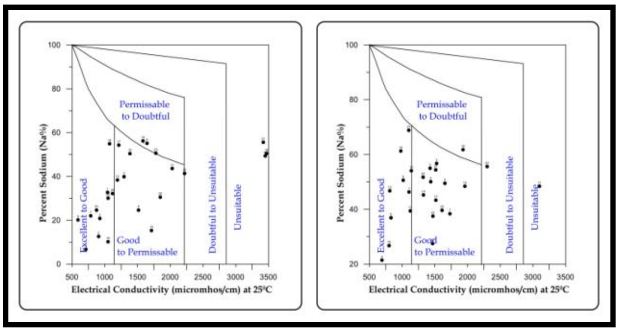

Figure 13 Suitability of groundwater for irrigation in Wilcox diagram

US SALINITY DIAGRAM

The correlation between sodium-absorption ratio and electrical conductivity were plotted on the US salinity diagram (Wilcox 1948) (Fig.14). It is found that 11.54 %, 3.85 % , 76.92 % , and 7.69 % of the samples fall in the field of SAR low EC high, SAR medium EC high, SAR low EC medium–high, and SAR low EC moderate class, in pre monsoon season. In post monsoon season, 7.69 %, 80.77 % , 7.69 %, and 3.85% fall in the limits of SAR low EC high, SAR low EC medium–high, SAR medium EC medium–high, and SAR low EC moderate class. The classification of groundwater samples, according to US salinity diagram, is summarized in Table.9.

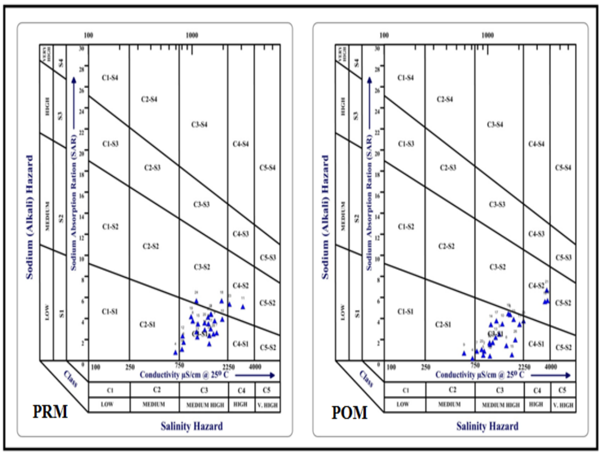

Figure 14 Classification of well water based on US salinity diagram

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RESIDUAL SODIUM CARBONATE (RSC)

In water having high concentration of bicarbonates, there is tendency for calcium and magnesium to precipitate as carbonates. To qualify this effect, an tentative parameter termed as residual sodium carbonate (Eaton 1950), which can be calculated using the equation,

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

Lloyd and Heathcote (1985) have classified irrigation water based on RSC as suitable (<1.25), marginal (1.25–2.5), and not suitable (>2.5). It is found that, 84.62 % (pre monsoon) and 80.77 % (post monsoon) of the groundwater samples fall in suitable class. According to RSCvalues, groundwater samples classified and presented in Table.10.The spatial distribution of sodium percentage in groundwater is illustrated in the Fig.15.

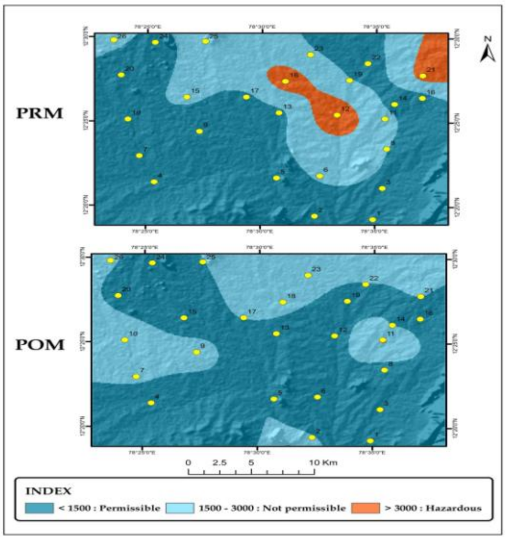

Figure 15 Spatial distribution of RSC

SUMMARY AND CONCLUSION

Groundwater quality and its fitness for drinking and agricultural use in part of Pambar river basin are assessed since groundwater is a major source of water for domestic and agricultural activities in the study area due to lack of surface water resources. For this study, 27 groundwater samples were collected from dug and bore wells during July and December 2012 and analyzed for pH, electrical conductivity, temperature, major ions, and nitrate. Irrigational suitability of groundwater in the study region was evaluated using quality parameters, e.g., EC, SAR, RSC, USSL classification, Na%, and Wilcox diagram.

The hydrogeochemical analysis reveals that the groundwater of the study area is moderate high to very hard.The hydrochemical facies infer groundwater samples irrespective of seasons fall NaHCO3, mixed CaMgCl, mixed CaNaHCO3, NaCl, and CaHCO3 types.Spatial analysis of various quality parameters in GIS environment was found to be effective and efficient. Thematic maps generated in the study will be helpful to planners and policy makers especially of public health and irrigation departments, for sustainable water management in a holistic way.

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