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ASSESSMENT OF GEOCHEMICAL CHARACTERISTICS FOR AGRICULTURAL LAND USE IN PERUNDURAI TALUK, ERODE DISTRICT, TAMILNADU, INDIA

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Abstract: In Perundurai Taluk, which is part of Tamil Nadu's Erode District, the adequacy of underground water for agricultural use was evaluated. Numerous tanneries, chemical plants, textile factories, and dyeing facilities are located close to Perundurai. These industries directly discharge their effluents into the groundwater, which then becomes contaminated. To determine the suitability of subsurface water for agricultural use, groundwater samples from 15 villages were analyzed over the course of two seasons. The appropriateness of the groundwater's chemical type was determined by interpreting Piper trilinear diagrams. It demonstrates that underground water is more alkaline. Most groundwater samples fall into class 4 and Seenpuram falls into class 2, as shown by the USSL Staff diagram. The test results indicate that contamination in the Seenapuram is more due to SIPCOT which poses a potential risk to both agricultural soils and the local population in that area.

Keywords: geochemical, groundwater, agriculture, Perundurai

1. INTRODUCTION

Chemical substances that lead to environmental degradation in Perundurai Taluk, Erode district, originate from industrialization and urbanization. Sathyamangalam, Gopichatipalayam, Bhavani, and Erode are some of the areas close to Perundurai that are actively involved in activities linked to the textile industry (Anjali et al., 2023; Duraisamy et al., 2019; Panneerselvam et al., 2021; Srinivasan et al., 2021). The production of textiles, especially dyeing, and bleaching, may use a lot of water and produce a lot of waste. A water shortage and groundwater vulnerability exist in Perundurai Taluk and its surrounding districts. Additionally, most of the bleaching and dyeing businesses in the Perundurai Taluk are grouped together along the banks of the rivers Kooduthurai and Kaveru, into which they dumped trash (Srinivasan et al., 2013). Because of this, the subsurface water quality in the vicinity of the collection of bleaching and dyeing units has become so contaminated that it cannot be used for agricultural, industrial, or domestic purposes (Thirumoorthy et al., 2020). Perundurai Taluk is facing the problems of Groundwater Scarcity, Vulnerability, Environmental Pollution, and Degradation because of the presence of dyeing industries and due to rapid urban population growth (Aravinthasamy et al., 2020; Sunantha & Vasudevan 2016). Studies on Groundwater Quality for Drinking and Irrigation, Rainfall Status, Groundwater Vulnerability Analysis, and Groundwater Recharge Potential Zonation Mapping are required for the sustainable development of groundwater in the study area.

Several studies have been conducted in different regions of the Erode district to examine water quality (Rajkumar et al., 2010; Sajil & Kuriachan 2022; Venkateswaran & Vediapppan 2013; Pradeep et al., 2021 In order to research the potential effects of leachate percolation on groundwater quality, Nagarajan et al., (2012) collected samples of groundwater and leachate from landfill sites in Erode, Tamil Nadu, India's Vendipalayam, Semur, and Vairapalayam. In leachate samples, concentrations of different physicochemical factors, including heavy metals, were found. Cl^-, NO_3^-, SO_4^{2-}, and NH_4^+ concentrations were found to be at high levels in groundwater samples, especially close to landfill sites, which is likely evidence that leachate percolation has had a significant impact on subsurface water quality. For industrial, and agricultural uses, the Lower Bhavani River basin's groundwater quality was assessed by Sajil & Kuriachan 2022. The World Health Organisation (WHO 2005) criteria were used as a benchmark for comparison after the Water Quality Index (WQI) approach and conventional hydro-chemical techniques were used to assess the quality of drinking water. According to Total Dissolved Solids (TDS) and other ionic components, 66% of the samples had drinking water quality. The WQI results, which indicated that 64% of the samples were of good quality or excellent, are consistent with these outcomes. Fluoride and nitrate concentrations are elevated in areas with high WQI levels.

Venkateswaran & Vediapppan (2013) worked in the Lower Bhavani sub-basin, with the majority of the study area falling in the Tamil Nadu state of India's Erode District. The 50 subsurface water samples were taken during the PRS (Pre-monsoon season), and the principal anions and cations, TDS, EC, and pH were examined. The appropriateness of the groundwater for irrigational purposes has been determined using irrigational criteria like Mg hazards HCO_3, SAR values, Kelley's ratio, and EC. Out of 50 samples, 33 samples, according to the Wilcox diagram, fall into the "good to permissible" group, while according to the Doneen diagram, all groundwater samples are Category I. All of the samples exhibit low SAR values, according to the graphing of Unites States Salinity Laboratory USSL diagram. 41 of the 50 samples were in the C3-S1 field. Pradeep et al., (2021) Numerous tanneries, chemical plants, and dyeing factories are located all around Erode North. These companies damage groundwater by dumping their effluents straight into it. 20 groundwater samples were collected in the Erode location, and the water's quality was determined using parameters like Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), chlorides, alkalinity, EC, pH, temperature, TDS, etc. Due to the effects of dyeing industries, chemical industries, textile, and tanneries, the findings of a small number of samples are found to be severely polluted (Sajil et al. 2022).

Characterizing and assessing the groundwater quality in Tamil Nadu state's Perundurai Taluk, Erode district is the main objective of the current investigation. According to Vennila et al., (2007), the study location is located in the Western Ghats' rain shadow zone, where yearly precipitation is on the low side at less than 600 mm. In this area, irrigation and drinking water supplies are primarily derived from groundwater. In the studied region, there are no sizable polluting industries. As a result, hydrogeochemical processes that occur below the surface largely regulate the chemistry of groundwater. However, the Kavery River consistently carries contaminated water, which could decrease the quality of the subsurface water in the research location's north region. Stress in the aquifer system results from overusing the groundwater in the fractured and weathered zones through bore and dug wells. Therefore, it is crucial to define the subsurface water potential and quality zones in order to supply the population with safe drinking water.

2. RESEARCH LOCATION

The research area is situated in the Erode districts of Tamilnadu(TN), India(IN), and spans latitudes 10°15′35″ N and 11°27′6″ E and longitudes 77° 25′ 0″ E and 79° 46′ 12″ E (Figure 1). It has a total range of around 563 km^2, of which 138.85 km^2 is urban and 424.21 km^2 is rural. Tropical climate conditions have been observed in the area. The average annual temperature and precipitation are 76.51 mm and 27 to 38°C, respectively. Between 60 and 80 percent in the morning and 35 to 65 percent in the afternoon, the humidity changes. Geographically, the Kavery River basin is situated near the Perundurai and Bhavani Taluk. Red gravelly, rocky, and sandy soils predominate in the Bhavani, Erode, and Perundurai Taluks. Samples were gathered from 15 different locations within the Perundurai Taluk (Table 1). The majority of the soil in the Gobichettipalayam and Sathyamangalam Taluks is red sand. Red loam is primarily found in the Taluks of Gobichettipalayam and Perundurai. Under phreatic conditions (Arveti et al., 2011), the groundwater is found in the weathered zone, and under semi-confined circumstances, it is also found in the fractured zone. The bore wells' depth is between 24 and 40 meters. Turmeric, sugarcane, cotton, silk, paddy, coconuts, and plantains are the main types of agriculture.

3. MATERIALS AND METHODS

From open wells and bore wells, a total of 15 samples of groundwater were taken. The tannery, chemical, textile, and dyeing industries were close to the sample locations. A combined conductivity bridge and electrode pH meter were used, respectively, to measure the pH and EC of water samples (APHA 2005; Acir & Günal 2020). By neutralizing OH^-, CO_3^{2-}, and HCO_3^- with pure H_2SO_4, the alkalinity was produced. Thus, the total alkalinity is determined by titrating the sample with methyl orange indicator against H_2SO_4.

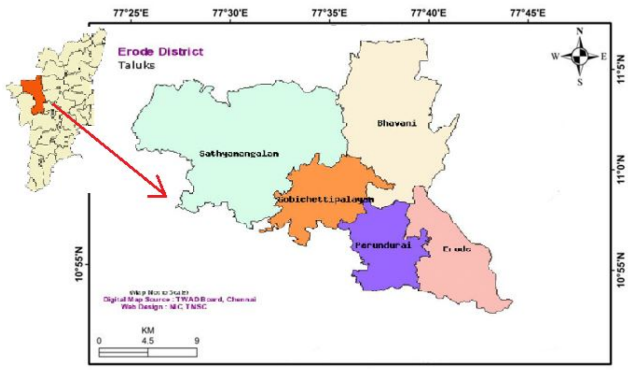

Figure 1. Research location

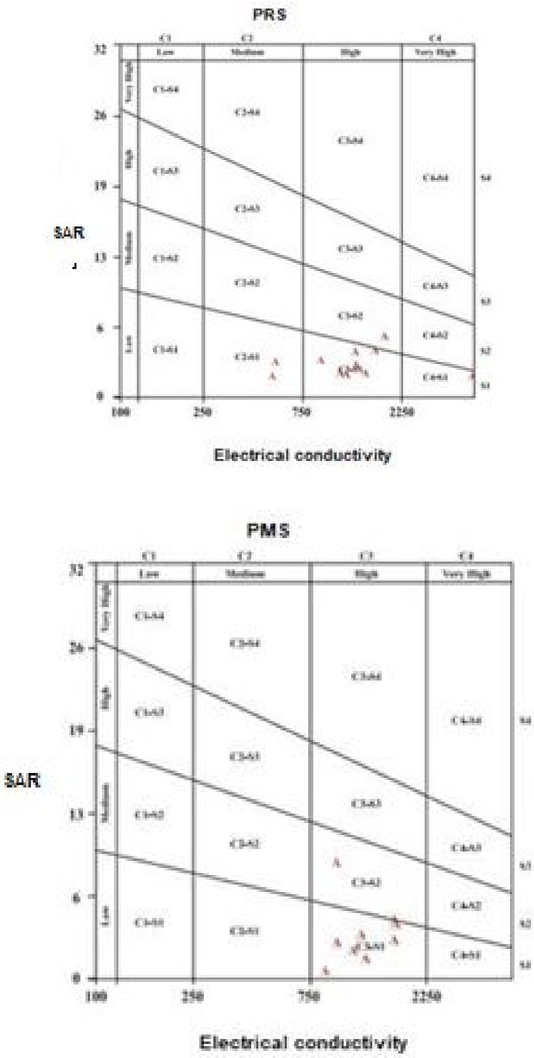

Figure 2. USSL staff diagram of Perundurai Taluk

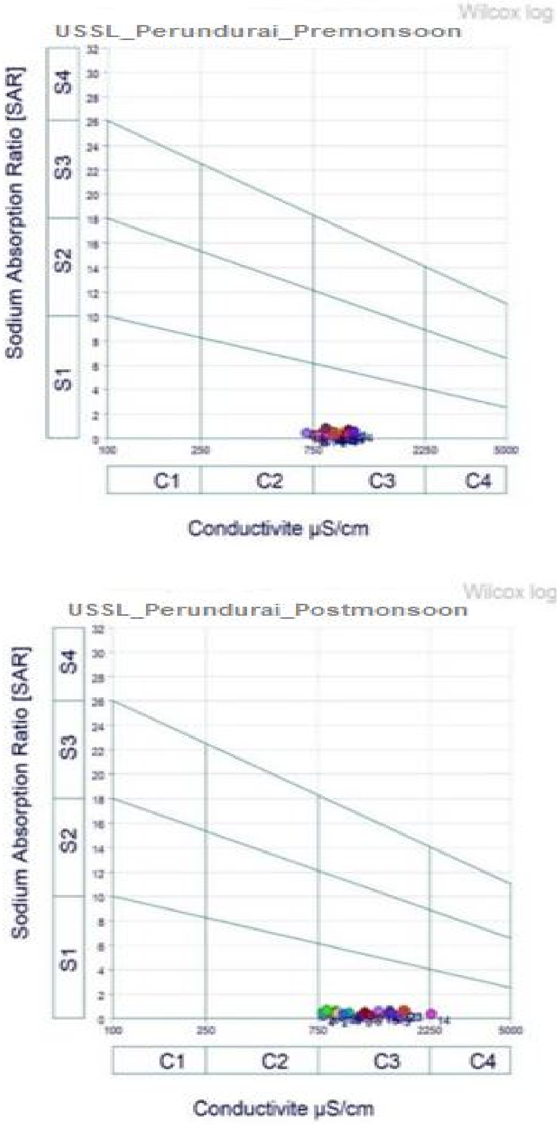

Figure 3. USSL diagram of Perundurai Taluk before and after monsoon

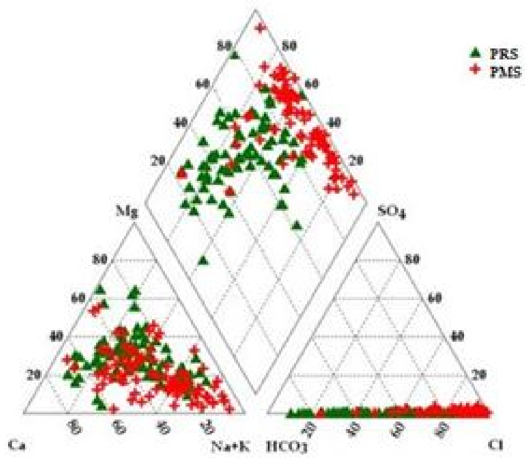

Figure 4. Piper diagram

Table 1. Sample locations at Perundurai Taluk

S.No.	Sample Station
1	Nasiyanur
2	Kanchikoil
3	Pethampalayam
4	Thingalur
5	Pandiyampalayam
6	Sankaranpalayam
7	Perundurai city
8	Seenapuram
9	Vaikalmedu
10	Vellodu
11	Ingur
12	Perundurai (R.S)
13	Chennimalai
14	Pudupalayam
15	Sirukkalanji

The complexation of the Ca and Mg divalent ions results in the hardness value when the sample containing Eriochrome Black T (EBT) is titrated with Ethylenediaminetetraacetic acid (EDTA). When the silver nitrate is titrated against the sample that has been mixed with an indicator, the chloride content in the samples is then determined using the Argentometric principle or Mohr's method. The Winkler method is employed as a basis to detect the presence of DO in water samples. The residue left over from the evaporation of the unfiltered and filtered samples is used to quantify Total Solids (TS) and TDS, and the difference between TDS and TS yields the suspended particles in the samples. The amount of COD present in water samples is determined by titrating the sample with ferrous ammonium sulphate, concentrated sulfuric acid, and potassium dichromate (Kilic 2021). The findings of these parameters were assessed using a correlation matrix. Locations of Perundurai Taluk Samples (PTS) are listed in Table 1. Several factors were estimated using the following equations in order to determine the appropriateness of groundwater for agricultural purposes:

Sodium Adsorption Ratio (SAR):

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

The concentrations of sodium (Na^{+}), calcium (Ca^{2+}), and magnesium (Mg^{2+}) ions in the water samples are used to calculate SAR. SAR helps determine the sodium hazard and its effect on soil permeability.

Magnesium Adsorption Ratio (MAR):

$$MAR = (Mg^{2+}) / \sqrt{(Ca^{2+})}$$

The concentrations of magnesium (Mg^{2+}) and calcium (Ca^{2+}) ions are used to calculate MAR. MAR provides insights into the magnesium hazard in irrigation water.

Residual Sodium Carbonate (RSC):

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

The concentrations of carbonate (CO_3^{2-}), bicarbonate (HCO_3^{-}), calcium (Ca^{2+}), and magnesium (Mg^{2+}) ions are used to calculate RSC. RSC indicates the potential of water to cause sodicity and alkalinity-related problems in soils.

Permeability Index (PI): $PI = (Ca^{2+} + Mg^{2+}) / \sqrt{(Na^{+})}$

The concentrations of calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^{+}) ions are used to calculate PI. PI reflects the relative effects of calcium, magnesium, and sodium on soil permeability.

By calculating these parameters using the measured concentrations of various ions and using the given equations, the irrigational quality of groundwater can be determined. These parameters help identify potential issues related to salinity, sodicity, and other factors that may affect the groundwater’s suitability for agriculture usage.

4. RESULTS AND DISCUSSION

For many uses, including irrigation, it is crucial to identify the quality of subsurface water. The pattern of the rain is continually changing according to a number of causes, which makes it highly unusual. Numerous techniques are used to identify the type of water that is detailed below since groundwater quality and quantity are of utmost importance.

4.1 Total dissolved solids (TDS)

The number of dissolved salts in water used for irrigation determines its quality. If salt builds up in the root zone, it causes salinity problems, which can have a big impact on how much crop yield is produced. The plant growth rate is slowed down if water intake is significantly lowered. Good water is defined as having a TDS of less than 450 mg/L, and inappropriate water is defined as having a TDS of more than 2,000 mg/L for agricultural use. The pre-monsoon season (March to Mid of June) in our study location sees TDS levels between 657 and 3671 mg/L. The post-monsoon (PMS) season sees a range of 859 to 3316 mg/L. Table 1 depicts the sample stations for the study during the PRS and PMS.

4.2 Electrical conductivity

Electrical Conductivity (EC) is used to gauge the salinity danger in water. Crop productivity is significantly impacted by EC values larger than 3,000 lS/cm; EC values of 250 lS/cm are ideal. The plant's ability to absorb water diminishes greatly when EC rises, which in turn significantly lowers output. In the PRS in the research area, EC ranges from 965 to 5314 lS/cm, and in PMS, it ranges from 1130 to 3346 lS/cm. Most samples with an EC of more than 240 lS/cm exhibit low to moderate crop productivity during both seasons. The values' discrepancy can represent a significant range in surface and subsurface environments.

4.3 USSL diagram and sodium adsorption ratio (SAR)

The permeability of the water sample is decreased by the increased sodium concentration, which lowers the amount of water that is available to the plant. It is dangerous when sodium replaces adsorbed calcium and magnesium because it weakens the structure of the soil, making it solid and less permeable to water. SAR assesses the excess sodium with calcium and magnesium. According to SAR, irrigation water is categorized (WHO 1989). Each of the ten samples was in great condition in both seasons. US salinity hazards (USSL 1954) reveal that for water samples in the Perundurai Block, most fall under C3/S1 (high-salinity hazard and low-sodium hazard) class, and some of them in the C3/S2 (high-salinity hazard and medium-sodium hazard) class, while one sample fell in C4/S1 (Very high-salinity hazard and low-sodium hazard) class in both the seasons (Figure 2). Most of the time, subsurface water that falls under the medium-salinity hazard class (C2) can be used without the need for any specific salinity management measures. To irrigate semi-tolerant crops, the subsurface water seen from zones C3/S2 and C3/S1 is thought to be of modest quality. The high-salinity locations, however, need careful management techniques when it comes to water samples. While water with a very high salt content (C3) is normally not appropriate for irrigation, salt-tolerant plants can be grown on permeable soil with specific management approaches.

4.4 Wilcox diagram and percent sodium (%NA)

The proportion of sodium is indeed a crucial factor to consider for irrigation purposes, as it directly affects soil permeability. The soluble sodium percentage (% Na) shows the concentration of sodium in the water. In the PRS, the % Na ranges from 30 to 72.4%, while in the PMS, it ranges from 3 to 76.2%. The Wilcox diagram, developed by Wilcox (1948), is a graphical representation of the water's suitability for agriculture based on its Na content. Analyzing the Wilcox diagram for the PMS, it can be observed that 70% of the samples fall within the permissible-to-doubtful range, indicating that the water may have some limitations but could still be used for irrigation with caution. 10% of the samples drop within the permissible-to-suitable limit, suggesting better suitability for irrigation. Another 10% of the samples drop within the good-to-permissible range, indicating good suitability for agricultural use (Figure 3). In the PMS, the distribution of samples on the Wilcox diagram changes. 40 percent of the trials were in the good-to-permissible limit, indicating better suitability for irrigation. 40% fall within the permissible-to-doubtful range, suggesting some limitations but still potential for irrigation use. 10% of the samples drop within the permissible-to-unsuitable range, indicating limited suitability, and the remaining 10% fall into the unsuitable range (Figure 3). The occurrence of excessive sodium content in the water leads to a higher percentage of samples falling within the permissible-to-doubtful ranges. This can have adverse effects on the soil by restricting air and water circulation during wet conditions. It highlights the importance of managing sodium levels in irrigation water to maintain optimal soil permeability and ensure adequate air and water movement for healthy plant growth. Figure 3, would show the graphical representation of the Wilcox diagram depicting the distribution of samples and their suitability for irrigation depending on sodium content. The groundwater classifications are listed in Table 2.

4.5 Permeability Index (PI)

The constant usage of groundwater for agriculture can indeed have an impact on soil permeability, which is influenced by the content of bicarbonate (HCO_3), magnesium (Mg), calcium (Ca), and sodium (Na) in the soil. Doneen (1964) developed a classification system for assessing the suitability of water for irrigation based on the Permeability Index (PI). In the study zone, the PI values for groundwater in both seasons indicate that most of the stations fall under class II which was having ranges between 25% to 75%. This suggests that the groundwater in the research zone generally maintains a moderate permeability. Almost all the samples, except those from three stations in the PRS and two stations in the PMS, lies within class II. The specific samples from these points exhibit higher permeability, falling under class I (75%) according to the classification by Ragunath (1982) based on the USSL diagram and Doneen's chart. Based on these findings, it can be determined that the groundwater in the research zone is generally appropriate for agriculture usage. The moderate permeability indicated by the majority of the samples suggests that the water can adequately penetrate the soil and support plant growth. However, the presence of certain samples with higher permeability indicates the potential for improved irrigation conditions at those specific locations.

4.6 Chloro-Alkaline indices (CAI)

To evaluate the quality of subsurface water, it is important to comprehend the changes in chemical structure that take place as it moves deeper beneath. Sastri (1994) emphasized the importance of studying the ion exchange between groundwater and its surrounding environment during residence or travel. Schoeller (1967) conducted research on this subject as well. With the exception of one sample, which displays a positive value for the Calcium to Alkaline Ion ratio in both seasons, the remainder of the samples shows undesirable values for this ratio. Sodium, potassium, and calcium ions in the rocks through which the water flows exchange places with calcium and magnesium ions when CAI is negative. This shows that potassium and sodium are exchanged with magnesium (Mg) and calcium (Ca) in the hard strata during the ion exchange process that occurs in the groundwater. The CAI ratio, on the other hand, indicates whether there is any major base exchange when it is positive. Based on the findings, most of the CAI values are negative in both seasons, indicating the existence of base exchange between magnesium and calcium in the hard strata and potassium and sodium in the water. This exchange process alters the chemical composition of the groundwater as it interacts with its geological environment. However, it is worth noting that there is one sample in both seasons that shows a positive CAI value. This constructive value suggests the absence of base exchange, indicating that the groundwater composition remains relatively stable without significant interactions with the surrounding rocks. By studying these CAI values, we can gain insights into the ion exchange processes that take place during the underground travel of groundwater and the resulting changes in its chemical composition.

4.7 Residual sodium carbonate

To assess the potential harmful properties of bicarbonate (HCO_3) and carbonate (CO_3) on water quality for agricultural use, the Residual Sodium Carbonate (RSC) values were calculated. Eaton (1950) and Richards (1954) are notable references for evaluating RSC values. The USSL diagram indicates that an RSC value below 1.25 meq/L is acceptable for agriculture and that a value above 2.5 meq/L is inappropriate. In the research zone during the PMS, 80% of the locations were found to have safe RSC values, indicating that the water quality is fit for agricultural use. 10% of the locations fell into the marginal category, suggesting some concerns about water quality, while the remaining 10% were deemed unsuitable for irrigation due to higher RSC values. In the PRS, all the RSC values were within the safe zone, indicative that the water quality was suitable for agriculture across all locations. These findings reveal that there is one sample in the research location that is inappropriate for irrigation due to the low soil permeability during the PMS. This suggests the presence of localized and seasonal pollution, which can have detrimental effects on crop yield in that particular area. It is important to address and mitigate such pollution sources to ensure the sustainability and productivity of agricultural activities in the region.

4.8 Kelley’s Ratio (KR)

Kelly (1951) proposed a convenient method to assess the sodium problem in agricultural water using KR. KR of one or above is typically regarded as being unsuitable for irrigation. By calculating Kelly's ratio for the research area, it was found to range from 0.20 to 2.00 meq/L in the PMS and from 0.29 to 3.65 meq/L in the PRS. Based on these values, any stations in the study area that have a KR exceeding one are considered unsuitable for agriculture. The specific values of Kelly's ratio can be used to identify the locations that fall into this category and indicate that the subsurface water quality is not fit for agriculture purposes. Assessing Kelly's ratio provides a valuable tool for evaluating the sodium problem in irrigation water. By identifying the stations with Kelly's ratio above one, it becomes clear which areas should be avoided for irrigation due to the unsuitability of the groundwater in terms of sodium content.

4.9 Magnesium ratio (MR)

The excessive presence of magnesium in the soil can have a detrimental impact on crop yield. In both seasons, the magnesium values exceed the permissible limit, except for a few positions. The magnesium concentration ranges from 17.98 to 13.74 meq/L in the PRS and from 28.66 to 38.00 meq/L in the PMS. The Magnesium Ratio (MR) is an indicator of the water’s suitability for agricultural usage and is considered unsuitable for agriculture when it exceeds 50.

Table 2. Groundwater classification for irrigation purposes during PRS & PMS in Perundurai Taluk

S.No.	Range	Class	Pre-Monsoon (PRS)		Post-Monsoon (PMS)	
			No. of samples	%of samples	No. of samples	%of samples
	Residual Sodium Carbonate					
1	>2.5	Unfit	0	0	0	0
2	1.25-2.5	Doubtful	0	0	0	0
3	<1.25	Good	15	100	15	100
	Sodium Absorption Ratio					
1	>26	Unfit	0	0	0	0
2	18-26	Doubtful	0	0	0	0
3	10-18	Good	0	0	0	0
4	0-10	Excellent	15	100	15	100
	Permeability Index					
1	>75	Class - 1	1	6.67	1	6.67
2	25-75	Class – 2	6	40	12	80
3	<25	Class – 13	8	53.33	2	13.33
	Magnesium Hazards					
1	<50	Suitable	3	20	4	26.67
2	>50	Unsuitable	12	80	11	73.33
	Percentage Sodium					
1	<20	Excellent	15	100	15	100
2	20-40	Good	0	0	0	0
3	40-60	Permissible	0	0	0	0
4	60-80	Doubtful	0	0	0	0
5	>80	Unfit	0	0	0	0
	Kelly Ratio					
1	<1	Suitable	15	100	15	100
2	>1	Unsuitable	0	0	0	0

Based on the values obtained, it can be inferred that the MR is higher than the acceptable limit in the research area. The granite rock, kankar (a type of limestone in India), and limestone formations in the research area may have caused the elevated magnesium ratio found in the groundwater. These geological formations can contribute to the higher levels of Mg in the groundwater, subsequently affecting the water's suitability for agriculture. The excessive presence of magnesium in the soil can potentially hinder crop growth and yield. It highlights the need for appropriate management strategies to mitigate the antagonistic effects of high magnesium levels in the soil. These strategies may include soil amendments, proper drainage, and the selection of magnesium-tolerant crop varieties to minimize the impact on agricultural productivity.

4.10 Hydrogeochemical trends

The milliequivalent percentages of the principal cations and anions are represented in different triangles on the Piper diagrams, (Piper 1944) (Figure 4). These projected points from the triangle fields into the central diamond field give the water its general appearance. The triangular fields are plotted separately with EPM values of cations (Ca^{2+}, Mg^{2+}) alkali earth, ($Na^{+} + K^{+}$) alkali, (HCO_3^-) weak acid, and (SO_4^{2-} and Cl^-) strong acid. Most PRS samples are concentrated in the Mixed Na-HCO_3-Cl and Na-Ca-HCO_3-Cl types, indicating anthropogenic and ion exchange activities, with only a few representations in Ca-HCO_3-Cl types. A few PRS samples are of the Ca-HCO_3 type, indicating natural groundwater replenishment. Some of the samples are dispersed in the type of mixed water. Most of the samples in PMS are of the Cl + Na type, with some of the Ca- Mg- Cl type, suggesting the prevalence of seawater intrusion and anthropogenic impact. Few Ca-Cl and Ca-Na-HCO_3 samples are found in PMS. The majority of the samples show cation and anion mixing, which could be attributed to the extra leachate.

5. CONCLUSION

In this research, the evaluation of groundwater suitability for agriculture was conducted using standard guidelines. Analysis of the Piper trilinear diagram indicates that the groundwater has an alkaline nature dominated by sodium (Na) and potassium (K), surpassing the presence of alkaline earth elements such as Ca + Mg. Based on the PI (Permeability Index) calculation, the majority of samples belong to Class II, indicating that most stations are suitable for agriculture.

With the exception of the Seenapuram area, which is not appropriate for irrigation under normal circumstances, the Wilcox categorization, which was monitored in both seasons, displays samples from the majority of locations situated within the Class 4 range. In addition, the USSL figure shows that the majority of stations have significant salinity hazards, but the Seenapuram city area station does not fit into any of the categories. The findings suggest that specialized irrigation methods are required to manage the high salinity levels at most stations, which can enhance crop yield.

Based on the aforementioned results, it is evident that contamination is present in the Seenapuram SIPCOT, likely caused by industrial and dyeing companies. This contamination poses a potential risk to both agricultural soils and the local population in that area. The pollutants originating from these industries can have adverse effects on soil quality, which can in turn impact crop productivity and the overall agricultural sector.

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