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Delineation and Mapping of Groundwater Quality Assessment in Salem District, Tamil Nadu, India using GIS Techniques

Rajavarshini T [a++], Baskar M [a#*], Sherene Jenita Rajammal. T [a†], Rathika S [a†], Nagarajan M [b‡] and R.L. Meena [c^]

[a] Department of Soil Science & Agricultural Chemistry, ADAC&RI, Tamil Nadu Agricultural University, Tiruchirappalli, Tamil Nadu, India.
[b] Department of Soil and Water Conservation Engineering, AEC&RI, Tamil Nadu Agricultural University, Kumulur, Tamil Nadu, India.
[c] ICAR – CSSRI, karnal, Haryana, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] Research Scholar;
[#] Professor & Head;
[†] Associate Professor;
[‡] Assistant Professor;
[^] Project Coordinator;
**Corresponding author: E-mail: mbaskaruma@gmail.com;*

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ABSTRACT

Groundwater is a crucial natural resource with significant economic importance, supporting industrial activities, irrigation, and drinking water supplies. However, its extensive use for these purposes depletes water tables, which diminishes its future availability and leads to increased salinity, stream depletion, and land subsidence. A study was conducted to evaluate and map groundwater quality across different blocks in Salem district viz., Salem, Gangavalli, Thalaivasal, Attur, Pethanaickenpalayam, Valappady, Ayothiyapattinam, Yercaud, Panamarathupatty, Veerapandi, Edappadi, Sankari, Kadayampatti, Kolathur, Konganapuram, Magudanchavadi, Mecheri, Nangavalli, Omalur, and Tharamangalam. Sampling was conducted in February 2024, during which a total of 200 samples were collected and examined for pH, electrical conductivity, cations like Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}, anions like CO_3^{2-}, HCO_3^{-}, SO_4^{2-}, and Cl^{-}. Based on the ionic concentration, the water quality parameters are derived such as Sodium Adsorption Ratio(SAR) and Residual Sodium Carbonate (RSC). The pH and EC values were ranged from 7.08 to 8.58 and 0.74 to 2.75 dS/m, respectively. The residual sodium carbonate (RSC) concentration ranged from -7.3 to 10.1 meq/L, while the sodium adsorption ratio (SAR) ranged from 0.7 to 9.7 meq/L. According to the CSSRI, Karnal Water Quality Classification, approximately 66.5 % of the samples fit into the good quality category, approximately 13% of the samples fit into the alkaline water category, and 20% of the samples fit into the saline water category in the Salem district. Using this classification, thematic maps depicting groundwater quality in the Salem district were generated with ArcGIS software. The study concludes that the majority of the samples are classified as good-quality water, while saline and alkali water emerge as the next major concern. Using this saline water for irrigation can change the soil's physical properties and lower agricultural productivity. Thus, it's crucial to apply soil amendments like gypsum and provide proper drainage to avoid long-term soil damage.

Keywords: Groundwater quality; delineation; mapping; salem district; GIS.

1. INTRODUCTION

Agriculture plays an important role in both India's political and social economies. The majority of agricultural processes are heavily reliant on irrigation. Water is an essential component of agricultural productivity and contributes significantly to food security. Groundwater supplies approximately 40% of irrigation water worldwide, and in India, this Fig. 1 is predicted to exceed 50%. Millions of farmers worldwide rely on groundwater irrigation to create 40% of the world's agricultural output. Furthermore, groundwater reserves are quickly dwindling in many crucial agricultural locations around the world. The quality of surface water and groundwater is currently deteriorating (Raju et al. 2011, Shrestha et al. 2020, Anand and Karunanidhi 2020). As a result, understanding hydrochemistry is critical for determining the quality of groundwater used for irrigation and drinking. Water quality studies can provide precise information about the underground geological conditions in which water exists (Raju et al. 2011). Numerous studies have been undertaken worldwide to assess the geochemistry of groundwater (Belkhiri 2012, García et al. 2001, Zhou et al. 2020, Mansouri et al. 2022, Putra et al. 2021, Abdelali et al. 2020). Studies on groundwater quality have also been conducted in India (Kaushik et al. 2000, Sarath et al. 2012). Few groundwater quality studies have been conducted in Tamil Nadu (Srinivasamoorthy et al. 2011, Sajil Kumar et al. 2013, Krishna Kumar et al. 2009). This investigation aims to assess groundwater quality in Salem District, one of the 32 districts in Tamil Nadu.

Salem District, established in 1772, is located between 11°14' and 12°53' North Latitude and 77°44' and 78°50' East Longitude. It is bordered to the north by Dharmapuri District, to the south by Trichy and Namakkal Districts, to the east by Kallakurichi and Perambalur Districts, and to the west by Erode District and Karnataka State. The district comprises 20 blocks: Salem, Gangavalli, Thalaivasal, Attur, Pethanaickenpalayam, Valappady, Ayothiyapattinam, Yercaud, Panamarathupatty, Veerapandi, Edappadi, Sankari, Kadayampatti, Kolathur, Konganapuram, Magudanchavadi, Mecheri, Nangavalli, Omalur, and Tharamangalam.Salem District generally experiences a warm climate. The hottest period is from March to May, with temperatures reaching 39.8°C in May. The coolest period is from December to February, with temperatures decreasing to a minimum of 16.7°C in December. The district receives an

average annual rainfall of 979.9 mm. Agriculture is the dominant sector of the district's economy, with 30 % of the population engaged in agricultural and allied activities. The district covers an area of 520,530 hectares, with a net cultivated area of approximately 220,138 hectares. The soils in Salem District are classified into red soil, black soil, alluvial soil, and loamy soil. The main crops grown in the region include turmeric, tapioca, cotton, and paddy, among others. The district lacks major irrigation systems, except for the Mettur Dam, which irrigates approximately 0.15 lakh hectares through the West Bank canal of the Cauvery River. The Cauvery River, along with wells, serves as the primary source of irrigation in the district.

Groundwater is the primary source of irrigation water in Salem District. However, various human activities, such as excessive groundwater extraction, silk weaving, and industrial pollution, along with global factors such as population growth and climate change—marked by rising temperatures and decreasing precipitation—are contributing to groundwater depletion. This depletion poses a significant threat to food security.

Therefore, this study focuses on creating a groundwater quality map for Salem District. The groundwater quality assessment employs Geographic Information System (GIS) technology and overlay analysis of water quality parameters. The main goal of this study is to assess the groundwater quality in different blocks of Salem District and to map the data via ArcGIS software.

2. MATERIALS AND METHODS

The study was carried out across several blocks in Salem district. In February 2024, 200 samples were collected via a grid survey with intervals of approximately 10 sq. km from different blocks within Salem district, Tamil Nadu (Balasubramanian et al., Dar et al. 2011).

Fig. 1 depicts the study area. The locations of the sample sites were recorded via a portable GPS receiver (Garmin GPS). The samples were collected in clean polyethylene bottles. To evaluate the quality of the irrigation water, laboratory analyses were conducted following standard analytical techniques (Fig. 2). The samples were tested for pH, electrical conductivity, cations (Ca^{2+} and Mg^{2+} using the versenate method), anions (CO_3^{2-}, HCO_3^-, and Cl^- using the titrimetric method), K^+ and Na^+ (using flame photometry), and SO_4^{2-} (using turbidimetry), according to the protocol outlined by Richards (Richards 1954).

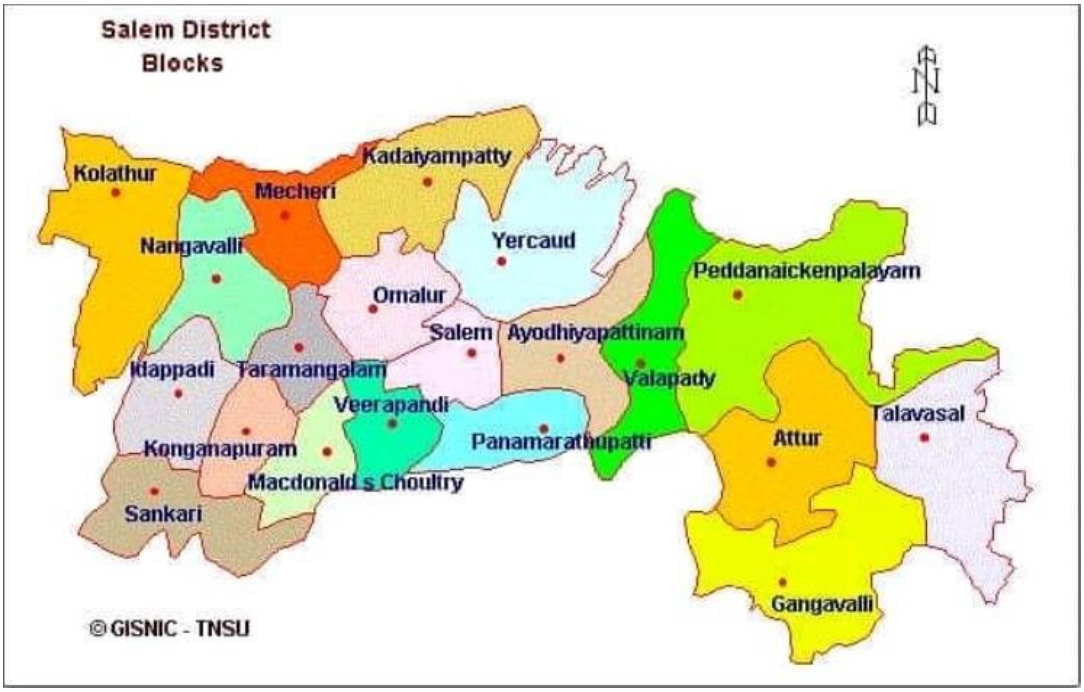

Fig. 1. Location map of the study area (Salem district) adapted from Ref. (Balasubramanian et al.)

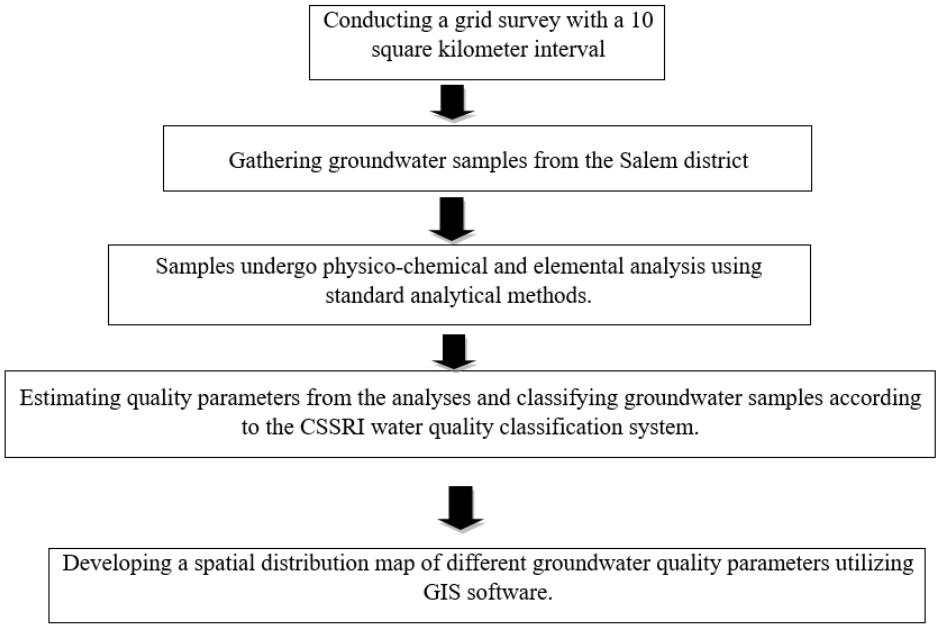

Fig. 2. Flow chart on experimental methodology

Water quality parameters, including Sodium Adsorption Ratio (SAR) (1) and Residual Sodium Carbonate (RSC) (2), were calculated on the basis of concentrations of cations and anions. The formulas used are as follows:

$$SAR = Na^{+}/\sqrt{(Ca^{2+} + Mg^{2+})/2} \quad (1)$$

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

The Central Soil Salinity Research Institute (CSSRI) in Karnal evaluated groundwater samples for irrigation suitability using EC, SAR, and RSC values (see Table 1) (AICRP 1991). On the basis of the CSSRI water quality classification, thematic maps of groundwater quality in Salem district were created with ArcGIS software. The ArcGIS Geostatistical Analyst technique was used to generate various thematic maps, and ArcGIS Spatial Analyst was used to produce the final groundwater quality map. The inverse distance weighting (IDW) interpolation technique was employed to determine the spatial distribution of groundwater quality parameters (Nas 2010).

3. RESULTS AND DISCUSSION

3.1 Cationic Concentration

The concentrations of cations and anions across different blocks of the Salem district are shown in Table 2. The research findings indicate that the concentrations of cations, specifically calcium, magnesium, sodium, and potassium, in the Salem district range from 1.2 to 9.9 meq/L, 0.9 to 6.6 meq/L, 1.5 to 15.68 meq/L, and 0.01 to 0.52 meq/L, respectively.

The average calcium levels in the groundwater samples from different blocks are as follows: Panamarathupatti at 5.0 meq/L, Salem at 6.5 meq/L, Omalur at 6.4 meq/L, Veerapandi at 6.3 meq/L, Tharamangalam at 4.6 meq/L, Edapaddi at 5.8 meq/L, Kadayampatty at 4.7 meq/L, Mecheri at 4.0 meq/L, Nangavalli at 4.6 meq/L, Kolathur at 4.5 meq/L, Sankari at 5.5 meq/L, Yercaud at 4.5 meq/L, Magudanchavadi at 3.1 meq/L, Gangavalli at 4.9 meq/L, Attur at 5.3 meq/L, Thalaivasal at 5.5 meq/L, Vallapady at 5.0 meq/L, Konganapuram at 6.5 meq/L, Ayodhipattinam at 6.1 meq/L, Pethanaickenpalayam at 6.7 meq/L.

The mean magnesium levels in the groundwater samples from different blocks are as follows: Panamarathupatti at 3.3 meq/L, Salem at 4.1 meq/L, Omalur at 4.1 meq/L, Veerapandi at 3.9 meq/L, Tharamangalam at 3.0 meq/L, Edapaddi at 3.4 meq/L, Kadayampatty at 2.5 meq/L, Mecheri at 2.7 meq/L, Nangavalli at 3.2 meq/L, Kolathur at 3.2 meq/L, Sankari at 3.4 meq/L, Yercaud at 2.6 meq/L, Magudanchavadi at 1.9 meq/L, Gangavalli at 2.5 meq/L, Attur at 3.2 meq/L, Thalaivasal at 3.6 meq/L, Vallapady at

3.0 meq/L, Konganapuram at 3.7 meq/L, Ayodhipattinam at 4.1 meq/L, Pethanaickenpalayam at 4.1 meq/L.

The average sodium levels in the groundwater samples from different blocks are as follows: Panamarathupatti at 6.1 meq/L, Salem at 7.3 meq/L, Omalur at 9.0 meq/L, Veerapandi at 7.3 meq/L, Tharamangalam at 7.4 meq/L, Edapaddi at 7.6 meq/L, Kadayampatty at 7.7 meq/L, Mecheri at 9.4 meq/L, Nangavalli at 8.0 meq/L, Kolathur at 7.7 meq/L, Sankari at 7.0 meq/L, Yercaud at 7.8 meq/L, Magudanchavadi at 7.5 meq/L, Gangavalli at 6.4 meq/L, Attur at 6.9 meq/L, Thalaivasal at 6.5 meq/L, Vallapady at 5.8 meq/L, Konganapuram at 7.3 meq/L, Ayodhipattinam at 6.8 meq/L, Pethanaickenpalayam at 7.5 meq/L.

The average potassium levels in the groundwater samples from different blocks are as follows: Panamarathupatti at 0.11 meq/L, Salem at 0.12 meq/L, Omalur at 0.17 meq/L, Veerapandi at 0.12 meq/L, Tharamangalam at 0.13 meq/L, Edapaddi at 0.08 meq/L, Kadayampatty at 0.07 meq/L, Mecheri at 0..16 meq/L, Nangavalli at 0.13 meq/L, Kolathur at 0.09 meq/L, Sankari at 0.09 meq/L, Yercaud at 0.07 meq/L, Magudanchavadi at 0.07 meq/L, Gangavalli at 0.07 meq/L, Attur at 0.05 meq/L, Thalaivasal at 0.06 meq/L, Vallapady at 0.07 meq/L, Konganapuram at 0.08 meq/L, Ayodhipattinam at 0.09 meq/L, Pethanaickenpalayam at 0.07 meq/L.

In almost every block, sodium ions constituted the majority of the cations. The erosion of salt deposits, the existence of rock minerals containing sodium, the intrusion of saltwater into wells, irrigation techniques, precipitation leaching through soils rich in sodium, or the infiltration of industrial effluent are some possible causes of this dominance. The second most common cation was calcium, which is usually present in relatively high concentrations due to the dissolution of gypsum, dolomite, and limestone (Viveka et al. 2019). Potassium was the least abundant element in the groundwater samples. This is probably because the weathering of rocks containing potassium weather occurs more slowly than that of rocks containing sodium, which lowers the amount of potassium (K+). Fertilizers and the breakdown of animal or waste materials are two ways potassium can enter groundwater (Saha et al. 2019). The main sources of magnesium include dark-colored micas, ferromagnesian minerals including olivine, pyroxene, and amphiboles, and dolomite. Magnesium is also added to groundwater by metamorphic rocks such as serpentine, montmorillonite, and chlorite (Nag 2009).

3.2 Anionic Concentration

In terms of anionic concentration (Table 2), the carbonate, bicarbonate, chloride, and sulphate contents in the Salem district ranged from 0 to 5.6 meq/L, 2.6 to 9.9 meq/L, 2.1 to 17.8 meq/L, and 0.02 to 0.85 meq/L, respectively.

The average carbonate levels in the groundwater samples from different blocks are as follows: Panamarathupatti at 2.1 meq/L, Salem at 1.9 meq/L, Omalur at 1.1 meq/L, Veerapandi at 1.7 meq/L, Tharamangalam at 1.1 meq/L, Edapaddi at 1.7 meq/L, Kadayampatty at 1.6 meq/L, Mecheri at 2.7 meq/L, Nangavalli at 1.8 meq/L, Kolathur at 2.2 meq/L, Sankari at 2.2 meq/L, Yercaud at 2.0 meq/L, Magudanchavadi at 1.8 meq/L, Gangavalli at 1.6 meq/L, Attur at 2.4 meq/L, Thalaivasal at 1.6 meq/L, Vallapady at 2.1 meq/L, Konganapuram at 1.6 meq/L, Ayodhipattinam at 2.3 meq/L, Pethanaickenpalayam at 2.8 meq/L.

Table 1. Grouping of low-quality groundwater for irrigation in India

Water quality	EC_{iw} (dS/m)	SAR_{iw} (m mol/L)	RSC (meq/L)
A. Good	<2	<10	<2.5
B. Saline			
Marginal saline	2-4	<10	<2.5
Saline	>4	<10	<2.5
High SAR saline	>4	>10	<2.5
C. Alkali water			
Marginally alkali	<4	<10	2.5-4.0
Alkali	<4	<10	>4
Highly alkali	Variable	>10	>4
D. Toxic water	The toxic water has variable salinity, SAR and RSC but has excess of specific ions such as chloride, sodium, nitrate, boron, fluoride or heavy metals such as selenium, cadmium, lead and arsenic etc.		

The mean bicarbonate levels in the groundwater samples from different blocks are as follows: Panamarathupatti at 5.7 meq/L, Salem at 6.0 meq/L, Omalur at 7.0 meq/L, Veerapandi at 5.4 meq/L, Tharamangalam at 5.7 meq/L, Edapaddi at 5.7 meq/L, Kadayampatty at 4.8 meq/L, Mecheri at 6.5 meq/L, Nangavalli at 6.4 meq/L, Kolathur at 6.4 meq/L, Sankari at 5.6 meq/L, Yercaud at 5.4 meq/L, Magudanchavadi at 4.6 meq/L, Gangavalli at 5.0 meq/L, Attur at 5.6 meq/L, Thalaivasal at 4.4 meq/L, Vallapady at 5.8 meq/L, Konganapuram at 6.0 meq/L, Ayodhipattinam at 5.2 meq/L, Pethanaickenpalayam at 6.5 meq/L.

The average chloride levels in the groundwater samples from different blocks are as follows: Panamarathupatti at 6.4 meq/L, Salem at 9.9 meq/L, Omalur at 10.9 meq/L, Veerapandi at 10.1 meq/L, Tharamangalam at 7.8 meq/L, Edapaddi at 10.1 meq/L, Kadayampatty at 8.2 meq/L, Mecheri at 6.9 meq/L, Nangavalli at 7.5 meq/L, Kolathur at 6.5 meq/L, Sankari at 8.2 meq/L, Yercaud at 7.3 meq/L, Magudanchavadi at 5.9 meq/L, Gangavalli at 6.6 meq/L, Attur at 7.0 meq/L, Thalaivasal at 9.3 meq/L, Vallapady at 6.0 meq/L, Konganapuram at 9.4 meq/L, Ayodhipattinam at 9.2 meq/L, Pethanaickenpalayam at 8.5 meq/L.

The average sulphate levels in the groundwater samples from different blocks are as follows: Panamarathupatti at 0.19 meq/L, Salem at 0.23 meq/L, Omalur at 0.41 meq/L, Veerapandi at 0.49 meq/L, Tharamangalam at 0.43 meq/L, Edapaddi at 0.37 meq/L, Kadayampatty at 0.30 meq/L, Mecheri at 0.29 meq/L, Nangavalli at 0.31 meq/L, Kolathur at 0.40 meq/L, Sankari at 0.24 meq/L, Yercaud at 0.20 meq/L, Magudanchavadi at 0.29 meq/L, Gangavalli at 0.42 meq/L, Attur at 0.35 meq/L, Thalaivasal at 0.42 meq/L, Vallapady at 0.07 meq/L, Konganapuram at 0.52meq/L, Ayodhipattinam at 0.44 meq/L, Pethanaickenpalayam at 0.51 meq/L.

Almost all the blocks showed the chloride ion to be the most prevalent anion. The chloride (Cl^-) content of groundwater may be caused by industrial waste or household sewage spills, evaporation, saltwater intrusion, connate and juvenile water, or other sources (Nag 2009). Aquifer organic matter that oxidizes to produce carbon dioxide, which speeds up mineral dissolution, is a potential source of bicarbonate (Khashogji et al. 2013). Silicate minerals may weather and release bicarbonate ions, according to Gastmans et al. 2010.

As a result of sulfur, sulphur, and the dissolution of other minerals containing sulphur, sulphate was discovered in groundwater. Sedimentary rocks, such as organic shale, may be important in this area because they oxidize marcasite and pyrite (Gastmanss 1982, Rahman et al. 2013, Rahman et al. 2013).

3.3 Water Quality Parameters

An indicator of the suitability of irrigation for use in agriculture is its quality. Water quality is a major consideration when determining the salinity or alkalinity levels in an agricultural area. The best possible agricultural production can be attained and beneficial changes in the soil can be facilitated by high-quality water (Kalaivanan et al. 2018). The ranges of pH, EC, RSC, and SAR values in the Salem district are displayed in Table 3. The pH of the water has a major effect on both the degree of salinity hazard and the quality of the water in the research area (Balasubramanian et al. 2005).

In contrast, the pH values of the groundwater samples in the Salem district , Panamarathupatti, Salem, Omalur, Veerapandi, Tharamangalam, Edapaddi, Kadayampatty, Mecheri, Nangavalli, Kolathur, Sankari, Yercaud, Magudanchavadi, Gangavalli, Attur, Thalaivasal, Vallapady, Konganapuram, Ayodhipattinam and Pethanaickenpalayam blocks ranged from 7.46 to 8.26 with an average of 7.89, 7.51 to 8.13 with an average of 7.88, 7.43 to 8.15 with an average of 7.89, 7.23 to 8.07 with an average of 7.64, 7.52 to 8.29 with an average of 7.99, 7.17 to 8.24 with an average of 7.65, 7.15 to 8.11 with an average of 7.70, 7.29 to 8.36 with an average of 7.96, 7.29 to 8.34 with an average of 7.85, 7.09 to 8.29 with an average of 7.75, 7.21 to 8.22 with an average of 7.75, 7.19 to 8.19 with an average of 7.62, 7.17 to 8.46 with an average of 7.80, 7.24 to 8.18 with an average of 7.66, 7.13 to 8.45 with an average of 7.76, 7.25 to 8.12 with an average of 7.20, 7.08 to 8.58 with an average of 7.84, 7.15 to 8.15 with an average of 7.59, 7.12 to 8.22 with an average of 7.70 and 7.12 to 8.12 with an average of 7.63, respectively. This suggests that the bulk of the samples has a neutral to slightly alkaline character.

Inorganic contamination in water is determined by measuring the total dissolved solids and ionized species (EC) in the water (Jenita et al. 2021). In Panamarathupatti, Salem, Omalur, Veerapandi, Tharamangalam, Edapaddi, Kadayampatty, Mecheri, Nangavalli, Kolathur, Sankari, Yercaud, Magudanchavadi, Gangavalli,

Attur, Thalaivasal, Vallapady, Konganapuram, Ayodhipattinam and Pethanaickenpalayam, the mean EC values varied from 1.45 dS/m, 1.80 dS/m, 1.94 dS/m, 1.86 dS/ m, 1.53 dS/m, 1.75 dS/m, 1.51 dS/m, 1.64 dS/m, 1.56 dS/ m, 1.58 dS/m 1.63 dS/m, 1.52 dS/m, 1.29 dS/m, 1.40 dS/ m, 1.53 dS/m, 1.60 dS/m, 1.40 dS/m, 1.77 dS/m, 1.75 dS/ m, and 1.87 dS/m, respectively.

The blocks with the highest EC were those in Omalur followed by those in Pethanaickenpalayam and Veerapandi. The variations in EC values could be attributed to the elemental composition of the aquifer rocks as well as geochemical processes that take place in the parent rock, such as oxidation, sulfate reduction, silicate weathering, reverse exchange, and rock–water interactions (Bandyopadhyay et al. 2009).

The sodium adsorption ratio (SAR) range in the Salem district was 0.7 to 9.7 meq/L, whereas the residual sodium carbonate (RSC) range was -7.3 to 10.1 meq/L. On the other hand, the average values of the Sodium Absorption Ratio (SAR) in the Panamarathupatti, Salem, Omalur, Veerapandi, Tharamangalam, Edapaddi, Kadayampatty, Mecheri, Nangavalli, Kolathur, Sankari, Yercaud, Magudanchavadi, Gangavalli, Attur, Thalaivasal, Vallapady, Konganapuram, Ayodhipattinam and Pethanaickenpalayam blocks were 3.0 meq/L, 2.9 meq/L, 3.9 meq/L, 3.3 meq/L, and 4.0 meq/L, 3.7 meq/L, 4.3 meq/L, 5.7 meq/L, 4.2 meq/L,4.3 meq/L, 3.6 meq/L, 4.3 meq/L, 4.9 meq/L, 3.7 meq/L, 3.2 meq/L, 3.0 meq/L, 2.8 meq/L, 3.3 meq/L, 3.0 meq/L and 3.3 meq/L, respectively.

The average values of residual sodium carbonate (RSC) in Panamarathupatti, Salem, Omalur, Veerapandi, Tharamangalam, Edapaddi, Kadayampatty, Mecheri, Nangavalli, Kolathur, Sankari, Yercaud, Magudanchavadi, Gangavalli, Attur, Thalaivasal, Vallapady, Konganapuram, Ayodhipattinam and Pethanaickenpalayam blocks were -0.5 meq/L, -2.7 meq/L, -2.3 meq/L, - 3.0 meq/L, -0.6 meq/L, -1.7 meq/L, -0.7 meq/L, 2.3 meq/L, 0.3 meq/L,0.8 meq/L, -1.1 meq/L, -1.5 meq/L, 1.3 meq/L, -0.7 meq/L, -0.5 meq/L, -3.1 meq/L, -0.1 meq/L, -2.6 meq/L, -2.6 meq/L and -1.5 meq/L, respectively.

The absorbance of calcium and magnesium ions adsorbed on clay surfaces are replaced by high concentrations of sodium ions in water, affecting soil permeability and leading to infiltration and soil particle dispersion (Ahamed, et al. 2013). An increase in exchangeable sodium in the soil results from an increase in the SAR of irrigation water (Santhosh et al. 2019). The Salem district's overall groundwater sample percentage distribution is shown in Fig. 3. The groundwater sample distribution percentage in each of the districts of Salem's blocks is shown in Fig. 4.

The Omalur area had the most saline water (40%), followed by the Salem block (30%). The blocks with the highest alkali water content were Mecheri (30%) followed by Kolathur (20 %). The best – quality water (100%) was added to the Yercaud block.

An elevated sodium content in water and soil particles increases the risk of a sodium hazard. High RSC values suggest that a considerable amount of calcium and some magnesium ions precipitate from the solution (Singh et al. 2020). A high RSC could prevent water and air from passing through the soil's pore space, degrading the soil and rendering it unusable for irrigation (Kawo et al. 2018, Srinivasamoorthy et al. 2011). Droughts, poor rainfall, and excessive groundwater use can exacerbate saline/somatic issues (Vishnu et al. 2021)

This will also result in a decrease in water penetration and soil permeability, as well as a loss of soil structure. Negative effects are felt on agricultural productivity. Since the sodium in the water might displace calcium and magnesium, the additions during irrigation with high SAR water may be necessary to prevent long-term soil damage (Prasanth et al. 2012, Sreekala et al. 2015). Saline irrigation hinders plant growth because of osmotic forces in the soil, which tend to reduce the amount of nutrients taken up by the plant. The implementation of several irrigation management systems, such as pitchers, sprinklers, and drip irrigation, is a crucial step in solving this issue (Monisha et al. 2021, Devi et al. 2023).

Compost and FYM are examples of organic manures that reduce the effects of salinity by producing organic acid during decomposition. Growers should plant green manure crops to reduce the risk of alkalinity.Rainwater conservation techniques should be adjusted to consider salt leaching from irrigation with saline and alkaline wate r (Vishnu et al. 2021).

3.4 Groundwater Quality Mapping Using GIS Software

On the basis of EC, SAR, and RSC, different groups were created for the groundwater

samples (Table 1). Using arc map software, a ground water quality map for each block in the Salem district was created. Fig. 5 shows the spatial distributions of the major groundwater quality parameters in different blocks of the Salem district. Comparing the regional distributions of water quality measures has been demonstrated to be a particularly beneficial application of inverse distance weighted (IDW) interpolation in GIS tools (Singh et al. 2020, Yuvaraj 2020, Mondal et al. 2008). The graphic indicates that high-quality groundwater was present in nearly every block on the basis of the various quality metrics of the groundwater samples.

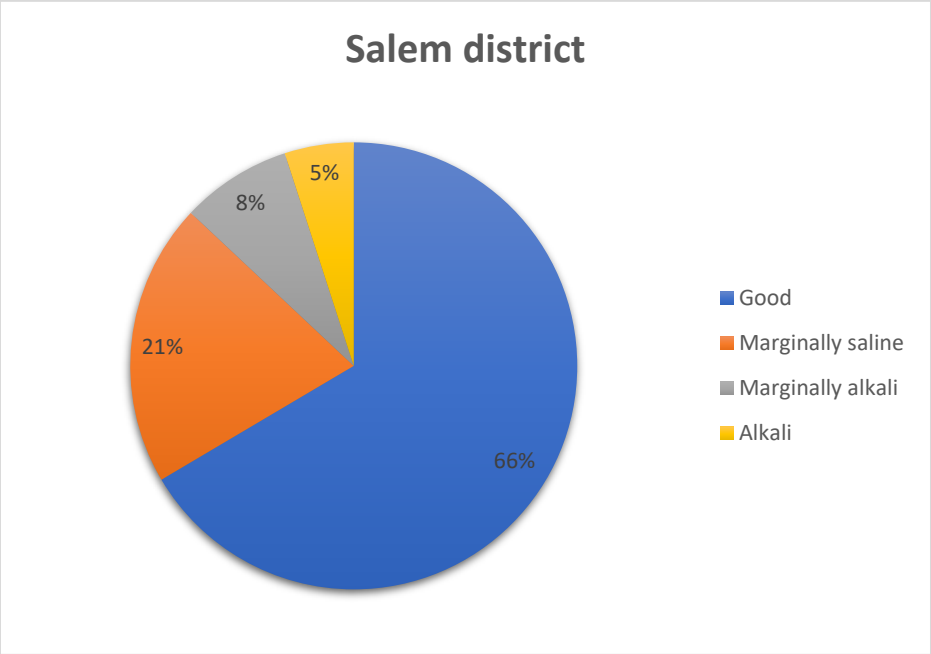

Fig. 3. Overall percentage distribution of groundwater quality in Salem district

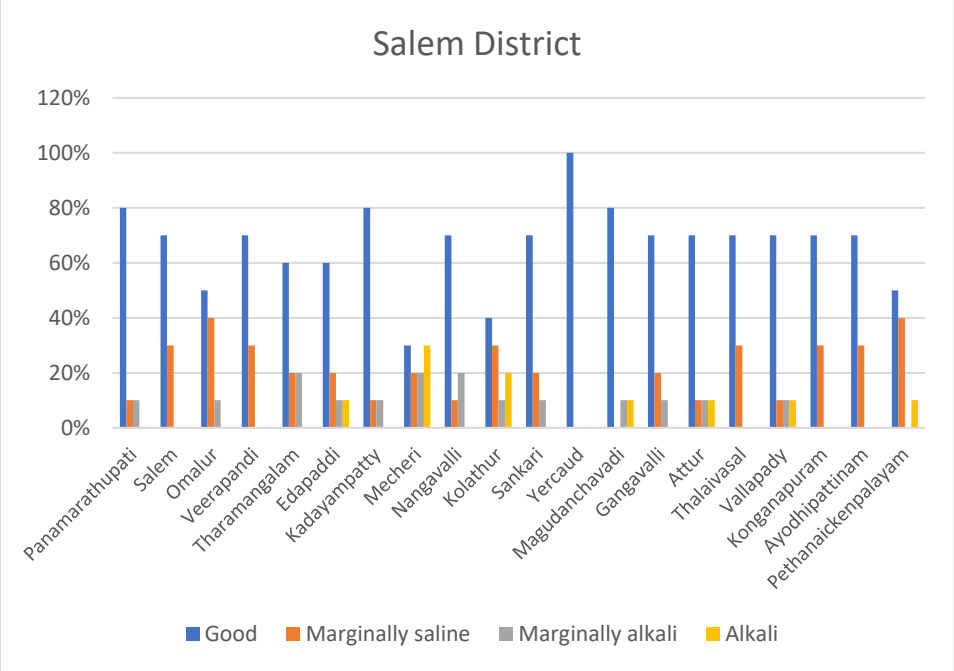

Fig. 4. Overall Percentage distribution of groundwater quality in Salem district

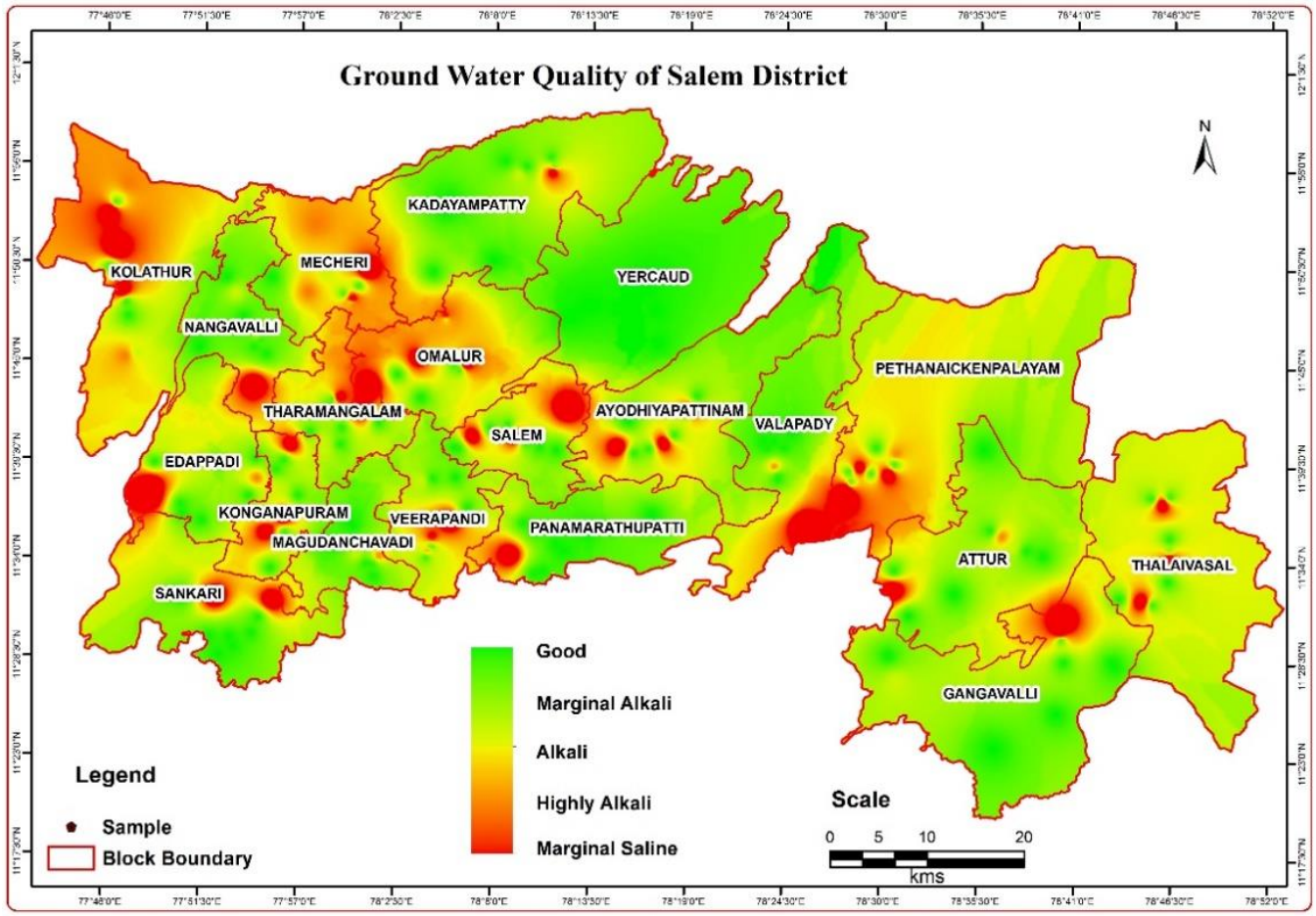

Fig. 5. Spatial distribution map of groundwater quality in Salem district

Table 2. Cationic and anionic concentrations of water in various blocks of the Salem district

Name of the blocks	No. of. Samples	Range / Mean	Ca2+	Mg2+	Na+	K+	CO32-	HCO3-	Cl-	SO42
							Meq/l			
Panamarathupatti	10	Min	4.1	2.9	1.57	0.01	0.7	4.2	3.6	0.03
		Max	6.8	4.8	14.32	0.37	3.6	8.4	12.4	0.45
		Mean	5.03	3.38	6.10	0.11	2.11	5.72	6.47	0.19
Salem	10	Min	4.2	2.2	2.52	0.04	0.4	2.6	5.4	0.02
		Max	9.9	6.5	15.6	0.26	5.1	9.2	16.4	0.54
		Mean	6.5	4.18	7.33	0.12	1.95	6.0	9.94	0.23
Omalur	10	Min	4.4	2.3	4.34	0.02	0	3.8	5.2	0.06
		Max	9.2	6.4	14.65	0.52	3.2	9.8	15.4	0.65
		Mean	6.4	4.11	9.01	0.17	1.11	7.04	10.93	0.41
Veerapandi	10	Min	4.3	2.1	2.53	0.01	0.8	3.1	5.2	0.09
		Max	9.2	5.8	15.68	0.51	3.2	7.8	13.6	0.85
		Mean	6.3	3.9	7.31	0.18	1.71	5.46	10.12	0.49
Tharamangalam	10	Min	2.2	1.2	4.36	0.01	0	3.6	3.1	0.14
		Max	9.9	6.6	11.52	0.46	2.4	9.6	16.4	0.72
		Mean	4.6	3.0	7.46	0.13	1.18	5.76	7.86	0.43
Edapadddi	10	Min	3.2	1.2	2.5	0.01	0	3.8	5.2	0.12
		Max	8.2	5.8	13.6	0.20	5.6	8.6	17.8	0.63
		Mean	5.8	3.4	7.64	0.08	1.7	5.7	10.11	0.37
Kadayampatty	10	Min	2.1	1.2	4.3	0.01	0.40	2.9	4.8	0.02
		Max	8.9	4.8	11.2	0.30	3.60	6.3	12.6	0.74
		Mean	4.7	2.5	7.74	0.07	1.68	4.8	8.2	0.30
Mecheri	10	Min	2.0	1.2	5.2	0.01	0	3.12	2.45	0.04
		Max	9.2	6.4	15.23	0.61	4.56	9.5	12.23	0.45
		Mean	4.02	2.72	9.46	0.16	2.72	6.53	6.98	0.29
Nangavalli	10	Min	2.4	1.6	2.9	0.01	0	3.2	3.65	0.07
		Max	8.8	5.4	14.65	0.65	4.25	9.5	11.56	0.62
		Mean	4.6	3.2	8.00	0.13	1.82	6.41	7.54	0.31
Kolathur	10	Min	2.2	0.9	3.6	0.01	0	4.62	2.00	0.05
		Max	7.4	6.3	11.45	0.36	4.25	9.53	15.00	1.03
		Mean	4.5	3.2	7.78	0.09	2.20	6.47	6.57	0.40
Sangagiri	10	Min	2.2	1.2	4.52	0.01	0	4.00	3.65	0.05

Name of the blocks	No. of. Samples	Range / Mean	Ca2+	Mg2+	Na+	K+	CO32-	HCO3-	Cl-	SO42
							Meq/l			
		Max	8.8	6.5	9.65	0.25	3.58	8.25	13.10	0.74
		Mean	5.5	3.4	7.07	0.09	2.20	5.61	8.20	0.24
Yercaud	10	Min	2.7	1.2	4.21	0.01	0	3.10	4.36	0.05
		Max	7.5	3.8	13.24	0.19	3.65	8.40	9.50	0.58
		Mean	4.5	2.6	7.86	0.07	2.03	5.40	7.36	0.20
Magudanchavadi	10	Min	1.5	0.9	3.64	0.01	0.65	3.86	2.58	0.07
		Max	6.2	3.4	9.98	0.16	3.56	5.54	9.23	0.65
		Mean	3.1	1.9	7.51	0.07	1.86	4.69	5.97	0.29
Gangavalli	10	Min	1.2	0.9	3.2	0.01	0	3.00	4.32	0.15
		Max	8.4	5.6	10.3	0.19	4.2	8.65	10.56	0.76
		Mean	4.9	2.5	6.42	0.07	1.6	5.03	6.69	0.42
Attur	10	Min	1.9	1.3	2.54	0.01	1.45	3.47	2.18	0.09
		Max	8.8	5.9	14.45	0.18	4.65	8.87	11.48	0.72
		Mean	5.3	3.2	6.97	0.05	2.43	5.69	7.02	0.35
Thalaivasal	10	Min	2.5	1.8	1.68	0.01	0	2.15	3.63	0.15
		Max	8.5	5.9	14.18	0.15	2.65	7.25	14.65	0.87
		Mean	5.5	3.6	6.52	0.06	1.68	4.46	9.37	0.42
Vallapady	10	Min	2.6	1.8	1.56	0.02	0	3.54	2.54	0.02
		Max	8.5	4.6	11.56	0.18	3.65	8.25	12.65	0.18
		Mean	5.0	3.0	5.87	0.07	2.16	5.80	6.01	0.07
Konganapuram	10	Min	4.2	2.1	3.5	0.01	0	4.65	5.98	0.19
		Max	8.6	5.2	11.18	0.20	3.05	7.15	13.24	0.74
		Mean	6.5	3.7	7.31	0.08	1.61	6.07	9.46	0.52
Ayodhipattinam	10	Min	3.6	2.1	3.65	0.02	0.87	3.65	5.34	0.18
		Max	7.4	5.4	11.65	0.19	3.65	6.58	12.65	0.76
		Mean	6.1	4.1	6.81	0.09	2.36	5.26	9.22	0.44
Pethanaickenpalayam	10	Min	4.2	2.1	4.18	0.02	0	4.25	3.98	0.18
		Max	9.7	5.9	10.35	0.18	4.89	9.97	12.65	0.87
		Mean	6.7	4.1	7.50	0.07	2.87	6.51	8.56	0.51

Table 3. The groundwater quality in different blocks of the Salem district

Name of the blocks	No. of. Samples	Range / Mean	pH	EC(dS/m)	SAR (m mol/L)	RSC (meq/L)
Panamarathupatti	10	Min	7.46	0.96	0.8	-4.3
		Max	8.26	2.15	7.4	3.8
		Mean	7.89	1.45	3.0	-0.5
Salem	10	Min	7.51	0.97	1.6	-5.7
		Max	8.13	2.73	4.9	0.1
		Mean	7.88	1.80	2.9	-2.7
Omalur	10	Min	7.43	1.24	1.8	-5.9
		Max	8.15	2.54	7.3	2.9
		Mean	7.89	1.94	3.9	-2.3
Veerapandi	10	Min	7.23	0.95	1.0	-5.9
		Max	8.07	2.36	7.9	1.7
		Mean	7.64	1.86	3.3	-3.0
Tharamangalam	10	Min	7.52	0.84	2.2	-6.1
		Max	8.29	2.75	8.5	3.7
		Mean	7.99	1.53	4.0	-0.6
Edapadddi	10	Min	7.17	1.09	1.0	-7.2
		Max	8.24	2.74	7.6	5.1
		Mean	7.65	1.75	3.7	-1.7
Kadayampatty	10	Min	7.15	0.96	2.3	-4.1
		Max	8.11	2.15	6.9	3.2
		Mean	7.70	1.51	4.3	-0.7
Mecheri	10	Min	7.29	1.26	1.8	-6.72
		Max	8.36	2.29	8.8	10.01
		Mean	7.96	1.64	5.7	2.3
Nangavalli	10	Min	7.29	0.77	2.0	-3.2
		Max	8.34	2.17	8.0	3.9
		Mean	7.85	1.56	4.2	0.3
Kolathur	10	Min	7.09	0.96	1.98	-4.7
		Max	8.29	2.39	7.76	7.4
		Mean	7.75	1.58	4.3	0.8
Sangagiri	10	Min	7.21	0.94	1.7	-7.3
		Max	8.22	2.18	6.6	4.0

Name of the blocks	No. of. Samples	Range / Mean	pH	EC(dS/m)	SAR (m mol/L)	RSC (meq/L)
		Mean	7.75	1.63	3.6	-1.1
Yercaud	10	Min	7.19	1.19	1.7	-6.0
		Max	8.19	1.89	8.8	2.0
		Mean	7.62	1.52	4.3	-1.5
Magudanchavadi	10	Min	7.17	0.86	2.3	-3.2
		Max	8.46	1.78	8.1	4.7
		Mean	7.80	1.29	4.9	1.3
Gangavalli	10	Min	7.24	0.98	1.5	-5.5
		Max	8.18	2.18	9.7	2.5
		Mean	7.66	1.40	3.7	-0.7
Attur	10	Min	7.13	0.75	1.3	-5.7
		Max	8.45	2.24	6.2	4.0
		Mean	7.76	1.53	3.2	-0.5
Thalaivasal	10	Min	7.25	0.74	0.8	-6.8
		Max	8.12	2.39	6.6	-0.6
		Mean	7.2	1.60	3.0	-3.1
Vallapady	10	Min	7.08	0.91	0.7	-4.7
		Max	8.58	2.15	6.0	5.3
		Mean	7.84	1.40	2.8	-0.14
Konganapuram	10	Min	7.15	1.34	1.4	-6.0
		Max	8.15	2.31	5.2	1.5
		Mean	7.59	1.77	3.3	-2.6
Ayodhipattinam	10	Min	7.12	1.18	1.5	-4.5
		Max	8.22	2.34	5.4	-0.6
		Mean	7.70	1.75	3.0	-2.6
Pethanaickenpalayam	10	Min	7.12	1.25	1.8	-5.4
		Max	8.12	2.58	5.4	5.4
		Mean	7.63	1.87	3.3	-1.5

4. CONCLUSION

The overall percentage distribution of water quality in the Salem district was 66.5% good - quality water, 13% alkali water, and 20.50% saline water. In contrast, the Yercaud block has a significant percentage of high-quality water (100 %). In the Mecheri block, the proportion of alkali water was the highest (30%). Alkali water accounts for approximately 20 % in the Tharamangalam block. The Omalur block included a significant concentration of saltwater (40%). Furthermore, the distribution of groundwater samples in different water quality classes revealed that samples of high-quality subsurface water were found in nearly all of the blocks. Therefore, salinity and alkalinity issues do not harm high-quality water samples.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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