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Assessment of groundwater quality and mapping in coastal blocks of Pudukkottai district, Tamil Nadu

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Abstract
The current study intends to examine quality of groundwater, based on mapping of two coastal blocks in Pudukkottai district, Tamil Nadu. During March 2020, around twenty-nine groundwater samples were collected from the coastal blocks, namely Avudaiyarkoil (15 Nos) and Manalmelkudi (14 Nos). The groundwater samples were analysed for physio-chemical (pH and EC), chemical properties (Ca, Mg, Na, K, CO3, HCO3, Cl and SO4) and calculated the derived properties (SAR and RSC). The physio-chemical properties *viz*., pH and EC were ranged from 7.7 to 8.62 and 0.54 to 78.25 dS m^{-1} respectively. The Sodium Adsorption Ratio (SAR) varied from 4.46 to 44.61 m mol/l and the Residual Sodium Carbonate (RSC) varied from nil to 13.67 meq L^{-1}. As per the CSSRI, Karnal Water Quality Classification in coastal blocks of Pudukkottai district, In Avudaiyarkoil block detected good quality water (13.33%) saline water (40%) and alkali water (46.67%) and in Manamelkudi block detected the good quality water 21.46% saline water (42.84%) and alkali water (35.7%) were found. The Geographic Information System (GIS) is used to analyse the spatial distribution of water quality. GIS was used to create a spatial distribution map of these groundwater quality data, which was compared with CSSRI water quality categorization. The resulting map depicts the Avudaiyarkoil and Manamelkudi groundwater quality maps.

Keywords: coastal block, groundwater quality, Pudukkottai district, SAR and RSC

Introduction
Water is an essential component of all living organisms. There are various sorts of water sources such as groundwater, surface water, shallow wells, rainwater, and seawater. In which, Groundwater is a valuable gift from nature to mankind that may be found almost anywhere. More than 85 percent of India's rural residential water requirements, 50 percent of its urban water requirements, and more than 50 percent of its irrigation requirements are supplied by ground water resources Jha *et al.* (2009) [4].

Pudukkottai district has an area of 4663 km^2 accounting for 3.58% of the total geographical area of Tamil Nadu State. The district lies between 9° 50' and 10° 40' of the northern longitude and between 78° 25' and 79° 15' of the eastern latitude and with a coastal line of 42.8Km. The district is bounded by Thanjavur district in the Northeast and East, Tiruchirappalli district in the Northwest, Ramanathapuram and Sivaganga district in the Southwest, Palk Strait in the Southeast. As reported by Tamil Nadu Agricultural Department 2010 during the last ten years, the usage of groundwater for agriculture in Tamil Nadu has increase dramatically. Due to the anthropogenic activities like, increasing industry, urbanisation, groundwater withdrawals, and sea-level rise, saline water ingress into aquifers has /become a serious hazard Gopinath *et al.* (2019) [3]. The accuracy of interpolation methods for spatially predicting the parameters of soil and water has been analysed in several studies (Bhunia GS *et al.*, 2018; Kundu *et al.*, 2019) [2, 6]. In the coastal blocks of Pudukkottai districts, groundwater quality assessments using a GIS technique have been attempted.

Materials and Methods
Totally, 29 water samples were gathered in the Coastal blocks *viz*., Avudaiyarkoil and Manalmelkudi of Pudukkottai district during the month of March 2020. The coordinates of the sample location were recorded using a handheld GPS receiver (GPS, Garmin). A pre-cleaned plastic polyethylene bottle was used to collect samples. Before sampling, all the sampling containers were carefully cleansed and rinsed with groundwater. The samples were analysed for pH, Electrical Conductivity, cations like Ca^{2+} and Mg^{2+} by versenate method and Na^{+} and K^{+} by Flame Photometry,

anions like Co_3^{2-}, HCO_3^-, Cl^- by Titrimetric and SO_4^{2-} by Turbimetric method as per standard procedure by Richards (1954) [10]. Other quality metrics, such as the Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC), were computed using the formula below.

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

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

The central soil salinity research institute (CSSRI) in Karnal evaluates groundwater samples for irrigation suitability by using EC, SAR, and RSC values (Table 1) and Arc GIS 10.1 Software was used to create thematic maps of the Pudukkottai district related to groundwater quality.

Table 1: Grouping of low-quality ground waters for irrigation in India

Water quality	EC (dS/m)	SAR (m mol/L)	RSC (me/L)
A. Good	<2	<10	<2.5
B. Saline			
i. Marginal saline	2-4	<10	<2.5
ii. Saline	>4	<10	<2.5
iii. High-SAR saline	>4	>10	<2.5
C. Alkali water			
i. Marginally alkali	<4	<10	2.5-4.0
ii. Alkali	<4	<10	>4.0
iii. Highly alkali	Variable	>10	>4.0
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.		

Results and Discussion

The quality of groundwater in Avudaiyarkoil and Manalmelkudi blocks are presented in table 2.

Physio-Chemical Properties

The pH of the collected groundwater samples in Avudaiyarkoil block ranged from 7.7 to 8.59 with mean of 8.23 and Manalmelkudi block ranged from 7.89 to 8.62 with mean of 8.2. It represents that in Avudaiyarkoil block 81.49 per cent of water samples are saline and 18.5 per cent are slightly alkaline. In Manalmelkudi block 72.48 per cent of water samples are saline and 27.52 per cent are slightly alkaline. The high concentration was recorded near to the coastal area of Pudukkottai district which was earlier reported by Yuvaraj 2020 [13].

In Avudaiyarkoil block**,** EC ranged from 0.54 to 78.25 dS m^{-1} with the mean of 7.92 dS m^{-1} and in Manalmelkudi block, EC ranged from 1.55 to 5.18 dS m^{-1} with the mean of 2.77 dS m^{-1}. In Avudaiyarkoil block the EC range was high which may be due to the sea water intrusion in that block. Similar trends were earlier reported by Sreekala *et al.* (2015) [12].

Cationic Concentration

The concentration of cations like calcium, magnesium, potassium and sodium in Avudaiyarkoil block varied from 0.5 to 28.8, 0.5 to 105.6, 0.23 to 34.72, 6.54 to 337.2 meq L^{-1} with the average of 4.84, 10.3, 3.35, 53.88 meq L^{-1}. In Manalmelkudi block the cationic concentration like calcium, magnesium, potassium and sodium varied from 1.5 to 9, 1 to 19.9, 0.25 to 2.29, 10.89 to 56.7 meq L^{-1} with the average of 4.61, 5.83, 1.11, 28.04 meq L^{-1}. The relative cationic concentration followed the order- Sodium, Magnesium, Calcium and Potassium. The predominance of Na and Cl ions in coastal groundwater shows that seawater interacts with groundwater Mohanty *et al.* (2019) [7]. Mg is often greater than Ca in various sites, which could be owing to the effect of the sea in that area, according to Mondal *et al.* (2008) [8].

Anionic Concentration

The concentration of cations like Carbonate, Bicarbonate, Sulphate and Chloride in Avudaiyarkoil block varied from 2 to 4.04, 3.03 to 11.11, 0.13 to 8.6 and 2.8 to 488 meq L^{-1} with the average of 2.69, 5.72, 1.32, 57.76 meq L^{-1}**.** In Manalmelkudi block the cationic concentration like calcium, magnesium, potassium and sodium varied from 2.02 to 6.06, 3.03 to 11.1,0.311 to 3.728 and 10 to 43.6 meq L^{-1} with the average of 3.89, 7.13, 1.185 and 22.8 meq L^{-1}. The relative anionic concentration followed the order- chloride, Bicarbonate, Carbonate and Sulphate. The chloride, which is formed from rain or saline water intrusion along the seashore, is actively circulating at relatively shallow depths of groundwater.

Over-pumping of groundwater in the coastal region frequently which leads to the transfer of saline water into freshwater aquifers. Saraswat *et al.* (2019) [11].

Water quality parameters

Irrigation water quality is a measure of its suitability for agricultural use. Water quality is an important consideration when determining salinity or alkalinity levels in an agricultural area. Good water quality can promote the good result in soil and helps to attain the maximum crop output Kalaivanan *et al.* (2018) [5].

The sodium absorption ratio (SAR) in the Avudaiyarkoil block was found to be in the range of 4.46 to 44.61 m mol L^{-1} with the mean of 24.38 m mol L^{-1}. In Manalmelkudi block the sodium absorption ratio (SAR) was found to be in the range of 5.05 to 28.51 m mol L^{-1} with the mean of 14.04 m mol L^{-1}. The Residual Sodium Carbonate (RSC) was recorded in Avudaiyarkoil and Manalmelkudi blocks were nil to 7.08 meq L^{-1} and nil to 13.67 meq L^{-1} with the mean of -6.73 and 0.587 meq L^{-1}. The high sodium level in the water sample limits permeability and then the amount of water available to the plant is also reduced (Ahamed *et al.*, 2013) [1].

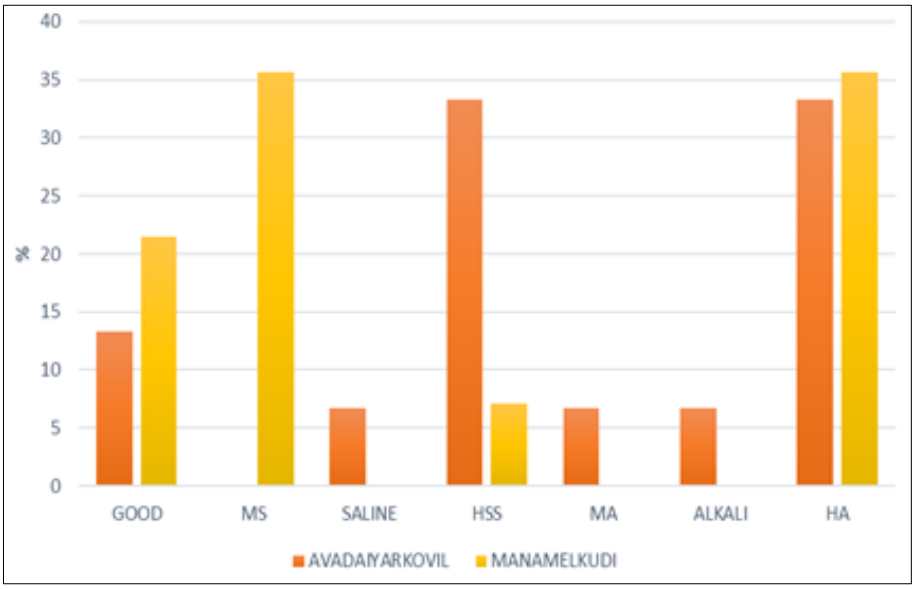

Fig 1: Percentage Distribution of groundwater quality in coastal blocks of Pudukkottai district

The distribution of good quality water in Avudaiyarkoil block (13.33%) and Manamelkudi block (21.46%). The high saline water in Avudaiyarkoil (33.33%) and Manamelkudi (7.14%). In Avudaiyarkoil block 6.67% of saline water, marginal alkali and alkali water were recorded. And then High Alkali water were found in Avudaiyarkoil (33.33%) and Manamelkudi at (35.7%). The marginal saline water was found in Manamelkudi (35.7%) (Fig 1). Irrigation with high SAR water may require soil additives to prevent long-term soil damage, since the sodium in the water can displace calcium and magnesium in the soil. This will also result in a reduction in infiltration and permeability of the soil to water, and loss in soil structure causing agricultural production issues (Prasanth *et al*., 2012*;* Sreekala *et al.,* 2015) [9, 12].

Out of the total groundwater samples collected from coastal blocks of Pudukkottai district, 17.39% of water samples are comes under good quality, Saline water was detected in both blocks approximately 41.41%. And then, 41.19% of Alkali water was detected in both the blocks. Saline irrigation has a negative impact on plant growth, mostly due to the impact of osmotic pressures in the soil, which tends to reduce the amount of nutrient taken by the plant. An essential strategy for overcoming this problem is to adopt the various irrigation management techniques like Drip, sprinkler and pitcher irrigation. Then there's the addition of organic manures like FYM and compost, which aid in minimising the negative effects of salinity caused by the release of organic acid during decomposition. And also planting the green manure crops to reduce the alkalinity hazards. And then, adapt the in-situ rainwater conservation for the leaching of salts collected from saline and alkali water irrigation in soil.

Groundwater quality map using GIS

On the basis of EC, SAR and RSC, the groundwater samples were grouped into different categories (Table1). Ground Water Quality Map for Avudaiyarkoil and Manamelkudi block of Pudukkottai district (Fig. 2) was generated in Arc Map 10.1. It demonstrates that Inverse distance weighted (IDW) interpolation in a GIS tool is particularly effective for comparing the spatial distribution of water quality parameters (Yuvaraj 2020) [13]. The map shows that the groundwater is deteriorating in the coastal blocks with some anthropogenic activities like pumping of groundwater near the coastal side area which cause the sea water intrusion and also waste discharged from industrial / agricultural activities and it reduce the groundwater quality.

Conclusion

Based on the findings of this study, it is possible to conclude that both the blocks have 17.39% of good quality water and equal percentage of saline and alkali water was found in both the blocks. Among these blocks, the equal percentage of high SAR saline water and highly alkali was found in Avudaiyarkoil block (33.33%). The Manalmelkudi block recorded highly alkali water (35.7%) and marginally saline water (35.7%). Near to the coastal area the groundwater samples were comes under the saline and alkali condition but the groundwater far away from coastal area the water was comes under good quality. So that the good quality samples are not harmed by any salinity or alkalinity issues.

Table 2: Mean chemical composition of groundwater in coastal blocks of Pudukkottai district

Name of the blocks	No. of samples	Range/ Mean	pH	EC (dS/m)	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Co_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	SAR	RSC
					meq L^{-1}								m mol/L	meq L^{-1}
Avudaiyarkoil	15	Min	7.7	0.54	0.5	0.5	6.543	0.226	2	3.03	2.8	0.13	4.463	-129
		Max	8.59	78.25	28.8	105.6	337.2	34.72	4.04	11.11	488	8.6	44.61	7.08
		Mean	8.23	7.92	4.84	10.3	53.88	3.354	2.69	5.72	57.76	1.32	24.38	-6.73
Manamelkudi	14	Min	7.89	1.55	1.5	1	10.89	0.25	2.02	3.03	10	0.311	5.051	-14.9
		Max	8.62	5.18	9	19.5	56.7	2.29	6.06	11.1	43.6	3.728	28.51	13.67
		Mean	8.2	2.77	4.61	5.83	28.04	1.11	3.89	7.13	22.8	1.185	14.04	0.587

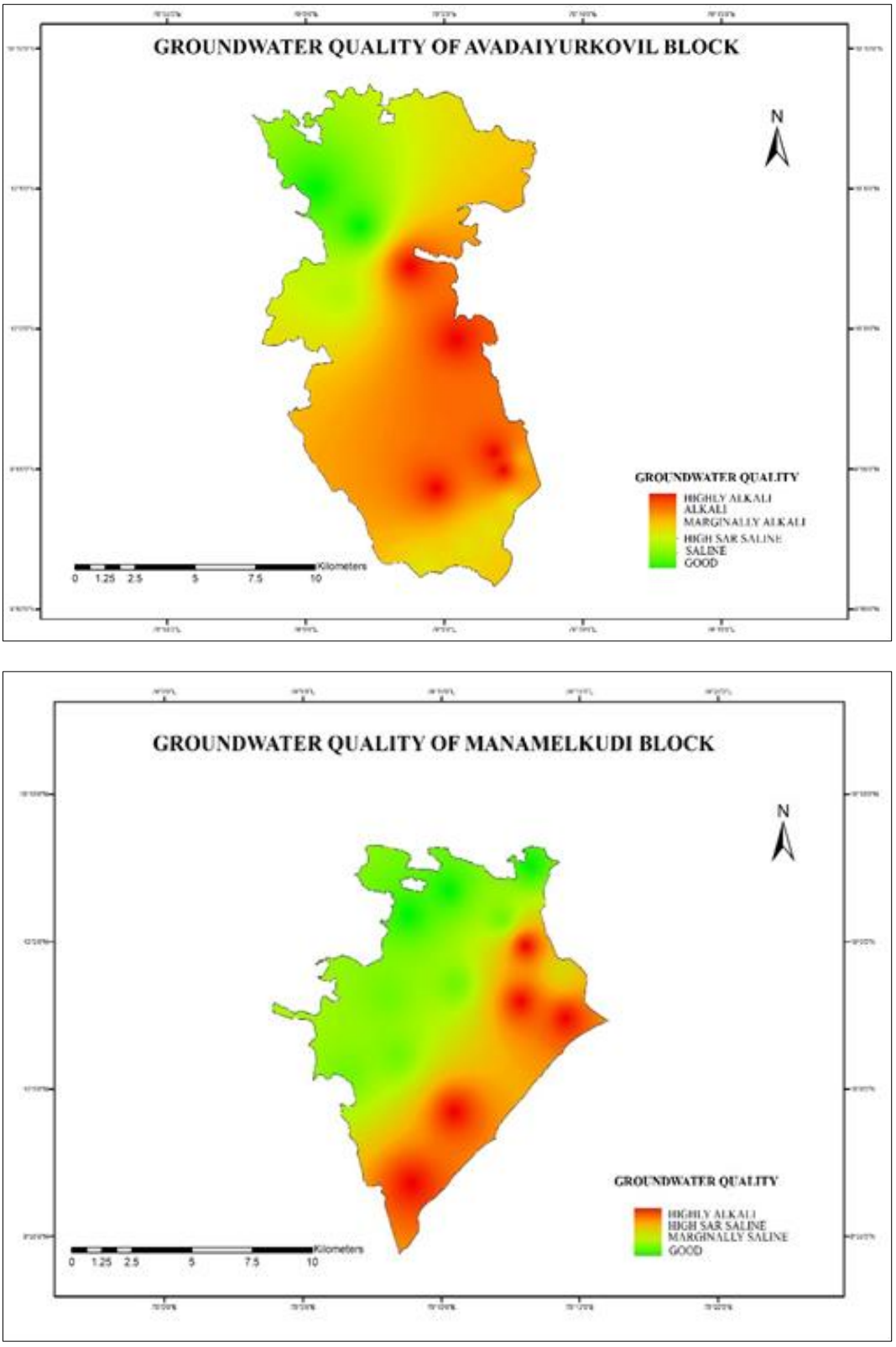

Fig 2: Spatial distribution of different quality parameters of groundwater in coastal blocks of Pudukkottai district

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