Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(3): 3524-3528
Received: 25-03-2019
Accepted: 27-04-2019

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Assessment of groundwater quality in mondipatti village and its surrounding area, Tiruchirapalli district, Tamil Nadu, India

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Abstract
Groundwater exploitation is one of the major problems due to increasing population, urbanization and industrialization which makes the groundwater unfavorable for living beings. This study deals with assessment of groundwater quality in Mondipatti and its surrounding area, Tiruchirapalli district, Tamil Nadu, India, where Tamil Nadu Newsprint and Papers Limited (TNPL) installed and commissioned its Unit II during January, 2016. The groundwater samples were collected and quality parameters were assessed for its applicability in irrigation and drinking purposes. The parameters analyzed were compared with water quality standards of World Health Organization (WHO).Geographic information system techniques were used for mapping the water quality consequence.

Keywords: Mondipatti, groundwater, quality parameters, water quality standards

Introduction

Groundwater is major 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 16% of the world population (Ramesh and Elango, 2011) [8]. The groundwater quality is influenced by natural and anthropogenic effects such as local climate, geology, irrigation practices and industrial pollution. The variable withdrawal of ground water along with scanty rainfall has led the change in water quality. The water composition may concentrate salts in soil and water to such an extent that limits the crop yield. Soil and water are the two indispensable natural resources of the earth. Therefore, this calls for optimum utilization of the available land and water resources, their conservation and effective management. This needs detailed information on land, water resources and agriculture in the region for meticulous planning of strategies and effective implementation (Gagandeep *et al*., 2017). Indiscriminate use of poor-quality water for irrigating agricultural crops deteriorates the productivity of soils through salinity, sodicity and toxic effects (Choudhary and Kharche, 2018) [1]. Moreover, use of poor-quality water deteriorates the quality of produce and also limits the choice of cultivable crops. Nevertheless, concerted efforts at different research centers located in different agro climatic zones of the country have yielded valuable concepts and viable technologies for the sustainable irrigation with poor quality water (Tyagiand Minhas, 1998) [10]. Increasing knowledge of geochemical processes that control groundwater chemical composition in arid and semi-arid regions could lead to improved understanding of hydro chemical systems in such areas. Understanding relations can improve management and utilization of the groundwater resource by clarifying relations among groundwater quality, aquifer lithology, and recharge type. Groundwater is the primary source of water for human consumption, as well as for agriculture and industrial uses (Jalali, 2009) [4].

The groundwater quality is influenced by natural and anthropogenic factors *viz.*, climate, geology, irrigation practices, sewage disposal and industrial pollution.Once pollutants enter into the ground, it is difficult to control their dissolution and hence, water quality assessment is required for the management of water bodies. The physico-chemical characteristics of ground water would provide better understanding of possible changes in groundwater quality.Tamil Nadu Newsprint and Papers Limited (TNPL) installed and commissioned its Unit II in Mondipatti village, Tiruchirapalli district, Tamil Nadu during January, 2016. Under this situation, groundwater quality assessment and mapping in Mondipatti area is an imperative. Therefore, this paperprovides the quality of groundwater in Mondipatti and its surrounding villages and illustrates the spatial variability of various parameters of groundwater quality and quality categorization on the basis of water quality standards of WHO (WHO, 2017) [11].

Methods and Materials

The ground water survey and characterization of TNPL Unit II Mondi Patti and its surrounding villages in Tiruchirappalli district was undertaken during 2016 to 2018. Eighteenground water samples were collected from open wells and tube wells. The position of sampling points was recorded by GPS at each location were presented in Table. 1 and Fig.1. The water samples were collected and physico-chemical properties were analysed by using Standard Methods (APHA 1989). Water quality indices like SAR (Richards, 1954) [9] and RSC (Eaton, 1950) [2] were worked out as described the following equations.

Sodium Adsorption Ratio (SAR)

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Residual Sodium Carbonate (RSC)

This index is important for carbonate and bicarbonate rich irrigation water. It indicates that tendency to precipitate Ca^{2+} as $CaCO_3$

$$RSC\ (meq\ L^{-1}) = \left(CO_3{}^{2-} + HCO_3{}^{-}\right) - \left(Ca^{2+} + Mg^{2+}\right)$$

Where concentration of both cations and anions is in meL^{-1}.
The results of the physico-chemical parameters are evaluated as per the World Health Organization (WHO, 2017) [11].

Result and Discussion

The quality of groundwater in Mondipatti and its surrounding villageswere presented in Table 2. The results are compared with WHO and ISI standards and tabulated in table 3.

pH

pH is defined as the negative logarithm of hydrogen ion concentration. The pH values of groundwater samples were found to be ranged from 7.43 to 8.01 with a mean of 7.62. The lowest pH was recorded in W_1 (R&D block – Porundalur village) and the highest pH was recorded in W_9 (Paddiripatti village) (Table2). According to the WHO water quality standard the pH of ground water falls under desirable limit (Table3).The pH value in groundwater is dependent on the carbon dioxide– carbonate–bicarbonate equilibria (Masters and Ela, 2008) [6].

Electrical Conductivity and TDS

The Electrical Conductivity in the study area was found to be ranged from 0.56 to 3.54 dSm^{-1} with a mean of 1.61 dSm^{-1} were presented in table. 2. The lowest Ec is 0.56 dSm^{-1} in water samples was observed in W_{15} (Karichampatti) and the highest value is 3.54 dSm^{-1} was recorded in W_7 (Sengudi) followed by Samudram (3.32 dSm^{-1}) and Therukuserpatti (2.58 dSm^{-1}). The distribution graph of sodium is shown in Fig. 2.TDS indicate the salinity behaviors of groundwater and it ranged from 358 and 2266 mg L^{-1} with an average value of 1033 mgL^{-1}. According to WHO the maximum acceptable concentration of TDS in groundwater for a domestic purpose is 500 mg/L and excessive permissible limit is 1,500 mg/L. Except four groundwater locations, all thegroundwater samples have TDS values well within permissible limit and the distribution graph of sodium is shown in Fig. 3.

Cationic concentration

The concentration of cations viz., calcium, magnesium, potassium and sodium in water samples varied from50 to 136, 20.7 to 41.5, 35.40 to 568.0and 5.50to 34.4mgL^{-1} with average of 81.6, 31.2,15.3and 200.5 mg L^{-1}. The cationic concentration followed the order- sodium, calcium, magnesiumand potassium. The presence of sodium in groundwater primarily results from the chemical decomposition of feldspars, feldspathoid and some iron, magnesium minerals. The amount of Na^+ ions in the water predicts the sodicity danger of the water (Singh, 2000) and Distribution graph of sodium is shown in Fig. 4. The presence of Ca^{2+} in groundwater might be attributed to calcium-rich minerals such as amphiboles, pyroxenes and feldspars and the Mg^{2+} in groundwater might be due to olivine mineral and the ion exchange of minerals in the surrounding rocks and soils. Concentration of calcium, magnesium, sodium and potassium are within the WHO prescribed limit of desirable and permissible limit (WHO 2017) [11].

Anionic concentration

The concentration of anions *viz.*, carbonate, bicarbonates, chlorideand sulphate varied from nil to 39, 152 to 420,78.2 to 805 and 17.8 to 121 mgL^{-1} with average values of 12.5, 252, 338and 52.8 mgL^{-1}, respectively. The reasons for carbonate ($CO_3{}^{2-}$) and bicarbonate ($HCO_3{}^{-}$) concentrations in groundwater can be ascribed to carbonate weathering as well as from the dissolution of carbonic acid in the aquifers Kumar *et al*. (2013) [5]. Concentration of chloride and sulphate are within the WHO prescribed limit of desirable and permissible limit (WHO, 2011).

SAR

The sodium absorption ratio (SAR) was recorded in the range of 1.06 to 11.1 $(mmol\ l^{-1})^{1/2}$ with mean value of 4.56 $(mmol\ l^{-1})^{1/2}$. The maximum value was observed in W7 (Sengudi) and followed by W12 (Muthapaudayanpatti), W13 (Samudiram) and W11 (Therkuserpatti). The minimum SAR value was received in W15 (Chokkampatti). Isaac *et al*. (2009) [3] ascertained that the SAR of soil solution is increased with the increase in SAR of irrigation water which eventually increases the exchangeable sodium of the soil.

Residual Sodium Carbonate (RSC)

Residual sodium carbonate (RSC) is usually used to evaluate the deleterious effect of carbonate and bicarbonate on the quality of water. The residual sodium carbonate was recorded in the range of nil 0.9 me l^{-1} with the mean value of -2.08 me l^{-1}. The maximum value was observed in W12 (Muthapaudayanpatti) and minimum value was found in W18 (Poongodipatti). Naseem *et al*. (2010) [7] reported that pH, EC and SAR of the irrigation water are significantly influenced by RSC.

Correlation matrix

The correlation values obtained in the present study in Mondipatti and its surrounding villages are presented in the Table 4. The TDS showed a strong correlation between conductivity, calcium, magnesium, potassium, bicarbonate, sulphate, chloride and SAR (r>1, r>0.830, r>0.603, r>0.848, r>0.987, r>0.939, r>0.981, r>0.995 and r>0.967) The cation Ca strongly correlated with Cl (r>0.820) and SO_4 (r>0.823). The major concurrent decrease/increase among the ions in the groundwater may be due to the result of dissolution/ precipitation reaction and concentration effects. Furthermore, the conductivity exhibited strong correlation (r>0.8) with TDS, Ca^{2+}, Mg^{2+} and Na^{+}.

Conclusion

The groundwater analysis of Mondipatti and around surrounding villages indicated that various constituents are in permissible limits with WHO water quality standard therefore, the groundwater can safely be used for drinking and irrigation purpose. Anions were found in order of CO_3^{2-}> SO_4^{2-}>HCO_3^{-}>Cl^{-} and cations followed the order K^{+}> Mg^{2+}> Ca^{2+}>Na^{+}. However, at some places, where the water is of doubtful category*viz*W6 –Mondipatti, W7 – Sengudi, W11 – Therkuserpatti, W12 – Muthupaudanpatti and W13 - Samudiram, care is to be taken to use the water for irrigation

Acknowledgements

We extend our thanks to the TNPL Unit II Plantation Department for providing the Vehicle support and labor for helping in the water survey/field work. We also acknowledge our Department of Soil Science and Agricultural Chemistry ADAC & RI for financial support.

Table 1: Location details of groundwater assessment study area

S. No	Name of the Location	Latitude	Longitude
W1	Research & Development Block	10.683384	78.436203
W2	East Gate Block	10.684726	78.449211
W3	Block 2	10.688043	78.459015
W4	Block 3	10.689652	78.465392
W5	Block 5	10.689282	78.474222
W6	Mondipatti	10.678474	78.447244
W7	Sengudi	10.673555	78.441494
W8	Chinnareddyapatti	10.681974	78.422204
W9	Paddiripatti	10.704304	78.440026
W10	Vadakuserpatti	10.683886	78.462467
W11	Therkuserpatti	10.671895	78.465262
W12	Muthapaudayanpatti	10.646944	78.457588
W13	Samudiram	10.663734	78.500104
W14	Maravanur	10.655227	78.473265
W15	Chokkampatti	10.672708	78.451804
W16	Kalikadu	10.678877	78.463981
W17	Karichampatti	10.685277	78.493178
W18	Poongodipatti	10.682027	78.452697

Table 2: Values of different properties of groundwater samples from TNPL Unit II in and around surrounding village

Parameter	pH	EC dSm^{-1}	TDS mg L^{-1}	Ca^{2+} mg L^{-1}	Mg^{2+} mg L^{-1}	K^{+} mg L^{-1}	Na^{+} mg L^{-1}	CO_3 mg L^{-1}	HCO_3 mg L^{-1}	Cl^{-} mg L^{-1}	SO_4^{-} mg L^{-1}	RSC meq L^{-1}	SAR milimol $L^{-1/2}$
W1	7.43	0.85	544	64	25.6	9.4	69.2	39	207	118	20.6	-0.5	1.86
W2	7.71	1.04	666	70	29.3	9.0	92.9	9.0	219	174	29.3	-2.0	2.34
W3	7.46	1.67	1069	76	41.5	8.2	188	9.0	244	343	54.7	-2.8	4.32
W4	7.44	1.12	717	74	35.4	5.5	100	0.0	231	217	39.8	-2.7	2.40
W5	7.60	1.46	934	90	31.7	7.4	149	0.0	262	306	50.4	-2.8	3.44
W6	7.45	2.42	1549	96	41.5	14.9	361	9.0	280	628	72.5	-3.3	7.75
W7	7.45	3.54	2266	136	37.8	32.8	568	21	359	805	104	-3.4	11.1
W8	7.58	0.71	454	58	24.4	13.7	55.7	0.0	183	119	23.5	-1.9	1.55
W9	8.01	0.85	544	58	24.4	15.6	77.3	9.0	189	142	23.5	-1.5	2.14
W10	7.64	0.84	538	84	20.7	10.2	63.7	21	176	124	27.4	-2.3	1.61
W11	7.57	2.58	1651	100	25.6	21.9	418	9.0	280	603	88.3	-2.2	9.64
W12	7.65	2.55	1632	72	30.5	24.6	416	30	366	564	85.4	0.9	10.4
W13	7.69	3.32	2125	116	41.5	34.4	496	30	420	770	121	-1.3	10.1
W14	7.95	1.33	851	60	34.2	19.6	157	9.0	244	248	44.6	-1.5	3.99
W15	7.85	0.56	358	50	20.7	7.8	35.4	0.0	152	78.8	17.8	-1.7	1.06
W16	7.74	1.92	1229	92	36.6	21.5	194	30	286	422	63.4	-1.9	4.34
W17	7.51	1.01	646	76	20.7	9.0	69.5	0.0	207	183	31.7	-2.2	1.82
W18	7.50	1.29	826	98	40.26	10.6	99.6	0.0	231	243	53.8	-4.4	2.13
Minimum	7.43	0.56	358	50	20.7	5.50	35.40	0.00	152	78.8	17.8	-4.40	1.06
Maximum	8.01	3.54	2266	136.	41.5	34.4	568.0	39.0	420	805	121	0.90	11.1
Mean	7.62	1.61	1033	81.6	31.2	15.3	200.5	12.5	252	338	52.8	-2.08	4.56

Table 3: Desirable and permissible limits of Groundwater parameters prescribed by WHO for drinking purposes

Water Quality Parameters	WHO (2017) [11]		Analytical results of Parameters		
	Desirable Limit	Permissible Limit	Minimum	Maximum	Mean
EC (dSm^{-1})	0.75	1.5	0.6	3.5	1.6
pH	6.5 – 8.5	9.2	7.4	8.0	7.6
TDS (mg L^{-1})	500	1,500	358	2266	1033
Ca^{2+} (mg L^{-1})	75	200	50.0	136	81.7
Mg^{2+} (mg L^{-1})	30	150	20.74	41.48	31.25

Na^+ (mg L^{-1})	50	200	35.4	568.1	200.7
K^+ (mg L^{-1})	10	12	5.47	34.4	15.3
HCO_3^- (mg L^{-1})	-	-	153	421	252
$CO3^{2-}$ (mg L^{-1})	-	-	0.0	39.0	12.5
Cl^- (mg L^{-1})	250	600	78.7	805	338
SO_4^{2-} (mg L^{-1})	200	600	17.76	121.92	52.93

Table 4: Correlation matrixof groundwater samples from TNPL Unit II in and around surrounding village

Parameters	**pH**	**EC**	**TDS**	**Ca^2**	**Mg^2**	**K**	**Na**	**CO3**	**HCO_3**	**Cl**	**SO_4**	**RSC**	**SAR**
pH	1												
EC	-.243	1											
TDS	-.243	1.000**	1										
Ca2	-.434	.830**	.830**	1									
Mg2	-.295	.603**	.603**	.565*	1								
K	.145	.848**	.848**	.623**	.356	1							
Na	-.213	.987**	.987**	.769**	.515*	.855**	1						
CO3	-.025	.429	.429	.266	.135	.548*	.423	1					
HCO3	-.170	.939**	.939**	.723**	.631**	.832**	.911**	.509*	1				
Cl	-.254	.995**	.995**	.820**	.610**	.823**	.983**	.388	.922**	1			
SO4	-.219	.981**	.981**	.823**	.630**	.835**	.957**	.387	.952**	.975**	1		
RSC	.385	-.029	-.029	-.451	-.384	.231	.045	.558*	.153	-.056	-.037	1	
SAR	-.179	.967**	.967**	.698**	.473*	.841**	.991**	.433	.906**	.964**	.942**	.135	1
*. Correlation is significant at the 0.05 level.													
**. Correlation is significant at the 0.01 level.													

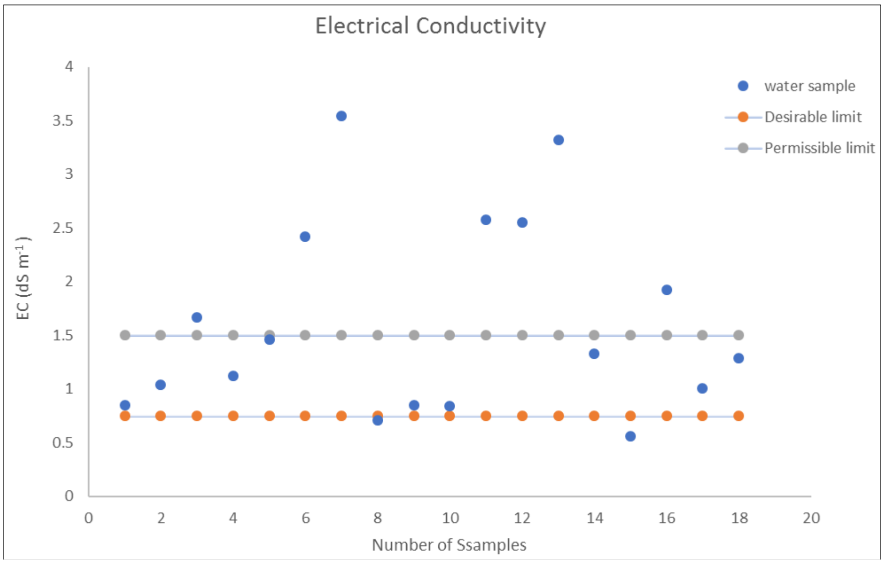

Fig 1: Distribution of Electrical conductivity

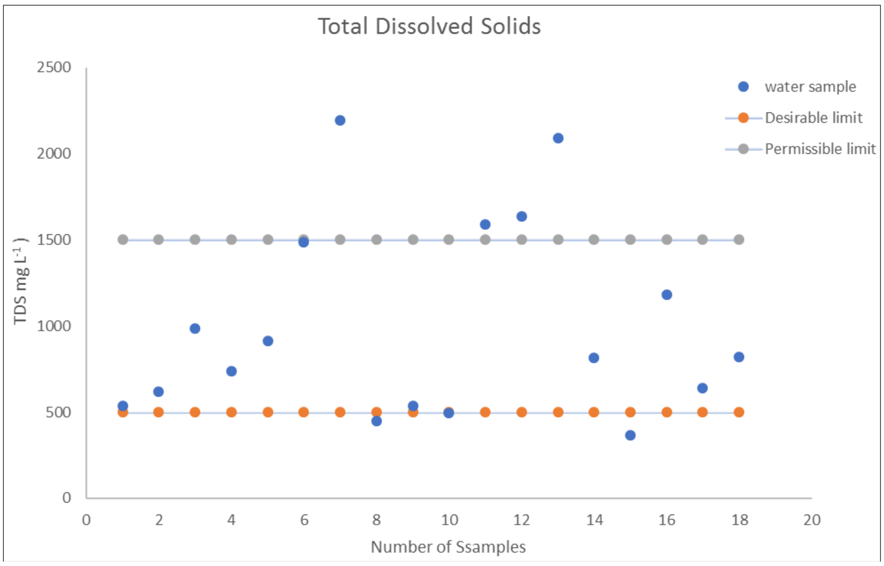

Fig 2: Distribution of TDS

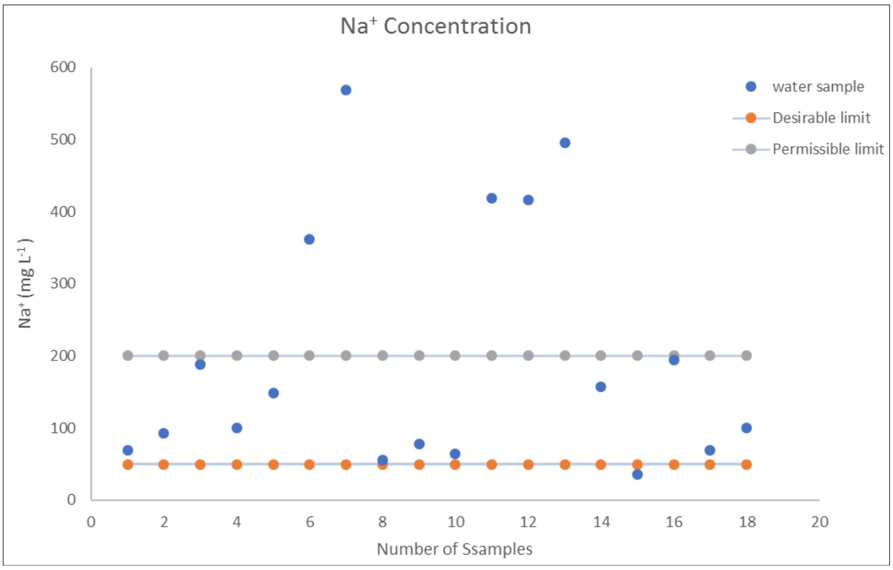

Fig 3: Distribution of Sodium

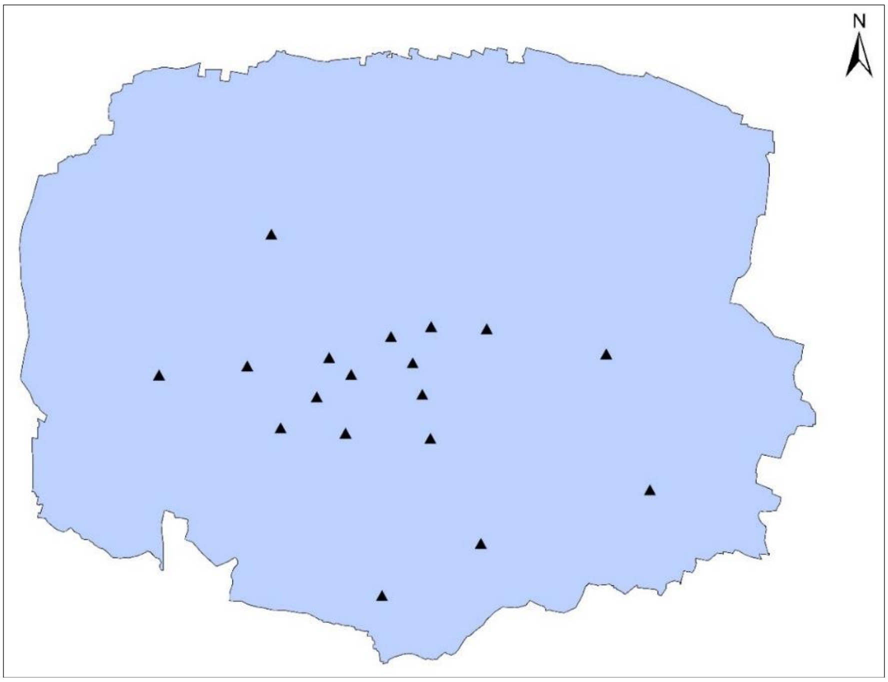

Fig 4: Location Map of Water Sampling Study Area

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