**Evaluation of Coastal Groundwater Quality for Irrigation Use in Thiruchendur Region of Tamil Nadu, India**

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ABSTRACT

This work addresses important problems with groundwater sustainability in coastal farming areas, where seawater intrusion compromises the quality of irrigation water. The study gives real-world examples of how hydrochemical levels change with the seasons, uses the usual AICRP categorization for irrigation appropriateness, and identifies areas in Thiruchendur taluk that are at high risk. Its GIS-based technique and block-by-block analysis give policymakers and farmers useful information on how to use climate-resilient water management methods. The results are very important for semi-arid areas around the world that are experiencing salinity problems because of climate change and excessive extraction. The groundwater quality was assessed by collecting 43 ground water samples during pre as well as post monsoon season and suitability of irrigation water was established based on AICRP classification. All the groundwater samples were analysed for pH, EC, anions (CO3, HCO3, Cl-, SO42-) and cations (Ca2+, Mg2+, K+ and Na+). The pH of the groundwaters of Thiruchendur taluk indicated that there was no much variation in pH of water samples collected during pre and post monsoon seasons. However, there was a wide variation noticed in EC values of groundwater, between blocks and seasons. The well waters of Thiruchendur and Udangudi blocks were of Na-Mg-Ca and Cl- SO4- HCO3 whereas, the groundwaters of Alwarthirunagari block were of Na- Ca-Mg and Cl- HCO3- - SO4 type. In higher salinity range, sodium was associated mainly with chloride and sulphate. It is concluded that most of the well waters in Thiruchendur and Udangudi blocks are intruded with sea water and are of poor in quality. The well waters Alwarthirunagari block are likely to be vulnerable to intrusion. The well waters of Thiruchendur and Udangudi blocks should be considered seriously since the quality parameters are nearer to the composition of sea water in sodium chloride and magnesium sulphate combination. The water samples of Alwarthirunagari block fall near composition of sea water in sodium chloride combination and they may get affected by sea water intrusion after sometime.According to the AICRP suitability classification, during the pre-monsoon season, 51%, 23%, 19%, and 7% of the water samples from the entire study area were categorized as good, high SAR saline, marginally saline, and saline, respectively. In contrast, during the post-monsoon season, 65% of the samples were classified as good.

**Key words:** Groundwater quality, EC, SAR, RSC, Irrigation

1. INTRODUCTION

India has 2.2 per cent of the global land, four per cent of the world water resources and 16 per cent of world’s population (Ramesh and Elango, 2011). Amongst water resources, groundwater is the major source for domestic, agricultural and industrial purposes in semi-arid and arid regions of India. Water is a prime resource which sustains life in this planet earth. Virtually no activity in society or process in the landscape or in the environment would be possible in the absence of water. Two-thirds of the earth surface is covered by water but 98 per cent of it is saline. The remaining 2 per cent freshwater supports all forms of terrestrial life. Rain is the source of freshwater in hydrological cycle and it flows as streams, rivers and percolates down to recharge groundwater.

Tamil Nadu heavily utilizes the available surface water (17.5 Billion Cubic Meter) and groundwater (15.3 Billion Cubic Meter). Agricultural sector consumes about 75 per cent of the water resources. The total water potential of Tamil Nadu is about 5.65 M ha (Million hectare) i.e., 2.5 M ha from surface water and 3.15 M ha from groundwater resource. The area irrigated by groundwater source in Tamil Nadu in the last five decades has increased from 0.5 M ha which is 23.6 per cent of total irrigated area of 2.12 M ha in 1950’s to 1.45 M ha which is 48.8 per cent of the total irrigated area of 2.97 M ha in 2000. In Tamil Nadu, there is dwindling surface water flows due to monsoon failure and decline in storage capacities of tanks due to encroachment and silting. This has led to lowering of ground water table, increasing pumping cost, sea water intrusion and ultimately a drastic change in water quality. Considering the seriousness of the issue an assessment of groundwater quality of Thiruchendur taluk was taken up

In Thiruchendur taluk, the sea water intrusion is the major factor responsible for increase of salt in groundwater. Soil salinity is directly related to groundwater salinity of the coastal region. In this area groundwater rise due to poor drainage system are considered to be the major factors responsible for salt accumulation in groundwater. In Thiruchendur taluk, soil sodicity problem limits agricultural productivity due to faulty irrigation, intensive cultivation of high water requirement crops, use of poor quality water, lack of adequate knowledge about soils and poor management practices.

2. material and methods

**2.1 Study area**

 Thiruchendur taluk lies between 8° 22’87’’N to 8° 35’93’’N Latitude and 77° 57’04’’E to 78° 06’65’’E Longitude at an altitude of 5 m above mean sea level. Thiruchendur taluk is bounded by Bay of Bengal in the East, Srivaikundam taluk in the North, Sattankulam taluk in the West, Bay of Bengal in the South. The rainy season covers June to December and maximum rainfall is received during North East monsoon from October to December followed by South West monsoon from June to September. There are about 7,303 canals, 1,135 tanks, 21 tube/bore wells and 4073 ordinary wells as source of irrigation. Total net area irrigated is 12,532 ha. (Department of Economics and Statistics, Govt. of Tamil Nadu, 2006). The principal crops grown are paddy, pulses and oilseeds. Thiruchendur taluk contain three blocks namely Abwarthirunagari. Tiruchendur and Udangudi. The taluk contain 58 revenue villages (as per TWAD). The taluk has a total geographical area of 47,608 hectares including reserved forest.

**2.2 Collection of groundwater**

The groundwater quality of Thiruchendur taluk was assessed by collecting 43 groundwater in Pre and Postmonsoon during 2015 at 4x4 km grids wise and characterized for its anionic and catiomic composition. To determine the groundwater quality, water samples were collected in bench mark locations during pre-monsoon (February to May) and post-monsoon (October to January) seasons.. Groundwater samples were taken in polyethylene containers from all available water sources, i.e., dug wells open wells and tube wells in the study area. Most of the sample wells are used for domestic, agricultural and drinking Water purpose. The groundwater quality was assessed based on criteria proposed by AICRP (Table 1).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **S.No** | **Grid No** | **Village** | **S.No** | **Grid No** | **Village** |
|
|  **Alwarthirunagari block** | 23 | G23 | Meerankulam |
| 1 | G1 | Punnaikayal | 24 | G24 | Srivenkateshwarapuram |
| 2 | G2 | Serndamangalam | **Thiruchendur block** |
| 3 | G3 | Athor kasba | 25 | G25 | Kayalpattinam |
| 4 | G4 | Suganthalai | 26 | G26 | Veerapandiyanpattanam |
| 5 | G5 | Sethukkuvaythan | 27 | G27 | KeelaThiruchendur  |
| 6 | G6 | Nalumavadi | 28 | G28 | Ammanpuram |
| 7 | G7 | Mavadipannai | 29 | G29 | Kanam |
| 8 | G8 | Kachanavilai | 30 | G30 | MelaThiruchendur  |
| 9 | G9 | Cemballebad | 31 | G31 | kandasamypuram |
| 10 | G10 | Kadaiyanodai | 32 | G32 | Kayamolli |
| 11 | G11 | Nazarath | **Udangudi block** |
| 12 | G12 | Thirukalur | 33 | G33 | ParamanKurichi |
| 13 | G13 | Udaiyarkulam | 34 | G34 | ManaduThandupathu |
| 14 | G14 | Kattarimangalam | 35 | G35 | Adiyakurichi |
| 15 | G15 | Malavarayanatham | 36 | G36 | KulasekaranPattinam |
| 16 | G16 | Kurippankulam | 37 | G37 | Kuthiraimoli |
| 17 | G17 | Vellamadam | 38 | G38 | Semmarikulam |
| 18 | G18 | Karungadal | 39 | G39 | Vagaivilai |
| 19 | G19 | Asirvathapuram | 40 | G40 | Venkattaramanujapuram |
| 20 | G20 | Puraiyur | 41 | G41 | Mathavankurichi |
| 21 | G21 | Mukkuperi | 42 | G42 | Nangaimozhi |
| 22 | G22 | Therkkankulam | 43 | G43 | Lakshmipuram |

**Table 1. Details of Groundwater Sampling Grid of Thiruchendur taluk**

**2.3 Sampling procedure**

The sampling locations of Thiruchendur taluk were marked on a base map at I: 50.000 Scales prepared from the State Revenue Maps and digitized using Arc-info GIS (10.1). The toposheet of Thiruchendur taluk map has been vectorized by taking 4x4 km grids for fixing required number of bench-mark sites for collection of groundwater samples. In order to characterize the regional resources of the study area, the GPS recorded sample site co-ordinates (i.e. latitudes and longitudes) were imported (as a point feature theme layer) in Arc- View/Arc

View Spatial Analyst-GIS software. The GIS information generated for these spatially distributed sampled locations was interpolated to assign an estimated value to each environmental variable for other (non-sampled) locations in the study area. Grid l represents Punaikayal village, which is the starting point in Thiruchendur taluk and the grid 43 represents Lakshmiuram which is the end point. GIS has been applied to visualize the spatial distribution of groundwater quality and salt affected soils in the Thiruchendur taluk.

The groundwater quality indices: SAR (Sodium Adsorption Ratio), RSC(Residual Sodium Carbonate) were then calculated using the formula

RSC = (CO32-+HCO3-) - (Ca2++Mg2+)

SAR = Na+/ {(Ca2++Mg2+) /2}0.5

 **Table 2. The quality of groundwater samples were also assessed by adopting the following classification (AICRP, 1991)**

|  |  |  |
| --- | --- | --- |
| **S.No** | **Quality** | **Quality parameter** |
| **EC (dS m-1)** | **SAR** | **RSC (me L-1)** |
| 1 | Good | <2 | <10 | <2.5 |
| 2 | Marginally saline | 2-4 | <10 | <2.5 |
| 3 | Saline | >4 | <10 | <2.0 |
| 4 | High SAR saline | >4 | >10 | <2.5 |
| 5 | Marginally alkali | <4 | <10 | 2.5-4.0 |
| 6 | Alkali | <4 | <10 | >4.0 |
| 7 | Highly alkali | Variable | >10 | >4.0 |



**Tamil Nadu**

**Thoothukudi**



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**Thiruchendur**

**Fig 1. Location map of study area of Thiruchendur taluk, Thoothukudi**

**3. RESULT AND DISCUSSION**

**3.1 Variation in pH and EC of Groundwater**

**3.1.1 Reaction (pH)**

The pH of the groundwaters of Thiruchendur taluk indicated that there was no much variation in pH of water samples collected during pre and post monsoon seasons. The mean pH of water samples ranged from 8.11(post monsoon) to 8.44 (pre monsoon), 8.59 (pre monsoon) to 8.76 (post monsoon) and 7.64 (post monsoon) to 8.09 (pre monsoon) in Alwarthirunagari, Thiruchendur and Udangudi blocks respectively.

The minimum pH value during pre monsoon varied from 7.32 to 8.42, whereas the maximum value varied in the range 8.12 to 9.07 indicating no significant impact of monsoon rainfall on maximum pH of groundwater. Moreover, the mean and standard deviation of pH values did not vary significantly between pre and post monsoon season. Thus locations and seasons did not have much effect on pH of water samples. In general, the pH values of irrigation water indicating that the waters of the region were alkaline in nature. Similar results of no significant impact of monsoon rainfall on pH values of groundwater were reported by Patil and Patil (1993) and Pradhan *et al*. (2011).

**3.1.2 Electrical conductivity (EC)**

There was a wide variation noticed in EC values of groundwater, between blocks and seasons. The maximum (15.75 dS m-1) and minimum EC (0.38 dS m-1) values were observed in Udangudi and Alwarthirunagari blocks respectively. The mean and standard deviation values indicated that there was a high deviation in magnitude of EC in both pre monsoon and post monsoon period. The reason for this significant difference in EC values among the blocks is due to hydrological influence of seawater. Seasonal increase in salinity in the wells near the seashore is primarily due to salt water encroachment (Basak and Nazimuddin, 1987), (Sharma *et al.,* 2023).

**3.2 Variation in Cations and Anions of Ground Water**

**3.2.1 Calcium**

The variation in calcium values of groundwater between pre and post monsoon season was highly significant. The variation in calcium content between the seasons was highly significant. The calcium was the second most dominant cation in Alwarthirunagari block and in Thiruchendur and Udangudi blocks, it was lower than sodium and magnesium. Result of the present investigation showed that most of the values of calcium content in the well waters of different blocks fell within the range of 3.2 to 9.8 me L-1. Irrigating with low calcium and sodium rich water will cause alkalinity in the soil as suggested by Kelley (1963).

**3.2.2 Magnesium**

The variation in magnesium of groundwater samples collected during pre and post monsoon season was highly significant. The magnesium is the second most abundant cation found in the groundwater of Thiruchendur and Udangudi blocks, whereas in Alwarthirunagari block, Ca2+ dominate over Mg 2+ ions. The fluctuation in Mg content was highly significant between seasons. The Mg2+content of groundwater varied from 3.10 to 8.27 and 4.47 to 12.2 me L-1 in Thiruchendur and Udangudi blocks respectively. This wide difference depends on the location of aquifers and MSL besides the extent of intrusion of seawater. That the magnesium is present in seawater in much greater concentration than calcium and therefore a low Ca/Mg ratio indicates the contamination by seawater (Handa, 1989). Occurrence of magnesium ions in higher proportion than calcium ions tends to cause adverse effect by increasing the adsorption of sodium on the exchangeable complex, particularly with high SAR. Higher magnesium levels (vs. calcium) increase sodium adsorption in soils, especially when SAR is high. (Jafar Ahamed *et al*., 2013).

**3.2.3 Sodium**

The variation in sodium values of groundwater between pre and post monsoon season was highly significant. Among different cations (Na+, K+, Ca2+, Mg2+) analysed in groundwater, sodium was found as the most dominant cation, followed by magnesium, calcium and potassium in Thiruchendur and Udangudi blocks during pre monsoon and post monsoon periods. But, in block Alwarthirunagari, the order of composition was sodium, calcium, magnesium and potassium. The difference in sodium content of water samples collected in different blocks was highly significant. The Na content of water samples was very high in the groundwaters of Thiruchendur and Udangudi blocks where Na content ranged from 8.50 to 13.71 and 6.92 to 25.79 me L-1 respectively.The presence of large proportion of Na+ in these blocks under investigation is indicative of a potential danger for the alkalinity hazards.(Table 3)

This variation might be due to seawater intrusion in the coastal aquifers. Mahendran and Arunachalam (2002) reported that about 37 per cent of the total samples wells of Chennai coastal zone were intruded with seawater and the dominant cation and anion was sodium and chloride respectively. Similarly results were also reported by Ashok Kumar *et al*. (2014).

**3.2.4 Potassium**

Potassium content of groundwater samples in different blocks during pre monsoon period, the potassium in Alwarthirunagari block ranged from 0.01 to 0.85 me L-1 with a mean of 0.32 me L-1, whereas in Thiruchendur block, it differed from 0.02 to 2.36 me L-1 with a mean of 0.45 me L-1. Similarly in Udangudi block, the potassium varied from 0.03 to 0.52 me L-1 with a mean of 0.28 me L-1.With reference to post monsoon period, potassium content varied from 0.05 to 0.57, 0.02 to 0.92 and 0.21 to 0.56 me L-1 with the mean values of 0.30, 0.31 and 0.35 me L-1 in Alwarthirunagari, Thiruchendur and Udangudi blocks respectively.

**3.2.5 Bicarbonate**

There was no much variation in bicarbonate content of groundwater samples collected in different seasons. The bicarbonates occurred in low salinity waters and their concentration usually decreased with increase in EC. The proportion of bicarbonate ions is lower than calcium and hence there was not much of Residual Sodium Carbonate (RSC) problems. Seasonal analyses of water samples for cations and anions from showed that the concentration of both anions and cations in different blocks increased considerably during summer season and decreased during rainy season. In general, the higher values were recorded during pre monsoon and lower during post monsoon due to dilution by rain water. Seasonal fluctuations of cation and anion sequence in saline groundwater were also reported by Mondal *et al*. (2010) and Selvam *et al*. (2013).

**3.2.6 Carbonate**

The carbonates of water samples in Alwarthirunagari block varied from 0.32 to 1.60 me L-1 with a mean of 0.93 me L-1 during pre monsoon and 0.00 to 2.43 me L-1 with a mean of 0.68 me L-1 during post monsoon. Similarly the carbonates content of water samples in Thiruchendur block ranged from 0.75 to 4.00 me L-1 with a mean of 2.19 me L-1 during pre monsoon and 0.58 to 1.68 me L-1 with a mean of 1.01 me L-1 during post monsoon season. In Udangudi block, the carbonates concentration was found to vary from 0.00 to 2.05 me L-1 with a mean of 0.77 me L-1 during pre monsoon and 0.00 to 1.03 me L-1 with a mean of 0.09 me L-1 during post monsoon (Table 4).

**3.2.7 Sulphate**

The sulphate content was low in most of the well waters. In Thiruchendur block, the mean sulphate content was 4.58 me L-1 in pre monsoon season whereas in other two blocks was less than 3.39 me L-1. This may be due to the variation on the extent of seawater intrusion into the coastal aquifers. No separate classification for specific ion toxicity of sulphate has yet been proposed. However, Eaton (1950) considered sulphate as half harmful compared to chloride. Based on this and also on the classification based on chloride content of waters proposed by Ayers and Wescot (1976), more than 8 me L-1 can be considered to pose problems and more than 20 me L-1 likely to accentuate the severity of the problem. On this basis, the well waters of Thiruchendur and Udangudi blocks were similar results were reported by Mahendran and Arunachalam (2002) and Nag and Das (2014).

**3.2.8 Chloride**

Chloride has the highest mean concentration (42.77 me L-1) in the groundwater of Udangudi block during pre monsoon and lowest mean concentration (8.56 me L-1) during post monsoon period was noticed in the block of Alwarthirunagari. Balasubramanian *et al*. (1985) also reported that the areas of East coastal belt of Tambraparani basin of Tamil Nadu had higher concentration of Chloride because of saline intrusion.

**3.3 Sodium Adsorption Ratio (SAR)**

The variation in SAR in content of the groundwater samples collected for pre and post monsoon season interval was highly significant.

During pre monsoon, the SAR values of water samples in Alwarthirunagari block ranged from 0.41 to 13.38 with a mean of 4.93, whereas in Thiruchendur block, it differed from 0.96 to 11.30 with a mean of 4.73. Similarly in Udangudi block, the SAR varied from 0.47 to 15.49 with a mean of 6.66.With reference to post monsoon period, SAR values varied from 0.27 to 10.69, 1.06 to 8.25 and 0.82 to 6.93 with the mean values of 3.29, 4.00 and 3.26 in Alwarthirunagari, Thiruchendur and Udangudi blocks respectively.

**3.4 Residual Sodium Carbonate (RSC)**

The variation in RSC values of groundwater between pre and post monsoon season was highly significant.

The RSC of water samples in Alwarthirunagari block varied from -18.26 to -0.17 me L-1 with a mean of -7.00 me L-1 during pre monsoon and -16.66 to 3.04 me L-1 with a mean of -2.32 during post monsoon. Similarly the RSC of water samples in Thiruchendur block ranged from -21.18 to 5.00 with a mean of -8.05 during pre monsoon and -9.03 to 2.06 me L-1 with a mean of -2.60 me L-1 during post monsoon season. In Udangudi block, the RSC of water samples was found to vary from -47.32 to -2.36 me L-1 with a mean of -18.70 me L-1 during pre monsoon and -24.09 to 1.91 me L-1 with a mean of -5.17 me L-1 during post monsoon.

**3.5 Suitability of groundwater for irrigation based on AICRP classification**

According to AICRP classification (Gupta *et al*., 1994), it was found that water samples of 3 locations were high SAR saline with the per cent distribution of 12.5; 16 locations good with the per cent distribution of 66.66 and 5 samples marginally saline with the per cent distribution of 20.83 in Alwarthirunagari block during pre monsoon period. Similarly, during post monsoon season, 20, 3 and 1 location of groundwater samples in the same block had good, marginally saline and high SAR saline with the per cent distribution of 83.3, 12.5 and 4.2 respectively.

In Thiruchendur blocks, 2, 2, 1, 2 and 1 were good, high SAR saline, marginally saline, saline and alkali with the per cent distribution of 25, 25, 12.5, 25 and 12.5 respectively during pre monsoon season. The quality of post monsoon data revealed that 4 locations were marginally saline as well as good with the per cent distribution of 50 and 50 respectively.

With regard to Udangudi block, 4, 5, 1 and 1 location were good, high SAR saline, marginally saline and saline respectively during pre monsoon period with the per cent distribution of 36.35, 45.45, 9.00 and 9.09 respectively. The groundwater of post monsoon data showed that 7 and 4 locations were good and marginally saline with the per cent distribution of 63.63 and 36.36 respectively.

|  |  |
| --- | --- |
| D:\ \Arul_Mani_All\PG\Article\Image\ppt Fig-premonsoon.jpg | D:\ \Arul_Mani_All\PG\Article\Image\ppt fig-postmonsoon_1.jpg |

**Fig 2. Groundwater quality classification for pre and postmonsoon of Thiruchendur taluk according to AICRP, 1991**

**4. Conclusion**

 As per the AICRP suitability classification, 51, 23, 19 and 7 per cent of water samples of entre study area were classified under good, high SAR saline, marginally saline and saline categories respectively during pre monsoon season. Whereas during post monsoon season, 65 per cent of water samples were classified under good. 33 per cent under marginally saline and 2 per cent under high SAR saline indicating dilution of water by rain. This will make it easier to cultivate crops that are sensitive to salt and acidity. Additionally, the farmers will be encouraged to grow more crops with higher productivity, providing a better economic return, due to the suitability of ground water for irrigation in the Postmonsoon period.

**DISCLAIMER (ARTIFIICIAL INTELLIGENCE)**

Authos(s) hereby declares that NO generative AI technologies such as large language models (ChatGPT, COPILOT, etc) and text-to-image generators have used during writing or editing of manuscripts.

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**Table 3. Classification of Groundwater for irrigation in Thiruchendur taluk (Premonsoon) as per AICRP (1991)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No** | **Grid No** | **pH** | **Ca2+****(me L-1)** | **Mg2+****(me L-1)** | **Na+****(me L-1)** | **K+****(me L-1)** | **CO3****(me L-1)** | **HCO3****(me L-1)** | **Cl-****(me L-1)** | **SO42-****(me L-1)** | **EC****(dS m-1)** | **SAR****(me L-1)** | **RSC****(me L-1)** | **Class** |
| **Alwathirunagari block** |
| 1 | G1 | 8.64 | 12.80 | 8.24 | 43.41 | 0.43 | 0.80 | 2.01 | 54.46 | 3.46 | 5.85 | 13.38 | -18.23 | HS |
| 2 | G2 | 8.68 | 12.49 | 8.48 | 41.93 | 0.54 | 0.32 | 2.58 | 54.10 | 3.27 | 5.59 | 12.95 | -18.07 | HS |
| 3 | G3 | 8.29 | 4.57 | 3.48 | 10.32 | 0.62 | 0.93 | 3.20 | 13.95 | 1.74 | 1.98 | 5.39 | -3.92 | G |
| 4 | G4 | 8.44 | 1.20 | 4.40 | 3.47 | 0.01 | 1.32 | 2.03 | 3.21 | 3.83 | 1.01 | 2.07 | -2.25 | G |
| 5 | G5 | 8.64 | 1.30 | 10.40 | 2.69 | 0.04 | 0.92 | 3.25 | 5.58 | 4.43 | 1.41 | 1.11 | -7.53 | G |
| 6 | G6 | 8.66 | 3.50 | 1.97 | 6.47 | 0.25 | 0.98 | 3.02 | 6.98 | 1.08 | 1.22 | 3.91 | -1.47 | G |
| 7 | G7 | 8.82 | 5.13 | 3.30 | 7.12 | 0.34 | 1.56 | 3.38 | 11.65 | 1.31 | 1.66 | 3.47 | -3.49 | G |
| 8 | G8 | 8.10 | 1.10 | 8.70 | 2.15 | 0.06 | 0.53 | 1.74 | 5.30 | 3.01 | 1.02 | 0.97 | -7.53 | MS |
| 9 | G9 | 8.70 | 8.72 | 3.99 | 24.28 | 0.38 | 0.53 | 1.90 | 34.60 | 1.03 | 3.79 | 9.63 | -10.28 | G |
| 10 | G10 | 8.72 | 5.00 | 8.10 | 1.05 | 0.11 | 0.74 | 1.80 | 11.00 | 2.83 | 1.45 | 0.41 | -10.26 | HS |
| 11 | G11 | 8.23 | 14.32 | 10.47 | 44.37 | 0.63 | 1.60 | 4.93 | 56.13 | 4.31 | 6.94 | 12.60 | -18.26 | G |
| 12 | G12 | 8.40 | 4.30 | 2.81 | 7.37 | 0.31 | 0.79 | 3.13 | 8.61 | 2.85 | 1.40 | 3.91 | -3.19 | G |
| 13 | G13 | 8.19 | 1.55 | 11.15 | 2.19 | 0.85 | 0.95 | 3.46 | 8.45 | 4.60 | 1.42 | 0.87 | -8.29 | G |
| 14 | G14 | 8.33 | 2.41 | 0.97 | 5.36 | 0.38 | 1.20 | 2.01 | 5.89 | 1.08 | 1.31 | 4.12 | -0.17 | G |
| 15 | G15 | 8.09 | 3.99 | 3.92 | 10.14 | 0.22 | 1.01 | 1.92 | 13.88 | 1.36 | 1.82 | 5.10 | -4.98 | G |
| 16 | G16 | 8.56 | 7.40 | 0.40 | 2.64 | 0.31 | 0.48 | 2.21 | 3.25 | 2.56 | 0.88 | 1.34 | -5.11 | G |
| 17 | G17 | 8.33 | 3.81 | 2.81 | 8.37 | 0.25 | 0.78 | 3.21 | 9.66 | 1.20 | 1.49 | 4.60 | -2.63 | G |
| 18 | G18 | 8.53 | 5.31 | 7.91 | 1.87 | 0.12 | 0.76 | 2.61 | 9.91 | 2.84 | 1.45 | 0.73 | -9.85 | G |
| 19 | G19 | 8.29 | 2.60 | 1.80 | 1.73 | 0.14 | 0.85 | 2.40 | 3.20 | 2.83 | 0.97 | 1.1`7 | -1.15 | G |
| 20 | G20 | 8.07 | 5.22 | 3.58 | 12.89 | 0.25 | 0.80 | 2.78 | 17.36 | 1.51 | 2.22 | 6.15 | -5.22 | MS |
| 21 | G21 | 8.44 | 4.83 | 3.10 | 6.82 | 0.20 | 1.01 | 3.08 | 11.45 | 1.01 | 1.51 | 3.43 | -3.84 | G |
| 22 | G22 | 8.44 | 5.34 | 4.98 | 14.63 | 0.29 | 0.76 | 2.80 | 20.50 | 1.48 | 2.43 | 6.44 | --6.76 | MS |
| 23 | G23 | 8.51 | 9.05 | 6.07 | 25.54 | 0.24 | 1.54 | 2.40 | 35.05 | 2.05 | 3.86 | 9.29 | -11.18 | MS |
| 24 | G24 | 8.46 | 4.67 | 3.68 | 10.92 | 0.72 | 1.23 | 3.20 | 14.05 | 1.84 | 2.08 | 5.34 | -3.92 | MS |
|  Min Max Mean | 8.07 | 1.10 | 0.40 | 1.05 | 0.01 | 0.32 | 1.74 | 3.20 | 1.01 | 0.88 | 0.41 | -18.26 |  |
| 8.82 | 14.32 | 11.15 | 44.37 | 0.85 | 1.60 | 4.93 | 56.13 | 4.60 | 6.94 | 13.38 | -0.17 |  |
| 8.44 | 5.44 | 5.20 | 12.43 | 0.32 | 0.93 | 2.71 | 17.43 | 2.40 | 2.28 | 4.93 | -7.00 |  |
| **Thiruchendur block** |
| 25 | G25 | 8.43 | 9.12 | 10.40 | 33.77 | 0.21 | 0.93 | 1.05 | 52.00 | 1.35 | 6.83 | 10.81 | -17.54 | HS |
| 26 | G26 | 8.72 | 10.10 | 19.50 | 3.80 | 2.36 | 2.42 | 6.00 | 38.95 | 6.40 | 4.45 | 0.99 | -21.18 | S |
| 27 | G27 | 8.62 | 2.10 | 5.30 | 2.50 | 0.07 | 0.75 | 2.10 | 6.20 | 2.98 | 1.07 | 1.30 | -4.55 | G |
| 28 | G28 | 8.42 | 2.70 | 5.40 | 3.54 | 0.16 | 3.83 | 5.24 | 10.55 | 6.52 | 2.10 | 1.76 | -0.97 | MS |
| 29 | G29 | 8.83 | 10.81 | 7.70 | 28.55 | 0.38 | 0.80 | 2.63 | 41.93 | 3.02 | 4.55 | 9.38 | -15.08 | S |
| 30 | G30 | 8.42 | 1.60 | 4.20 | 1.64 | 0.04 | 4.00 | 6.80 | 4.46 | 7.45 | 2.62 | 0.96 | -5.00 | A |
| 31 | G31 | 8.64 | 1.10 | 6.40 | 2.56 | 0.02 | 3.62 | 6.00 | 5.70 | 6.72 | 1.87 | 1.32 | -2.12 | G |
| 32 | G32 | 8.64 | 10.14 | 7.24 | 33.31 | 0.33 | 1.20 | 2.03 | 45.85 | 2.21 | 4.61 | 11.30 | -14.15 | HS |
|  Min Max Mean | 8.42 | 1.10 | 4.20 | 1.64 | 0.02 | 0.75 | 1.05 | 4.46 | 1.35 | 1.07 | 0.96 | -21.18 |  |
| 8.83 | 10.81 | 19.50 | 33.77 | 2.36 | 4.00 | 6.80 | 52.00 | 7.45 | 6.83 | 11.30 | 5.00 |  |
| 8.59 | 5.96 | 8.27 | 13.71 | 0.45 | 2.19 | 3.98 | 25.71 | 4.58 | 3.51 | 4.73 | -8.05 |  |
| **Udangudi block** |
| 33 | G33 | 8.34 | 1.35 | 4.75 | 1.60 | 0.03 | 1.04 | 2.70 | 2.45 | 3.16 | 0.88 | 0.92 | -2.36 | G |
| 34 | G34 | 8.38 | 1.17 | 10.17 | 1.12 | 0.09 | 0.91 | 3.28 | 8.48 | 3.72 | 1.39 | 0.47 | -7.15 | G |
| 35 | G35 | 8.09 | 12.68 | 8.30 | 38.42 | 0.34 | 1.02 | 2.70 | 49.42 | 3.22 | 5.61 | 11.86 | -17.26 | HS |
| 36 | G36 | 8.86 | 16.25 | 17.28 | 62.00 | 0.34 | 0.97 | 1.83 | 100.79 | 1.85 | 11.40 | 15.14 | -30.73 | HS |
| 37 | G37 | 7.43 | 1.90 | 4.00 | 1.98 | 0.47 | 0.00 | 2.50 | 8.30 | 3.76 | 3.10 | 1.15 | -3.40 | MS |
| 38 | G38 | 8.24 | 1.20 | 4.90 | 1.63 | 0.09 | 0.42 | 2.93 | 6.11 | 3.38 | 1.09 | 0.93 | -2.75 | G |
| 39 | G39 | 7.32 | 16.76 | 17.09 | 61.03 | 0.31 | 0.00 | 2.45 | 98.52 | 2.00 | 10.36 | 14.83 | -31.40 | HS |
| 40 | G40 | 8.13 | 18.00 | 33.25 | 78.42 | 0.52 | 1.60 | 2.33 | 122.38 | 5.60 | 15.75 | 15.49 | -47.32 | HS |
| 41 | G41 | 8.58 | 11.09 | 7.20 | 33.10 | 0.31 | 2.05 | 2.83 | 46.30 | 2.84 | 4.95 | 10.95 | -13.41 | HS |
| 42 | G42 | 8.03 | 3.08 | 3.98 | 2.04 | 0.19 | 0.43 | 2.12 | 7.38 | 2.97 | 1.11 | 1.09 | -4.51 | G |
| 43 | G43 | 7.64 | 24.70 | 24.30 | 2.36 | 0.36 | 0.00 | 3.60 | 20.29 | 4.80 | 7.02 | 0.48 | -45.40 | S |
|  Min Max Mean | 7.32 | 1.17 | 3.98 | 1.12 | 0.03 | 0.00 | 1.83 | 2.45 | 1.85 | 0.88 | 0.47 | -47.32 |  |
| 8.86 | 24.70 | 33.25 | 78.42 | 0.52 | 2.05 | 3.60 | 122.38 | 5.60 | 15.75 | 15.49 | -2.36 |  |
| 8.09 | 9.83 | 12.29 | 25.79 | 0.28 | 0.77 | 2.66 | 42.77 | 3.39 | 5.70 | 6.66 | -18.70 |  |

G - Good S - Saline

MS - High SAR Saline A - Alkali

HS - Marginally Saline

**Table 4. Classification of Groundwater for irrigation in Thiruchendur taluk (Postmonsoon) as per AICRP (1991)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No** | **Grid No** | **pH** | **Ca2+****(me L-1)** | **Mg2+****(me L-1)** | **Na+****(me L-1)** | **K+****(me L-1)** | **CO3****(me L-1)** | **HCO3****(me L-1)** | **Cl-****(me L-1)** | **SO42-****(me L-1)** | **EC****(dS m-1)** | **SAR****(me L-1)** | **RSC****(me L-1)** | **Class** |
| **Alwathirunagari block** |
| 1 | G1 | 8.28 | 4.22 | 1.82 | 3.32 | 0.15 | 0.96 | 4.22 | 5.02 | 0.78 | 1.18 | 1.91 | -0.06 | G |
| 2 | G2 | 8.12 | 3.14 | 3.34 | 3.09 | 0.39 | 0.84 | 5.64 | 4.94 | 0.30 | 1.20 | 1.72 | 0.00 | G |
| 3 | G3 | 8.10 | 2.93 | 3.53 | 3.61 | 0.21 | 1.03 | 6.53 | 0.93 | 1.12 | 1.09 | 2.01 | 1.10 | G |
| 4 | G4 | 7.79 | 7.38 | 4.48 | 20.15 | 0.28 | 0.03 | 2.33 | 27.63 | 2.17 | 3.05 | 8.27 | -9.53 | MS |
| 5 | G5 | 7.78 | 1.20 | 0.60 | 0.26 | 0.05 | 0.03 | 1.20 | 0.81 | 2.01 | 0.55 | 0.27 | -0.60 | G |
| 6 | G6 | 8.13 | 0.32 | 2.52 | 1.92 | 0.28 | 1.00 | 3.92 | 0.92 | 0.24 | 0.71 | 1.61 | 2.08 | G |
| 7 | G7 | 8.52 | 1.00 | 1.40 | 0.41 | 0.05 | 1.30 | 1.60 | 1.22 | 0.36 | 0.38 | 0.37 | 0.50 | G |
| 8 | G8 | 8.48 | 2.56 | 2.66 | 1.96 | 0.14 | 1.16 | 2.16 | 2.96 | 0.57 | 0.73 | 1.21 | -1.90 | G |
| 9 | G9 | 8.32 | 3.67 | 2.67 | 8.24 | 0.27 | 0.96 | 3.07 | 9.54 | 1.06 | 1.47 | 4.63 | -2.31 | G |
| 10 | G10 | 7.99 | 1.20 | 1.80 | 9.87 | 0.05 | 0.03 | 2.40 | 1.22 | 1.12 | 0.63 | 3.16 | -0.60 | G |
| 11 | G11 | 7.72 | 12.16 | 8.38 | 34.25 | 0.53 | 0.03 | 3.88 | 47.47 | 3.99 | 4.93 | 10.69 | -16.66 | HS |
| 12 | G12 | 8.13 | 2.75 | 6.95 | 7.42 | 0.41 | 0.75 | 4.95 | 9.95 | 1.15 | 1.76 | 3.37 | -4.00 | G |
| 13 | G13 | 7.90 | 3.40 | 1.6 | 6.36 | 0.42 | 0.00 | 3.18 | 7.71 | 0.94 | 1.17 | 3.92 | -2.08 | G |
| 14 | G14 | 7.72 | 4.44 | 3.35 | 10.59 | 0.39 | 0.00 | 2.97 | 13.72 | 1.51 | 1.97 | 5.37 | -4.82 | G |
| 15 | G15 | 7.95 | 0.34 | 2.57 | 1.95 | 0.31 | 0.00 | 4.02 | 1.03 | 0.35 | 0.48 | 1.62 | 1.11 | G |
| 16 | G16 | 8.14 | 1.25 | 3.83 | 2.74 | 0.32 | 0.85 | 2..41 | 2.46 | 0.76 | 0.81 | 1.72 | -1.82 | G |
| 17 | G17 | 8.12 | 3.60 | 2.60 | 8.16 | 0.24 | 0.10 | 3.01 | 9.45 | 1.01 | 1.37 | 4.63 | -3.09 | G |
| 18 | G18 | 8.35 | 6.40 | 4.96 | 16.73 | 0.56 | 1.93 | 3.38 | 22.51 | 2.08 | 2.94 | 7.02 | -6.05 | MS |
| 19 | G19 | 8.73 | 2.43 | 3.83 | 2.90 | 0.26 | 2.43 | 2.63 | 3.03 | 0.67 | 0.98 | 1.64 | -1.20 | G |
| 20 | G20 | 7.82 | 6.11 | 4.67 | 15.99 | 0.57 | 0.00 | 3.45 | 21.58 | 2.18 | 2.69 | 6.89 | -7.33 | MS |
| 21 | G21 | 7.83 | 2.76 | 2..56 | 2.96 | 0.50 | 0.00 | 3.16 | 4.96 | 0.56 | 1.00 | 1.81 | -2.16 | G |
| 22 | G22 | 8.23 | 0.97 | 2.37 | 1.79 | 0.18 | 2.01 | 4.37 | 0.97 | 0.55 | 0.91 | 1.39 | 3.04 | G |
| 23 | G23 | 8.27 | 1.76 | 1.76 | 3.00 | 0.44 | 0.35 | 5.16 | 1.96 | 0.64 | 0.93 | 2.26 | 1.99 | G |
| 24 | G24 | 8.21 | 1.75 | 3.15 | 2.38 | 0.29 | 0.75 | 2.75 | 3.95 | 0.65 | 0.81 | 1.52 | -1.40 | G |
|  Min Max Mean | 7.72 | 0.32 | 0.60 | 0.26 | 0.05 | 0.00 | 1.20 | 0.81 | 0.24 | 0.38 | 0.27 | -16.66 |  |
| 9.73 | 12.16 | 8.38 | 34.25 | 0.57 | 2.43 | 6.53 | 47.47 | 3.99 | 4.93 | 10.69 | 3.04 |  |
| 8.11 | 3.24 | 3.24 | 6.84 | 0.30 | 0.68 | 3.43 | 8.58 | 1.12 | 1.41 | 3.219 | -2.32 |  |
| **Thiruchendur block** |
| 25 | G25 | 9.07 | 4.82 | 3.82 | 9.39 | 0.29 | 0.94 | 4.24 | 10.69 | 1.35 | 2.55 | 4.52 | -3.46 | MS |
| 26 | G26 | 9.01 | 6.92 | 4.10 | 18.34 | 0.92 | 1.03 | 3.81 | 23.3 | 6.40 | 3.62 | 7.81 | -6.18 | MS |
| 27 | G27 | 8.69 | 0.37 | 2.57 | 1.97 | 0.33 | 1.03 | 3.97 | 0.93 | 2.98 | 0.65 | 1.62 | 2.06 | G |
| 28 | G28 | 8.40 | 2.28 | 2.08 | 2.17 | 0.28 | 1.68 | 2.08 | 2.08 | 6.52 | 0.74 | 1.47 | -0.60 | G |
| 29 | G29 | 8.72 | 2.77 | 1.77 | 1.60 | 0.15 | 0.91 | 3.95 | 1.95 | 3.02 | 0.78 | 1.06 | 0.32 | G |
| 30 | G30 | 8.44 | 7.43 | 4.53 | 20.18 | 0.27 | 0.58 | 2.35 | 27.68 | 7.45 | 3.25 | 8.25 | -9.03 | MS |
| 31 | G31 | 9.02 | 5.16 | 3.52 | 12.83 | 0.20 | 0.85 | 2.74 | 17.30 | 6.72 | 2.24 | 6.16 | -5.09 | MS |
| 32 | G32 | 8.69 | 1.65 | 2.42 | 1.54 | 0.02 | 1.05 | 4.20 | 1.80 | 2.21 | 0.95 | 1.08 | 1.18 | G |
|  Min Max Mean | 8.40 | 0.37 | 1.77 | 1.54 | 0.02 | 0.58 | 2.08 | 0.93 | 1.35 | 0.65 | 1.06 | -9.03 |  |
| 9.07 | 7.43 | 4.53 | 20.18 | 0.92 | 1.68 | 4.24 | 27.68 | 7.45 | 3.62 | 8.25 | 2.06 |  |
| 8.76 | 3.93 | 3.10 | 8.50 | 0.31 | 1.01 | 3.42 | 10.73 | 4.58 | 1.85 | 4.00 | -2.60 |  |
| **Udangudi block** |
| 33 | G33 | 7.39 | 6.17 | 5.17 | 6.41 | 0.36 | 0.00 | 4.05 | 11.97 | 0.87 | 1.68 | 2.69 | -7.29 | G |
| 34 | G34 | 7.34 | 1.54 | 3.64 | 1.94 | 0.28 | 0.00 | 4.14 | 1..94 | 1.07 | 0.75 | 1.21 | -1.04 | G |
| 35 | G35 | 7.39 | 15.76 | 13.76 | 3.15 | 0.52 | 0.00 | 5.43 | 17.86 | 1.04 | 2.42 | 0.82 | -24.09 | MS |
| 36 | G36 | 7.82 | 2.81 | 3.59 | 3.73 | 0.21 | 0.00 | 6.49 | 0.93 | 1.11 | 1.03 | 2.09 | 0.09 | G |
| 37 | G37 | 7.98 | 2.77 | 1.77 | 1.63 | 0.23 | 0.00 | 2.97 | 1.97 | 0.46 | 0.65 | 1.08 | -1.57 | G |
| 38 | G38 | 8.12 | 1.12 | 2.52 | 2.00 | 0.33 | 1.03 | 4.52 | 1.12 | 0.70 | 0.79 | 1.48 | 1.91 | G |
| 39 | G39 | 7.21 | 5.66 | 4.23 | 14.85 | 0.35 | 0.00 | 3.00 | 20.37 | 1.70 | 2.48 | 6.68 | -6.89 | MS |
| 40 | G40 | 7.79 | 3.07 | 1.53 | 6.03 | 0.25 | 0.00 | 2.85 | 7.38 | 0.73 | 1.24 | 3.98 | -1.75 | G |
| 41 | G41 | 7.78 | 5.80 | 4.37 | 14.97 | 0.34 | 0.00 | 3.14 | 20.45 | 1.84 | 2.51 | 6.64 | -7.03 | MS |
| 42 | G42 | 7.68 | 3.03 | 2.87 | 3.83 | 0.46 | 0.00 | 5.43 | 4.83 | 0.63 | 1.21 | 2.23 | -0.47 | G |
| 43 | G43 | 7.53 | 7.19 | 5.75 | 17.62 | 0.56 | 0.00 | 4.18 | 23.35 | 2.87 | 2.91 | 6.93 | -8.76 | MS |
|  Min Max Mean | 7.21 | 1.12 | 1.53 | 1.63 | 0.21 | 0.00 | 2.85 | 0.93 | 0.46 | 0.65 | 0.82 | -24.09 |  |
| 8.12 | 15.76 | 13.76 | 17.62 | 0.56 | 1.03 | 6.49 | 23.35 | 2.87 | 2.91 | 6.93 | 1.91 |  |
| 7.64 | 4.99 | 4.47 | 6.92 | 0.35 | 0.09 | 4.20 | 10.20 | 1.18 | 1.61 | 3.26 | -5.17 |  |

G - Good

MS - High SAR Saline

HS - Marginally Saline