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A project to learn about the groundwater potential, with a focus on salinization in the coastal area of South East India

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ABSTRACT:

Exploiting groundwater resources is very important and has become even more so in the last few decades, especially along the coasts of dry and semi-dry regions. Salty seawater is getting into these areas' shore groundwater, putting them at great risk. 68 samples of groundwater were taken from the study area during NEM and SWM and looked at for factors that show how salinized and polluted the aquifer is. The findings show that the factors Electrical Conductivity, Na, K, Mg, Cl, and SO4 have high values. This is likely because of seawater entering the groundwater, with Cl being the main pollution. The Stuyfzand groundwater classification says that the main kinds of water are Na-Cl and Ca-Mg-Cl. If you mix freshwater and saltwater, these types of water show that cation exchange events change the chemistry of the groundwater.

INTRODUCTION:

The most important sources of fresh water for many countries around the world are coastal springs. Drawing a lot of groundwater from coastal aquifers lowers the flow of freshwater to the ocean and raises the water table nearby, which makes seawater move inland and rise toward the wells (Masciopinto 2006; Mjemah et al. 2009; Van Camp et al. 2014), which lowers the quality of the groundwater. This amazing thing, known as seawater interruption, has become one of the main things that makes it hard to use groundwater in coastal areas. Saltwater interruption is one of the most important and far-reaching ways that water quality drops below acceptable levels for drinking and water systems, and it puts future water abuse in coastal aquifers at risk. Along with the rising sea level caused by global warming, coastal groundwaterare, in fact, more at risk. This problem is getting worse because of population growth and the fact that about 70% of the world's people live in coastal plain zones (Jones et al. 1999; Meybeck et al. 2013).The focus of the problem rests on how much thought has gone into it. It has to do with the normal groundwater recharge, as well as the well field's size and shape, as well as the hydrogeological characteristics of the filled aquifer.Recently, there's been more and more interest in figuring out how much seawater is being cut off because of overfishing and rising sea levels (Werner et al. 2013).So, one of the most common ways to find out how seawater gets into an aquifer in coastal areas is to look at the chemistry of the groundwater every once in a while (Todd 1980; Sukhija et al. 1996; Saxena et al. 2003; Beddows et al. 2007; Sarwade et al. 2007; Kim et al. 2009). When saltiness is caused by seawater seepage, groundwater usually has high levels of different trace elements (Saxena et al. 2004; Mondal et al. 2010b), as well as high levels of total dissolved solids (TDS).The area under study is on the eastern coast of Southern India. It is vulnerable to the effects of seawater intrusion because it is close to the Bay of Bengal. It is important to look at the saline water interruption marvel of the coastal aquifer because the coastal area of Puducherry has grown so quickly in the last few decades. This will help people find better ways to use the region's groundwater resources without lowering the quality of the water.

STUDY AREA:

Pondicherry is a place on the east coast of India that forms islands in the south arcot area of Tamil Nadu. Its northern latitudes are 11° 45' and 12° 03' and its eastern longitudes are 79° 37' and 79° 53'. It is shown on Survey of India topographical maps Nos. 58 M/9, M/13, and 57 P/12 and P/16. The Pondicherry region covers 293 km² and has

seven communes (Fig. 1) with a total of 179 towns. The study area is crossed by the deltaic waterway of the Gingee and Pennaiyar rivers. The rock layers that cover the Pondicherry area range in age from the Cretaceous to more modern times, as shown on the geologic map. For the most part, this area is a flat peneplain that is about 15 meters above mean sea level.
Coastal plain, alluvial plain, and uplands are the three main types of landforms that can be seen.
The weather in Pondicherry is warm and hot. The harsh weather changes from month to month and is between 22 and 33 degrees Celsius. A total of 1281 mm of rain falls on it every year. The water table moves from 1.5 meters below ground level to 27 meters below ground level. The Pondicherry area is mostly used for gardening, and about 56% of the land is used for farming. But because of development and industrialization, more people are moving there for reasons other than farming, and as a result, the net area that was flooded and the area that was appeared is constantly going down.

Industrial areas can be found in Periyakalapet, Sedarapet, Karasur, Mudaliarpet, and Mettupalayam. These places are known from Pondicherry. The Cretaceous and Tertiary layers generally run NE to SW, with a small dip. Even though the Cuddalore shapes stay the same, they show a dip of up to 100. Because fresh water is being taken out of the coastal groundwater, ocean water is seeping into the area.

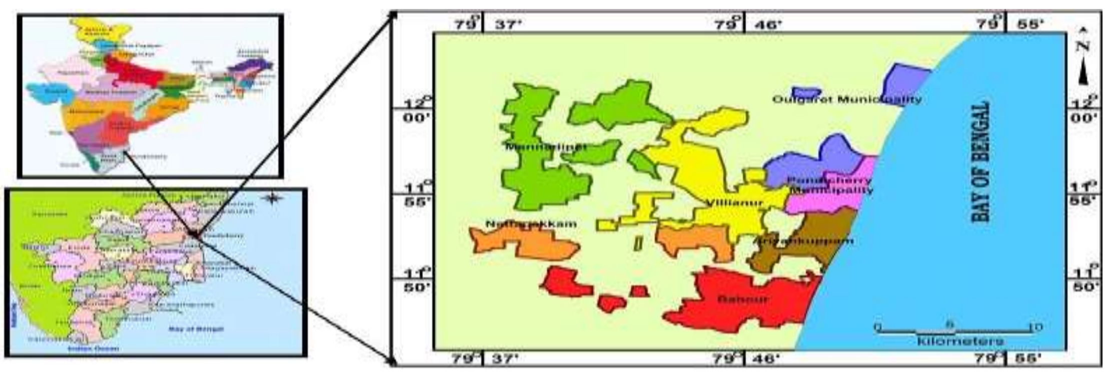
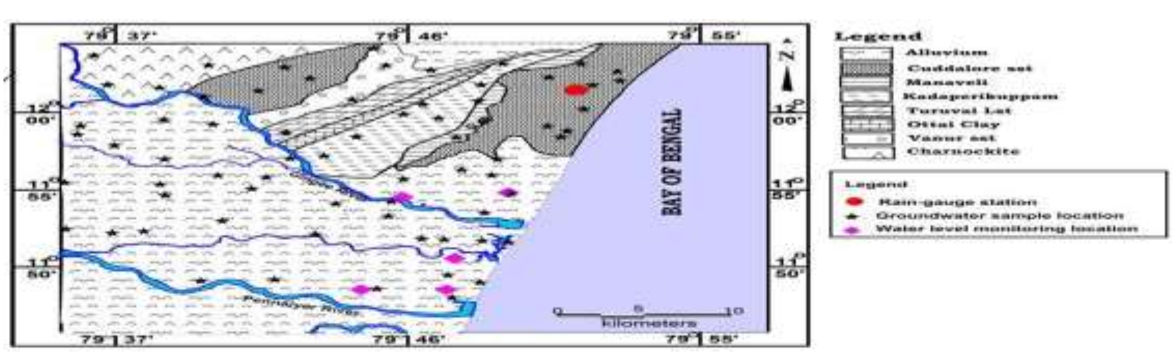


Fig 1: Location and Communes map of the study area

MATERIALS AND METHODS

A total of 68 groundwater samples from North East Monsoon (NEM) and South West Monsoon (SWM) located at different distances from the Pondicherry region, were selected for groundwater sampling (see Figure 2). The samples were collected during pumping and sealed. The



collected water samples were preserved in polyethylene bottles after filtering with 0.45 µ cellulose membrane filters. Samples were taken from each well, for determining anions, cations. Samples for cation analysis were acidified to lower the pH to around pH= 2 by adding a few drops of nitric acid. Parameters measured are physical properties such as: pH, temperature, TDS and electrical conductivity. Cations (Na, and K) were analyzed using Flame photometer. Anions (SO_4, PO_4 and NO_3, were analyzed using the Spectrophotometer. Determination of bicarbonate (HCO_3), Ca, Mg and Cl used the titration method respectively. The above-mentioned analytical methods were followed by American Public Health Association (APHA, 1985). Careful quality controls were undertaken for all samples to obtain a reliable analytical dataset with an ionic balance error less than 10%. The interpretation process is mainly based on the calculation from conservative freshwater/seawater Stuyfzand classification system, graphical illustration methods including Piper diagram, calculation of ionic ratios, and elaboration of hydrochemical and maps showing the spatial distribution of water quality parameters in the study area.

RESULTS AND DISCUSSION:

RESISTIVITY AND LITHOLOG ELUCIDATION:

The three-dimensional picture portraying the spatial dispersion of the subsurface resistivity and litholog of eight diverse boreholes were created by utilizing Rockworks version14 computer program. The resistivity cross-section for Ariyankuppam, Chinnaverampattinam, Keezhparikalpattu, Muthalyarpet, Nallavadu, Pillaiyar Kuppam, Reddiyarpallayam, Thavalakuppam shows that the upper layers above 100 m are low, and the layers below 100 m have high resistivity patches. The resistivity cross-section appears that the layers are > 50 m of thickness. The lesser resistivity zone is thicker in the SE region than in the Northern region at Nallavadu (Fig 3). The layers below a depth of 100 mbgl (meter below ground level) have high resistivity. The more profound aquifer has lesser resistivity within the Northern region and higher resistivity in SW region. The borehole litholog appears an interceding impermeable clay layer and nearness of lignite seam.

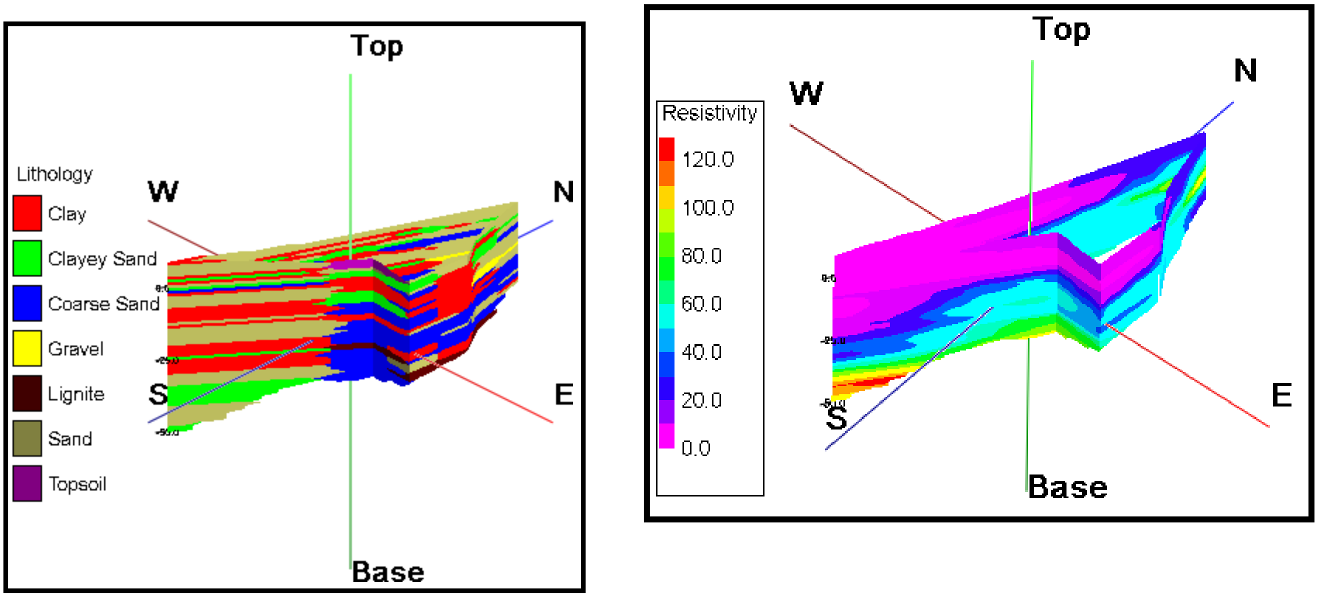


Fig . 3 Three-dimensional variation of litholog (m) and resistivity (Ωm) for six locations in the study area

It is additionally apparent that the thickness of the top clay is lesser at Ariyankuppam than at Nallavadu (Thilagavathi et al. 2014). The shallow aquifers illustrate the current Alluvium with less resistivity, which may be due to the prevailing clay layer or saline intrusion in SE area. It is experimental from the litholog that Nallavadu has less significant resistivity in the depth of

about 50m which is signify by Coarse Sand, representing the presence of salinity at this depth which is mostly appropriate to sea water intrusion near the coast. It has not extended beneath to the lower aquifer at this borehole appropriate to the presence of impermeable layer. Higher resistivity is noted in the deeper layers, which is illustrate by the upper Cuddalore (Mio-Pliocene) formation examine by the occurrence of lignite in Muthalyarpet and Nallavadu. The lower resistivity may also be due to the salinity in the formation as they form a part of the coastal aquifer. It is manifest from the hydrogeochemical studies (Thilagavathi et al. 2012; Pethaperumal et al. 2008) that the deeper aquifer is moderately fresh compared to shallow groundwater's of thearea.

MAJOR HYDROCHEMICAL PARAMETERS:

Major anions and cations were analyzed and pH, electrical conductivity (EC) as well as temperature were assessed on all samples. The results show that: temperature ranges 26 - 32˚ C, pH range is 6.7–7.9, EC range is 469 - 3830 µS/cm (25 C), TDS range is 310 - 2367 mg/L and chloride concentration ranges 53 - 914 mg/L. Table 1 appears explanatory comes about for physico-chemical parameters of groundwater for selected samples in NEM. The high concentration of major ions such as Cl, Na, Ca, K, Mg, and a high EC indicate the presence of seawater in an aquifer (Mollema et al. 2015). Concentration of major ions such as Cl, Na, Ca, K, Mg, and a high EC indicate the presence of seawater in an aquifer (Mollema et al. 2015). Out of 68 samples analyzed, 6% have NO_3 higher than the highest desirable level of 45 mg/L according to WHO (2004), For chloride 70.5% exceed the recommended Cl value for standard drinking water (250 mg/L) and 37% have Na Out of 68 samples analyzed, 72% have higher EC (Fig 4) . For TDS 59% have the highest admissible level of 1000 mg/L (WHO 2004). During SWM 51% of samples have EC higher than the highest desirable level of 1400 µS/cm according to WHO (2004). The levels of TDS in samples 62% are higher than the permissible limit. For chloride 41% exceed the recommended Cl value for standard drinking water (250 mg/L).49% of samples for Na higher than the permissible limit. The levels of Cl and EC are the simplest indicators of seawater intrusion or salinization (Mercado 1985, El Moujabber et al. 2006). EC is positively correlated with the concentration of ions, mainly Cl concentration. Figure5 shows three zones on a plot of Cl vs. EC: freshwater zone, mixing zone and strong mixing (intrusion). It appears that

groundwater samples with Cl surpassing 250 mg/L and EC above ~1400 µS/cm are most probably influenced by seawater intrusion. Groundwater samples that are characterized by EC between 1400 and 2400 µS/cm represent a mixing between freshwater and saltwater. Samples with EC of more than 2400 µS/cm characterize the strong seawater inference. During NEM most of the samples (68% of samples) are having higher EC and Cl representing the Na-

Table 1. Analytical results for physico-chemical parameters of selected groundwater samples

		pH	EC	TDS	Ca	Mg	Na	K	Cl	HCO_3	SO_4	PO_4	H_4SIO_4	NO_3
NEM(N=68)	Max	7.9	**3830**	**2367**	**228**	**84**	**561**	88	**914.3**	512.4	**2.5**	11.9	**265**	65.1
	Min	6.7	469	310.2	20	2.4	11.4	0.5	53.2	24.4	0	0	6	0
	Avg	7.3	1774	1126	92.4	19.4	173.6	25.7	357.2	270	0.4	0.6	123.4	13.1
SWM (N=68)	Max	**9.5**	2343	1773	124	84	394.3	**247.8**	514.03	**597.8**	0.99	**17.98**	258	**184.1**
	Min	5.2	751	494.2	16	2.4	42.7	1.7	68.63	73.2	0.03	0	33	0
	Avg	6.8	1476	1046	63.3	23.3	190.1	30.78	250.8	320.9	0.52	1.02	143.2	16.2
WHO	2004	6.5-8.5	1400	1000	100	50	200	20	250	300	250			50
BIS	2004	6.5-8.5	-	500	75	30	-	-	250	-	200			45
NEM			50	41	46	12	25	37	49	34	0			7
SWM		1	35	42	19	18	33	19	28	39	0			6

The Total Dissolved Solids ranges between 310 and 2367 mg/l in NEM and 494 and 1773 mg/l. Higher concentration of EC and TDS are noted in Dhavalakuppam (Fig 5). The groundwater quality equivalent to freshwater, with lesser EC values are noted in the South Western and South eastern part. Higher EC concentration is observed in North West and North Eastern part of the study region. The monitoring wells with more than 3000 µS/cm indicates that the ground water is highly mineralized /contamined with saline intrusion. Higher EC values observed during SWM (Fig 6) in central and southern region of the study area.

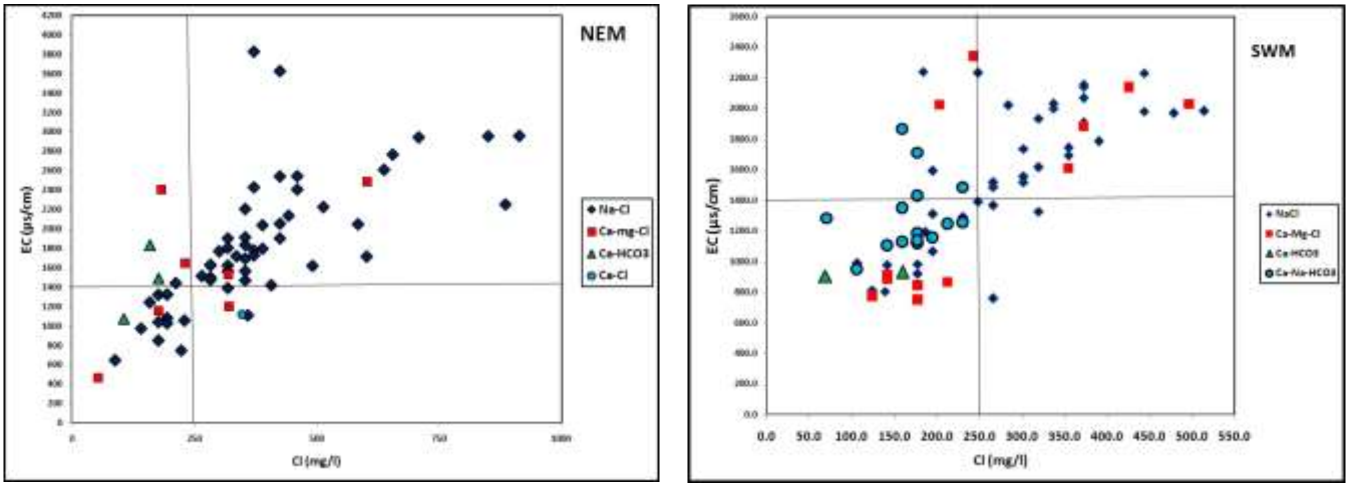


Fig 4. A plot of chloride vs. electrical conductivity showing fresh groundwater conditions, saltwater Intrusion and mixing between Samples.

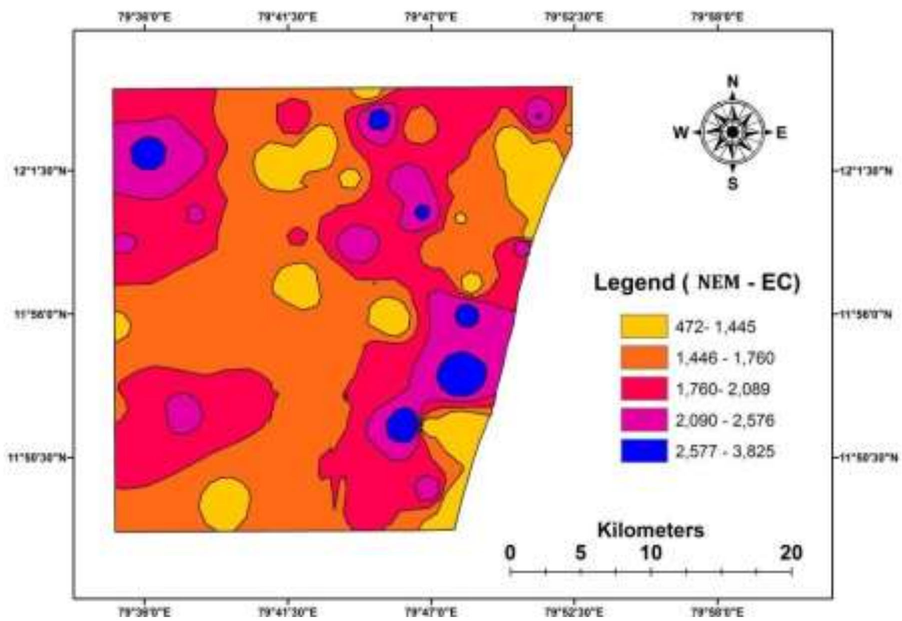


Fig 5: Spatial Distribution of EC (μs/cm) in groundwater during NEM

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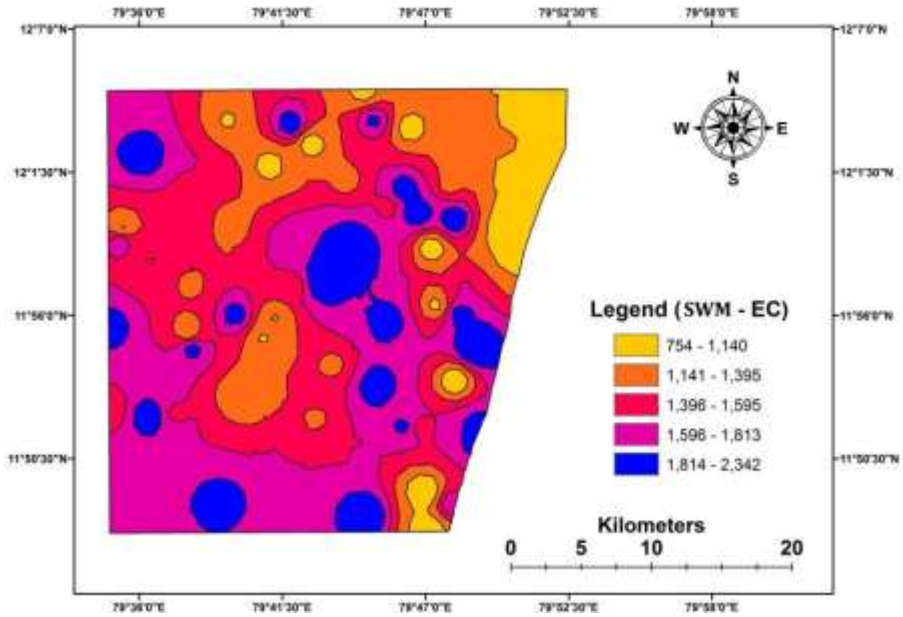

Fig 6: Spatial Distribution of EC (μs/cm) in groundwater during SWM

The groundwater (Fig 7) has dominant representation of Na-Cl and Ca-Mg-Cl facies. Most of the samples of Na-Cl type, has high sodium and chloride may be due to the process of removal of other ions from the system either by adsorption or by precipitation due to the saturation or, they can also be due to seawater intrusion (Thilagavathi et al. 2012). Migration of the samples from transition zone of mixed Ca- Mg-Cl and Na-Cl facies towards the sea water composition as few samples represent Ca-Mg-Cl facies, the groundwater in this region may also have been influenced by seawater intrusion. It is additionally propose the impact of seawater interruption due to the overwhelming facies of both Na and Cl. The seawater composition is due to the diminishment in precipitation, consumption of water level with additional exploitation of groundwater during NEM. These samples may also indicate the long residence time of shallow groundwater (Prasanna et al. 2010) where Na exceeds Ca and Mg, Cl exceeds HCO_3 and SO_4 (Prasanna et al. 2008). Na-Cl water type in discharge zone shows the saline nature (Prasanna et al. 2009). During SWM (Fig 7) most of the samples falls in the mixed zone facies of Na-Cl and Ca-Na-HCO_3 facies indicating the transition zone. Na-Cl is dominant facies in both the seasons of NEM and SWM.

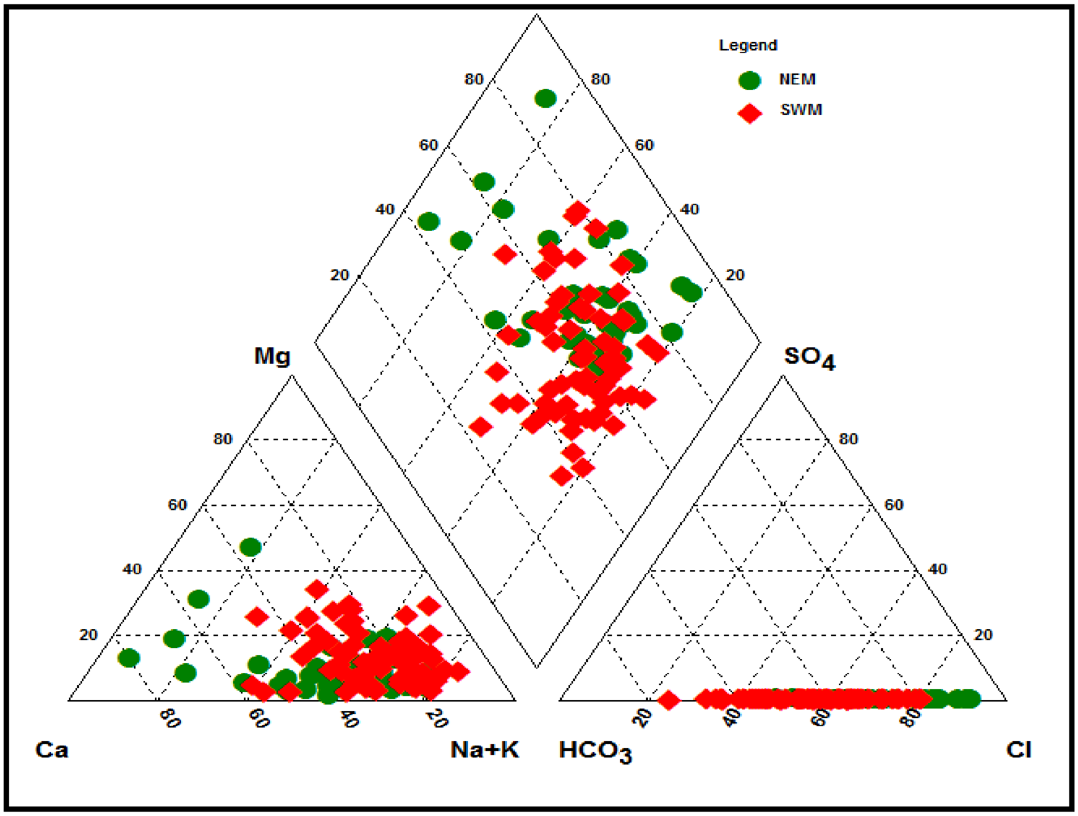

Fig 7. Water types according to Piper diagram.

Distribution of electrical conductivity is shown in (fig 8). The groundwater quality is found to be equivalent to freshwater if the EC values less than 750 µS/cm (Ravichandran et al. 2011 ,Islam et al. 2016).In the study area during NEM and SWM freshwater is about 3% of the sample analyzed as indicated by low EC value <750 µS/cm.. About and 77% and 99% of samples vary between 751 - 2250 µS/cm. and about 17% and 1% are ranges between 2251-3000 µS/cm with respect to different season groundwater is slightly mineralized (Ravichandran et al. 2011) and about 3 % of groundwater Monitoring wells during NEM is more than 3000 µS/cm indicating that the ground water is highly mineralized with a highest value of 3830 µS/cm. There is gradual increase of salinity is observed where as 17% and 3% of water are saline to high saline during NEM is being reduced to 1% in SWM. The drastic higher EC values are noted during NEM.

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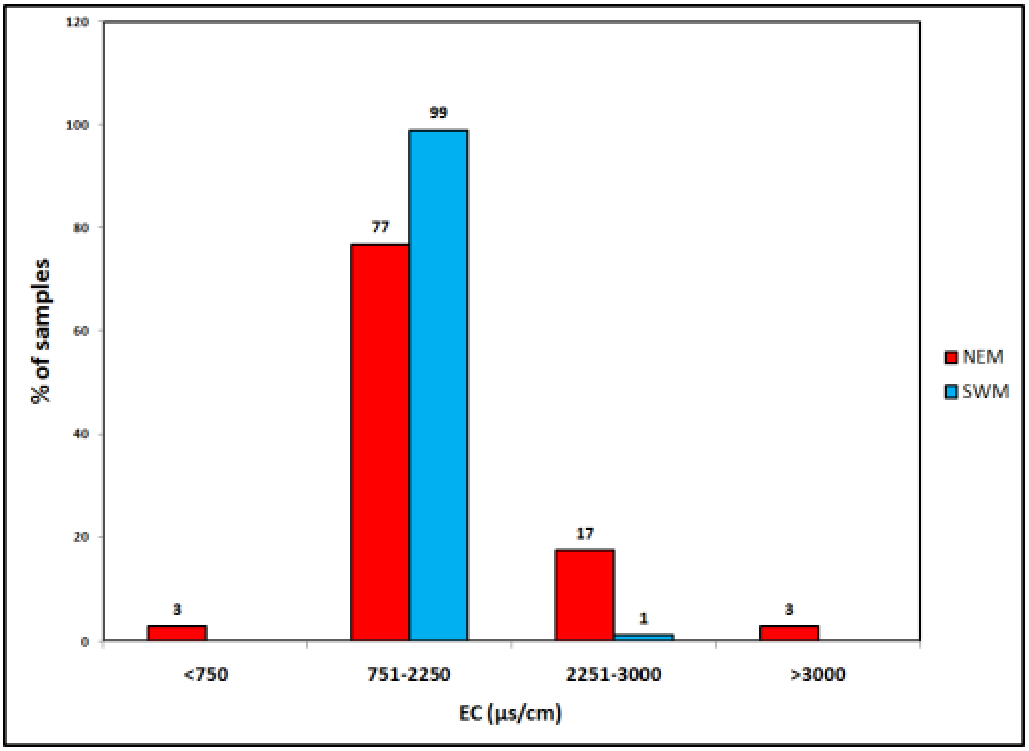

Fig 8. Variation of EC in groundwater with respect to different ranges.

IONIC RATIO APPLICATION FORM:

A hydrochemical graph proposed by (Chadha 1999) has been connected in this region to interpret the hydrochemical forms happening within the study area. The same method was effectively connected by (Karmegam et al. 2010; Vandenbohede et al. 2010) in a coastal aquifer to decide the advancement of two distinctive hydrogeochemical processes. The resultant graph is appeared in (Fig 9). During NEM majority of samples drop in Field 3 (Na– Cl) recommending that the waters appear typical seawater mixing and are generally obliged to the coastal zones. Only few samples are in Field 1 (recharging water). Irrespective of samples fall in Field 2 (reverse ion exchange), Field 4 (Na–HCO_3) waters, which is less prominent in the study area, indicating base ion exchange.During SWM predominance of samples fall in Field 3 (Na–Cl) and 4 (Na–HCO_3). Some of the of samples fall in Field 2 (reverse ion exchange), Field 1 (recharge) waters, which is less prominent during SWM (Fig 9), typical seawater mixing in Field 3 and with less representation in Field 2 and Field 1 indicating the less ion exchange and recharge in NEM and ion exchange during SWM. However, when seawater intrudes into fresh coastal aquifer, CaCl or MgCl type water may also be represented (Appelo and Postma 1999).

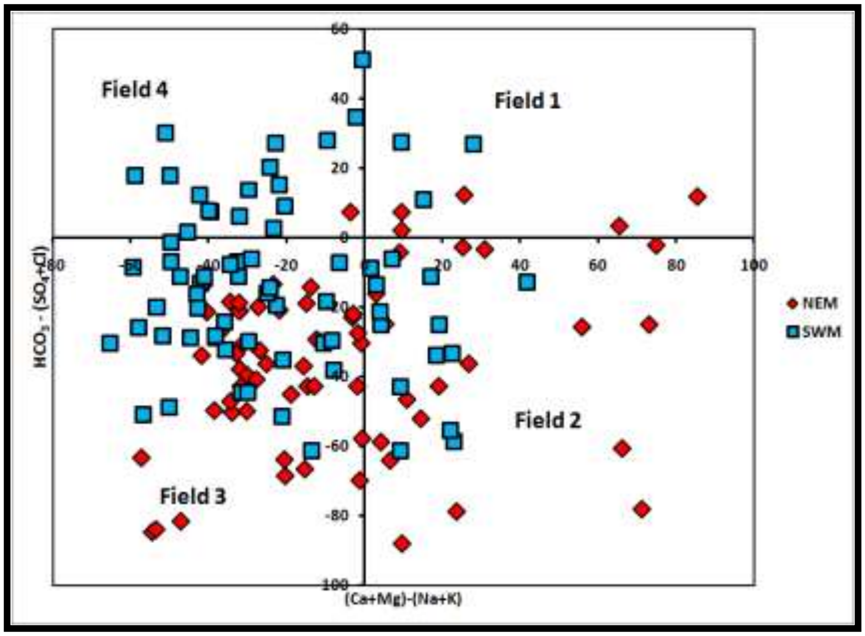

Fig 9:
Geochemical process evaluation plot for groundwater samples (after Chadha et al. 1999)

When saltwater and freshwater mix normally, it's not surprising that Na and Cl levels rise directly (Sanchez-Martos et al.1999). This is shown by the strong link [r = 0.702 (NEM) r=0.482 (SWM)] between the two variables. The effects of seawater getting in have been estimated by looking at the ratio of Na+ to Cl- ions. If the levels of Na/Cl are lower than the standards for seawater (0.88), it means that seawater has gotten in. We can see that there is a link between the molar ratios of Cl and Na/Cl (Sanchez-Martos et al.1999). During NEM, most of the groundwater samples had a ratio that was less than or slightly higher than the ocean ratio (0.88). The lower numbers compared to the saltwater ratio are caused by cation replacement, which happens when seawater enters freshwater groundwater and leaves behind more Ca than Na.

Table 2: Comparative ionic ratio of potential salinization sources with present groundwater compositions

	Sea water intrusion	NEM (%)	SWM (%)
Na/Cl	0.86-1	20.6	10.3
K/Cl	0.05	13.2	17.6
SO_4/Cl	0.019	0.0	0.0
Mg/Ca	>5	0.0	0.0
Ca/(HCO_3+SO_4)	0.35-1	52.9	76.5

Table 2 shows that seawater has certain amounts of ions (Vengosh et al. 2002; Vengosh and Rosenthal 1994). On the other hand, 13% of samples from NEM and 63% of samples from SWM have high ratios of Na/Cl, and 15% of samples from NEM and 46% of samples from SWM have high ratios of Ca/(HCO3 +SO4) (Vengosh et al. 2002). Geochemical properties of seawater and seawater that has been weakened by freshwater have been identified (Metcafe and Eddy 2000). These amounts are more important than one in the study area. This could be because of deep salt upconing or the ion-exchange process (Thilagavathi et al. 2012). The geochemical makeup of these salty waters changes because of the interaction between water and rock. This can happen in three ways: (1) clay minerals reacting with base (Vengosh et al. 1994); (2) clay minerals adsorbing water; and (3) carbonate dissolving and precipitating (Vengosh et al. 1994; Ghabayen et al. 2006). One of the main reasons why coastal aquifers become salty may be the shameful way that home wastewater is treated and moved (Metcafe and Eddy 2000). The chemical makeup of water that has been polluted by wastewater from cities or wastewater that has been cleaned and then reused is very clear. As a whole, sewage has a higher Na/Cl ratio (more than 1) and a higher SO4/Cl ratio (0.09) (Ghabayen et al. 2006). The amounts given are because of how Na–Cl salts are used and the properties of wastewater from homes. In deeper groundwater, K/Cl rates are lower, which shows that human activity has a slightly smaller impact on the water quality. Using the Na/Cl ratio to show that mixing rainwater with saltwater can lead to high salinity in the zone (Table 2) Now that the brief phase is over, the freshwater salt is back to normal.

looks to be the person in charge. K seems to come from human-made sources. This conclusion is supported by the fact that the K/Cl ratios for NEM (13% of the total) and SWM (18%) were found to be quite high, which means that wastewater was absorbed. The Ca/(HCO3+SO4) ratio shows that the ocean entry method is usually to blame (Kumar et al. 2006).

CONCLUSION:

It's hard to explain the hydrochemistry of the marine groundwater in dry and semi-dry areas. Large-scale groundwater pumping in the Pondicherry area, mostly for farming purposes, has caused major ocean damage. Water that is salty and in an underground reservoir. The main toxins are Cl, SO4, and NO3. The main types of water in the study area are Na-Cl and Ca-Mg-Cl (ClHCO3). This study looks into this possible problem. The salinity is slowly rising. During NEM, 17% to 3% of the water was salted to very salty, but in SWM, that number drops to 1%. During NEM, the EC numbers are much higher than usual. When seawater comes in, chemical processes happen that change the hydrochemistry of the groundwater along the coast. The reversed cation exchange process is the most interesting. It shows how the theoretical mixing of seawater and freshwater changes.

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