Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

A Case Study in Aruovil Blocks Villupuram District Tamil Nadu, India: To Evaluate Ground Water Quality for Drinking and Irrigation Suitability

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The study area Aruovil blocks is water starved region for the past few years due to insufficient rainfall, led to the groundwater depletion and affect the groundwater quality. Ground water samples were collected from different localities in and around Aruovil blocks. Analysis result was compared with the WHO standards of drinking water quality parameters namely EC, TDS, Calcium, Magnesium, Sodium, Potassium, Nitrate, Carbonate, Bicarbonate, Fluoride etc., usefulness of these parameters in predicting ground water quality characteristics is discussed. The quality of ground water in the study area is classified into fresh to brackish water and moderately hard to very hard water. From the overall evaluation of collected groundwater sample it is observed that the water from the study area is suitable for drinking purposes. Groundwater Chloro-Alkaline-Indicies (CAI) suggests that there is an exchange of Mg2+ and Ca2+ in water with Na+ and K+ in rock. The calculated values in RSC, SAR, Na %, show that the water is suitable for Irrigation purposes.

Keywords: Groundwater; Physical; Chemical; Characteristics; Analysis; WHO standards.

1. Introduction

In the global level groundwater is needed for human consumption, for ecosystem support and for the conservation of the quality of the river base flow in addition to the use of surface water. In order to ensure the effective and healthy use of resources for drinking, agricultural and industrial purposes groundwater quality assessment is essential [1].There has been a tremendous increase in the demand for groundwater due to the increase in population, irrigation practices and industrial usages [2]. Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes [3]. Groundwater quality is largely controlled by discharge and recharges patterns of aquifers, nature of host and related rocks, and contaminated actions [5]. The change in the quality of groundwater in an area is a result of physical and chemical parameters that are greatly affected by geological formations and anthropogenic activities. Several researchers have focused on groundwater quality monitoring and assessment for domestic and industrial activities [4, 6]. Due to over withdrawal of groundwater for agricultural, domestic and industrial purposes groundwater level has gone

down and this decreases the quality and quantity of groundwater [7]. The value of groundwater lies not only in its vast occurrence and availability but also in its reliable quality [8]. Poor water quality will affect the plant growth and human health [9]. Regular monitoring of groundwater is important to protect their quality from the pollution [10]. The major aim of this research is to investigate the levels of Calcium, Magnesium, Sodium in the surrounding villages of Aruovil blocks and thereafter compare the obtained results with the WHO standards for water quality and to give direction for further implementation action plan to the concerned body.

2. Materials and Methods

During the post-monsoon cycle in the year 2018, groundwater samples were collected in clean polythene bottles. 20 groundwater samples were collected from open and bore wells in the study area. The electrical conductivity and pH were measured in the field using portable kit. The collected samples were chemically analysed by standard analytical method APHA[11].

2.1 Study area

The study area Aruovil blocks (Fig:1) is one of the blocks in Viluppuram district, Tamilnadu, India. The block is situated in the northern part of the Viluppuram district. The Aruovil blocks lies at latitude of 12º 10’ to 12º 25’N and at longitude of 79º 35’ to 79º50’E. The total area is 270.5 sq.kms. Samples collected from open wells and bore wells are labelled with details of the locations. They are 1. Pattanam (OW) 2. Ural 3. Melpakkam (OW).4. Evalur (OW) 5. Evalur (BW) 6. Evalur. 7. Purangarai (OW) 8. Purangarai (BW) 9. Olakkur(OW) 10.Saram 11.Echeri 12.Nolambur 13.Kilkudalur 14. Melpettai 15. Panjalam (OW). 16. Melpakkam (BW) 17.Pattanam (BW) 18.Olakkur(BW) 19. Venmaniathur 20. Panjalam (BW). Water samples collected in the field were analyzed in the laboratory for the major cations and anions using the standard methods as recommended by the American Public Health Association [12].

3. Results and Discussions

The physical and chemical parameters of Aruovil blocks is shown in Table 1. The groundwater quality data analysis for drinking water has been carried out as per the guidelines [13]. The pH value of ground water samples varies from 6.9 to 8.2 with an average of 7.34 indicating alkaline nature. Almost all samples fall (6.5 to 8.5) within the recommended limits of WHO [14] for human utilization.

Table: 1 Physical and chemical parameters of Groundwater in Aruovil block

Sample No	TDS	PH	TH	EC (µS/cm)	Ca	Mg	Na	K	HCO3	CL	NO3	FL	CO3	SO4
1	1080	7	300	1020	54	58	480	22	104	200	18	1	24	36
2	1128	7.2	290	670	44	37	280	32	98	240	20	1	18	22
3	1260	7.1	350	790	28	19	300	13	67	300	15	1	6	12
4	960	7.7	250	2120	40	49	540	40	183	200	37	0.5	36	46
5	864	7	220	2050	37	42	485	42	121	180	28	1	18	23
6	1236	7.5	370	1460	40	53	480	40	134	250	19	0.5	24	12
7	1068	6.9	290	560	51	47	495	39	141	200	34	1	18	11
8	924	7.5	250	780	22	18	185	19	98	220	33	1	19	16
9	1248	7	340	320	74	103	720	26	146	300	12	1	36	48

10	1572	7.5	450	670	30	14	45	0	24	360	16	1	6	14
11	1020	7.2	300	780	56	23	66	2	85	250	22	1	6	21
12	1164	8.2	340	1230	28	16	62	4	61	210	34	0.5	6	30
13	1572	7.5	430	750	86	50	440	11	85	380	28	0.5	12	34
14	1212	7	280	920	38	35	600	24	49	250	14	1	18	21
15	1080	7.5	360	840	34	20	300	12	73	320	23	1	24	17
16	792	7.5	240	970	30	35	280	17	122	140	27	1	18	39
17	708	7	200	490	43	43	245	23	56	170	11	1	21	23
18	1080	7.5	300	1780	56	22	325	12	73	250	24	1	14.45	18
19	924	7.6	260	1200	43	56	143	35	70	160	21	1	14.02	24
20	732	7.5	210	3100	23	36	275	37	67	150	18	0.5	13.6	16

All parameters are in mg/L except pH, EC and EC in μS/cm.

The electrical conductivity values range from 320 to 3100 μS/cm (Table 1). The electrical conductivity (EC) of water is a function of dissolved mineral content. It is a good marker of Total Dissolved Solids (TDS) which is an indication of salinity that affects the taste of potable water [16]. TDS concentration of study area is observed as minimum of 708 mg/l in (Panjalam) and maximum of 1572 mg/l in (Nolambur). TDS value of less than 1000 mg/l in groundwater can be used for consumable purpose without any risk, because it has lower content of soluble salts.

Calcium concentration in groundwater samples ranges from 22 to 86 mg/l. Magnesium concentration in groundwater samples ranges between 14 and 103 mg/l. Calcium and magnesium ions present in groundwater is due to leaching of limestone, dolomites and gypsum because of weathering of rocks. All the groundwater samples have sodium concentration, because most of the rocks and soils contain sodium compounds from which sodium is easily dissolved. Sodium is necessary for the human body to function normally. Pollution or salt water intrusion may be demonstrated by a rise in sodium in groundwater above normal levels. The sodium concentration varies from 45 to 720 mg/l in the groundwater of the study area, with an average value of 337.3 mg/l. The maximum concentration of sodium is observed in the locations Olakkur, Kilkodalur, Evalur, (S.no:9,4,14). 15 samples from the study area are having the concentrations above the permissible limit prescribed by WHO standards. Potassium concentration is good if it is less than 10 mg/l for drinking water [15]. The major source of potassium in groundwater is due to weathering of rocks which are rich in minerals like microcline, orthoclase and biotit. Potassium concentration ranged from 0 to 42 mg/l. It is observed that potassium concentration is low in groundwater; the reason is that potassium is resistant to decomposition. The bicarbonate concentration of the groundwater samples range from 24 to 183 mg/l. Dissolved CO_2 from rainwater is the source of bicarbonate in groundwater and dissolves more CO_2 as it percolates into the subsurface soil.

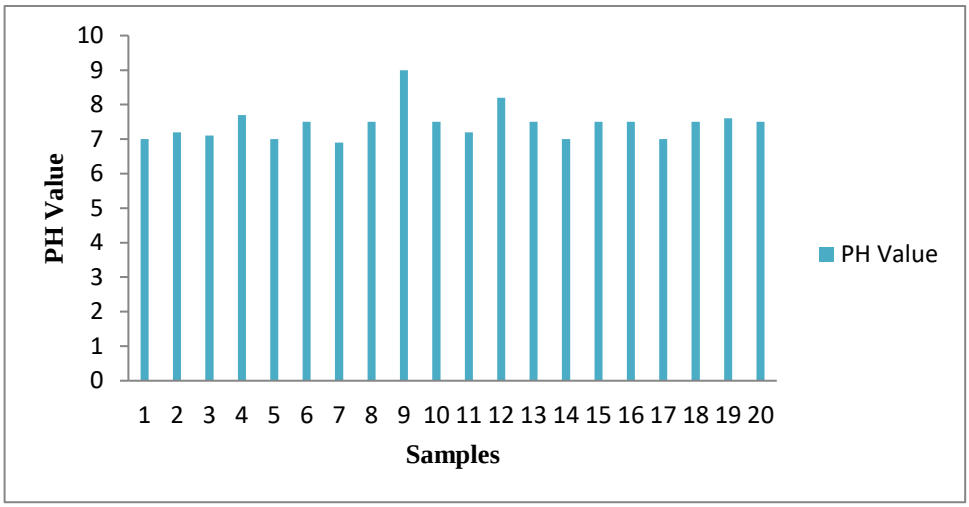

Fig.2: Variation of PH Value and Samples

Figure 2 indicates the PH of samples. On the acidic side, there has always been a shift in PH value. The PH value ranges from 7.0 to 9.0 this is largely due to the large quantity of agricultural input inflows and also due to the decomposition of plankton and organic matter. The degree of PH is shown to be lower than that of the minimum prescribed value.

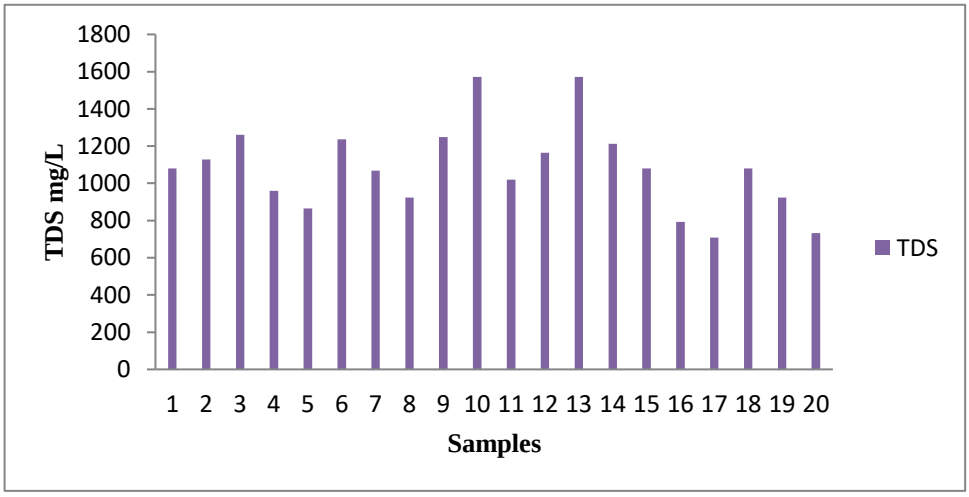

Fig.3: Variation of TDS and Samples

Table: 2 Physico-chemical parameters for drinking water prescribed by WHO (2004)

S.no	Substance/ Characteristic	Desirable Limit	Permissible limit	No.of Samples Exceeding Permissible limit
1	pH	6.5-8.5	-	Nil
2	TDS(mg/l)	500	1500	2
3	Hardness, mg/L	100	500	Nil
4	Calcium (mg/l)	75	200	Nil
5	Magnesium (mg/l)	50	150	Nil
6	Sodium, mg/L	-	200	15

7	Chloride (mg/l)	200	600	Nil
8	Sulphate (mg/l)	200	400	Nil
9	Nitrate (mg/l)	-	45	Nil
10	Fluoride, mg/L	0.6	1.5	Nil

In groundwater samples, total dissolved solids range from 492 to 945 mg L−1, as shown in Fig 3. Site 7 was on the other hand, distinguished by low TDS. From the value of the standard deviation, it is obvious that there is a large difference between the samples with respect to their TDS. The distribution of TDS levels in groundwater samples indicates that the best quality water (TDS<500, as specified by USEPA) was present at two sites (No, 1 and 7) of the water samples. Whereas the water sampling sites (no, 1, 2, 3, 6 and 7) [TDS= 1000-1500 mg L−1] comply with the overall standards and guideline limits for drinking water set by SASO, G.C.C.S and WHO.

Chloride concentration ranges from140 to 380 mg/l .The high chloride concentration was recorded in villages Nolambur, Olakkur, Melpettai (S.no:13,10,15). It is due to replacement of hydroxide to chloride in the hornblende biotite gneissic rocks [17]. Nitrate is one of the most common indicators of manure and inorganic fertilizer impacts. Numerous researchers indicate that concentration of nitrate is often high in groundwater in areas of intensive agriculture. Nitrate concentration in the study area ranges from 11 to 37 mg/l. Fluoride concentration in the groundwater samples ranges from 0.5 to 1 mg/l. Fluoride values are within the desirable limit. Physical and chemical parameters of groundwater in the study area fall within the permissible limit as per WHO [18], shows that the samples are suitable for drinking purposes, except sodium concentration (table:2). The enrichment of sodium concentration in groundwater occurs may be due to long residence time of water, dissolution of minerals from lithological composition and in addition input of fertilizers with irrigation waters [19].

3.1 Suitability of Groundwater for Irrigation

The EC of the ground water in the study area ranges from 320 to 3100(µS/cm) with an average of 1125(µS/cm). 17 samples of groundwater from the study area shows good to permissible category, remaining 2 samples collected from the location Evalur (OW & BW), fell in the doubtful category and 1 sample comes under unsuitable category from the location Venmaniathur. The study shows that 85% of samples are suitable for irrigation purposes. The higher value of EC is attributed to geochemical processes and anthropogenic activities given in Table 3.

Table.3 Ground water Quality based on Electrical conductivity

EC (µS/cm)	Category	No. of Samples
< 250	Excellent	NIL
250-750	Good	6
750-2000	Permissible	11
2000-3000	Doubtful	2
>3000	Unsuitable	1

3.2 Sodium Adsorption Ratio (SAR)

For determining the suitability of groundwater for irrigation purpose, Sodium Adsorption Ratio (SAR) is broadly used. If the water used for irrigation consists high concentration of Na^{2+} and low concentration of Ca^{2+} then the ion exchange complex may turn into saturated with Na^{2+}, which affects the soil structure and plants growth [20]. Based on the categorization,

25% of samples fall in the excellent category and 60% of samples fall in the good and the remaining 15 % of the samples come under doubtful category(Table:4). Hence 85 % of samples are suitable for irrigation purposes [21].

Table.4 Ground water Suitability for Irrigation purposes based on Sodium Adsorption Ratio (SAR)

SAR Range	Categories	No. of Samples
<10	Excellent	5
10 to 18	Good	12
18 to 26	Doubtful	3
>26	Unsuitable	NIL

3.3 Sodium percentage (Na%)

Alkali soils contain a significant amount of sodium with carbonate as the chief anion; saline soils are those with chloride or sulphate as the predominant anion. Sodium plays a major role in the classification of water, used for irrigation, due to the fact that sodium reacts with the soil and as a consequence particle clogging occurs, thus decreasing permeability [22].The Na% is computed with respect to relative proportion of cations present in water; all ionic concentrations are expressed in meq/l [23]. Sodium percentage in water is a parameter computed to evaluate the suitability for irrigation [24]. Based on the classification 60 % of samples from the study area observed as doubtful category and 15 % of samples are under permissible category and 20 % of samples fall in Unsuitable category (Table:5).

Table.5 Ground water Suitability for Irrigation purposes based on Sodium Percentage (Na %)

Range	Categories	No. of Samples
<20	Excellent	Nil
20-40	Good	1
40-60	Permissible	3
60-80	Doubtful	12
>80	Unsuitable	4

3.4 Residual Sodium Carbonate (RSC)

The RSC values shown in the table: 6 is rated based on RSC value. If the RSC value is smaller than 1.25 meq/l then it is safe for irrigation, a value between 1.25 and 2.5 meq/l is of marginal quality, and a value of greater than 2.5 meq/l is incompatible for irrigation, according to the US Salinity Laboratory (1954). The calculated RSC values reflect that all the groundwater samples in the study region are suitable for irrigation purposes.

Table.6 Ground water Suitability for Irrigation purposes based on Residual Sodium Carbonate (RSC)

RSC (meq/l)	Categories	No. of Samples
< 1.25	Safe	20
1.25 - 2.5	Moderate	NIL
> 2.5	Unsuitable	NIL

3.5 Index of Base Exchange

It is essential to understand the changes in chemical composition of groundwater during its journey in the underground [25]. The CAI 1 and CAI 2 chloro-alkaline indices[26], which show the ion exchange between groundwater and its host community. The Chloro-alkaline

indices used for the Base Exchange evaluation are determined using formulas.

1. Chloro Alkaline Indices 1 = $(Cl^- – (Na^+ + K^+)) / Cl^-$

2. Chloro Alkaline Indices 2 = $(Cl^- – (Na^+ + K^+) / (SO^{2-}_4 + HCO^-_3 + CO^{2-}_3 + NO^-_3)$

The exchange is known as direct when the indices are positive, if there is an ion exchange reaction of Na+ and K+ from water with Mg and Ca in the rock. If the trade is reversed, the exchange is indirect and it is found that the indices are negative [27].

The Chloro-alkaline Indices of groundwater has been observed that CAI -1 value ranges between -3.36 and 0.80, while CAI-2 vales fall between -9.50 and 7.17. The present study shows that 85 % of groundwater samples show negative ratios and 15 % of groundwater samples show positive ratios. Positive Chloro-Alkaline Indices indicate exchange of Na^+ and K^+ from the water with Mg^{2+} and Ca^{2+} of the rocks [28]. Negative Chloro-alkaline Indices of groundwater indicates there is an exchange of Mg^{2+} and Ca^{2+} of the water with Na^+ and K^+ of the rocks [29].

4. Conclusion

Based on the analysis of groundwater, it has been possible to understand the geochemical quality of groundwater in the study area and to evaluate its suitability for drinking and irrigation purposes. The study inferred that the groundwater in the study area is slightly alkaline in nature. Na, Ca, HCO3, and Cl are the dominant ions and 45 % of the study area exceeded the recommended limits of TDS. Total hardness reveals that the water is generally hard in nature.

From the analysis it is inferred that the physical and chemical characteristics of groundwater in the study area are alkaline in nature. The concentrations of major ions in the groundwater are within the permissible limits of WHO standards, except Sodium concentration. The Fluoride concentration in the groundwater is within the permissible limits and overall parameters shows that the groundwater is suitable for drinking purposes. Groundwater Chloro-alkaline indices suggest an exchange of Mg^{2+} and Ca^{2+} of water with Na^+ and K^+ of the rocks. The values in EC, SAR, Na%, RSC indicates that the water is suitable for irrigation purposes.

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