Assessing the suitability of the Vermpirai Water Supply Wells in Thenmaradchi Aquifer in Jaffna Peninsula, Sri Lanka by Analyzing Seasonal Water Quality and Geochemical Parameters

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Abstract – *Access to safe drinking water is a fundamental human right, and an essential step towards improving living standards. The National Water Supply and Drainage Board, Jaffna is supplying drinking water to around 20,000 people. However seasonal variation of groundwater quality of intake wells is a serious concern. These intake wells are comparably used for extracting more water and they are in active operation during the whole year in the identified aquifers. The main objective of the study is to assess the suitability of the Vermpirai water supply Intake wells in the Thenmaradchi aquifer by analyzing seasonal water quality and geochemical parameters with 2018 data. Water quality data of intake wells from 2013 to 2017 were obtained and the seasonal and periodical variation of quality parameters were analyzed. Seasonal water quality analyses were carried out for wet (April) and dry (August) seasons in 2018 in the intake wells and control wells from the same aquifer to see the variation of geochemical characteristics of the aquifer. All the wells are located in the sodium-calcium chloride sulphate type water, except control well no 03, which showed the mixed type water in both seasons and others were changed to sodium chloride type water in the dry season. The chloride ion concentration of the intake wells was increased prominently in the dry season, it may be due to the continuous extraction. High chloride contamination may be due to the influence of saltwater lagoons. The specific area in the Thenmaradchi Aquifer has sodium chloride type low-quality water, chloride ion, and total hardness were in high concentration and showing high seasonal fluctuation. Geochemical parameters were showing chloride ion influences other than the geological influences; this has shown that the aquifer is vulnerable to saltwater contamination. Hence, the Vermpirai scheme needs additional water sources or alternative water sources to meet the increasing demand and to protect the further deterioration due to continuous pumping.*

Keywords: *Aquifer, Intake well, Seasonal variation, Water quality*

1 INTRODUCTION

Groundwater is considered as the most important natural water resource for human consumption, and it occurs in a large quantity in the rock formation in the earth's crust (Cooray, 1984). Groundwater is saved under the ground surface as a hidden resource, which is more reliable and also less subject to the type of year-round variation compared to surface water. Almost 80% of the rural populations in Sri Lanka rely on groundwater for their domestic needs today because of its excellent natural quality and sustained availability throughout the year.

The composition of groundwater naturally reflects the underlying geology, the residence time in the rock, the previous composition of the groundwater, and in some instances, the flow path. Due to the slower movement of groundwater as compared to that of surface water, the composition of the groundwater shows a negligible variation with time for a given aquifer (Dissanayake, 1987).

The need for clean water as one of the most essential commodities for mankind can never be over-emphasized. The quality and quantity of groundwater monitoring is one of the most important aspects of groundwater resource management and prevention of groundwater pollution. In the case of Jaffna, people mainly depend on groundwater for their drinking, irrigation, and domestic uses. Hence attention has to be paid to protecting and conserving the existing good quality water.

1.1 Background Information

1.1.1 Geology

The Jaffna peninsula is underlain by three formations: the pre-Paleozoic basement rocks, Mannar sandstone, and the Jaffna limestone of the early Miocene age. The pre-Paleozoic basement rocks are described as massive, crystalline, igneous, and metamorphic. They can be found at a depth of 240 m. The basement rocks are overlain by the quartzitic sedimentary deposits, the Mannar sandstone formation of early tertiary up to Miocene age. Groundwater has been mainly confined to the sedimentary Miocene formation in the Jaffna peninsula (Palitha Manchanayake and Madduma Bandara, 1999). Lithologically the limestone is creamy-colored, hard, compact, highly karstic, indistinctly bedded, and partly crystalline. It is massive in places, but some layers are fossiliferous and weathered into a honeycombed mass (Cooray, 1984). The formation is almost flat bedded but may have a slight regional dip to the west, and consequently, it thickens to the west. It has a vertical thickness of at least several hundred feet, and at one drilling site in the southeastern part of the peninsula at Palai was found to be 90 m thick and underlain by a thick sandstone formation overlaying the Precambrian basement.

In the Jaffna peninsula, the occurrence of freshwater is typical of that of any small island with the groundwater lenses floating over the seawater, the thickness and the uniformity of these freshwater lenses would be greatly affected by the cavernous limestone found in the area.

1.2 Problem Statement

The Jaffna district has 16 water supply schemes. More than 20,000 people are estimated to be getting a safe water supply in Jaffna District. Daily production of the scheme is a total of about 52,000 m^3. One of the water supply schemes is Vermpirai for which water sources are Vermpirai wells which are in the Thenmaradchi aquifer. The production of water is currently drawn from two tube wells in Vermpirai. Overall average daily production is 60 m^3/day and around 280 families get water through the pipeline for their day-to-day activities. The Water Supply System is supplying water to the Vempirai, Sarasalai, and Maduvil areas. The water supply scheme was not operated from July 2014 to March 2015 due to the rehabilitation works.

Generally, Groundwater quality becomes crucial during dry periods; there is a tendency for increased concentration of geochemical parameters in groundwater due to less recharge. Due to that quality of the supply water is varies with the seasons and the quality is periodically degrading according to the consumer's complaints.

Also, several water supply schemes were given up due to quality degradation such as Mayakkai (2013), Karaveddy (2015), and in the 1990s Naranthanai, Karainagar, and Punkudutheevu. Vermpirai Intake wells were developed during the internal displacement period to feed the IDP (Internal Displaced People) in 2009, later it has been developed as a water supply scheme to supply to the adjacent people. Due to the high seasonal quality fluctuation and the periodical degradation, NWSDB is facing difficulties to expand the scheme and manage the present demand.

2 MATERIAL AND METHOD

2.1 Location

Mainly four groundwater aquifers are available for water consumption in Jaffna Peninsula; those are varied with the water capacity and quality of the water (Table 1). Those four aquifers are Vadamarachchi-east aquifer, Thenmaradchi aquifer, Chunnakam aquifer, and Kayts aquifer. The Vermpirai water supply scheme belongs to the Thenmaradchi aquifer. Two tube wells are used as a production well to the water supply system out of which one tube well is in use and the other tube well as stand-by for supply.

2.2 Sample collection

Water samples were collected from two production tube wells and other three control tube wells. High-density polyethylene bottles were used to collect the water samples. These bottles were soaked in Hydrochloric acid overnight. Again, bottles were washed thoroughly with distilled water. Further, bottles were rinsed with water to be sampled. Before the collection of water samples, pumping was done for several minutes. Two sets of samples were collected from each location to represent the dry (April) and wet (August) seasons in 2018 to see the variation of geochemical characteristics of the aquifer.

2.3 Method of Chemical Analysis

pH and EC of water samples were measured on-site. All collected samples were kept cool until the analyses were performed. Table 2 shows the parameter analyzed and the method of analysis. All the analysis was carried out according to the APHA (2016).

Table 1 Sample locations

S.No	Sample code	Detail of the sampling point	Latitude	Longitude
1	CHA 1	Intake tube well 01, Vermpirai	9.634442	79.918169
2	CHA 2	Intake tube well 02, Vermpirai	9.687275	80.177775
3	CHA 3	Control tube well 01, Vermpirai	9.784061	80.233609
4	CHA 4	Control tube well 02, Vermpirai	9.688094	80.177760
5	CHA 5	Control tube well 03, Vermpirai	9.688088	80.177773

2.3.1 Data Analysis

Data were analyzed by using stiff and piper geochemical diagrams which were developed by using Aquachem application.

Table 2 Method of Analysis

Parameter	Method of Analysis
Electrical conductivity	APHA 2510 B
pH	APHA 4500- H^+
Chloride	APHA – 4500 Cl^- B
Calcium	APHA, 3500 - Ca B
Magnesium	APHA 3500-Mg B
Carbonate	APHA , 2320 B
Bicarbonate	APHA , 2320 B
Sodium	AAS – 3500 Na B
Potassium	AAS – 3500 K C

AAS – Atomic absorption Spectrometer

3 RESULTS AND DISCUSSION

3.1 General Water Quality Parameters

According to the Table 3, Electrical conductivity, Chloride, Total hardness, Alkalinity, and Nitrite were the problematic parameters in CHA 01 and CHA 02, average values were exceeding the SLS 614:2013 maximum permissible level. Average values of other parameters were lower than the SLS maximum permissible level.

3.1.1 Electrical Conductivity

Fig. 1 shows the fluctuation of electrical conductivity of two tube wells with SLS standard value of 750 µS/cm. Most of the time electrical conductivity values were increasing trend with the period and minor fluctuations with the season. From July 2014 to March 2015 the system was not operated, after that, they started the operation, and from that the water quality degradation was high. CHA 02 was not in operation. It was used as a standby intake well, most of the time the well had stagnated water.

Even though two intakes well are in the same location, the electrical conductivity of tube well 02 was comparably low than that of tube well 01. Tube well 02 is and standby production well and it was not in continuous operation, which may be the reason for low electrical conductivity.

3.1.2 Chloride

According to Fig. 2, chloride ion also is showing a periodical increasing trend with time, concentration showed a sudden increase after April 2015 similar as electrical conductivity, After the rehabilitation, production, and number of consumers increased, which may be the reason for the increase trend and tube well 02 also showed a periodical increasing trend. Tube well 01 average was beyond the maximum permissible limits and the average value of Tube well 02 showed lower concentration than SLS 614:2013 standard.

Table 3 Variation of the water quality parameters for the period of 2012 to 2017

Parameter	CHA 1			CHA 2			SLS 614 2013
	Max	Mini	Avg	Max	Mini	Avg	
EC (µS/cm)	2670	593	1568	1703	624	864	750
Chloride (mg/L)	737	123	410	590	103	200	250
Alkalinity (mg/L)	610	180	332	410	180	251	200
Total hardness (mg/L)	684	160	390	413	118	235	250
Nitrite (mg/L)	0.260	0.000	0.014	0.004	0.000	0.001	0.100
Nitrate (mg/L)	4.0	0.0	0.7	5.0	0.0	1.2	50.0
Fluoride (mg/L)	1.44	0.00	0.21	0.40	0.00	0.09	1.00
Phosphate (mg/L)	1.82	0	0.36	0.95	0	0.35	2.00
Sulphate	422	90	163	285	69	137	200
Iron (mg/L)	1.82	0	0.24	1.25	0	0.13	0.3

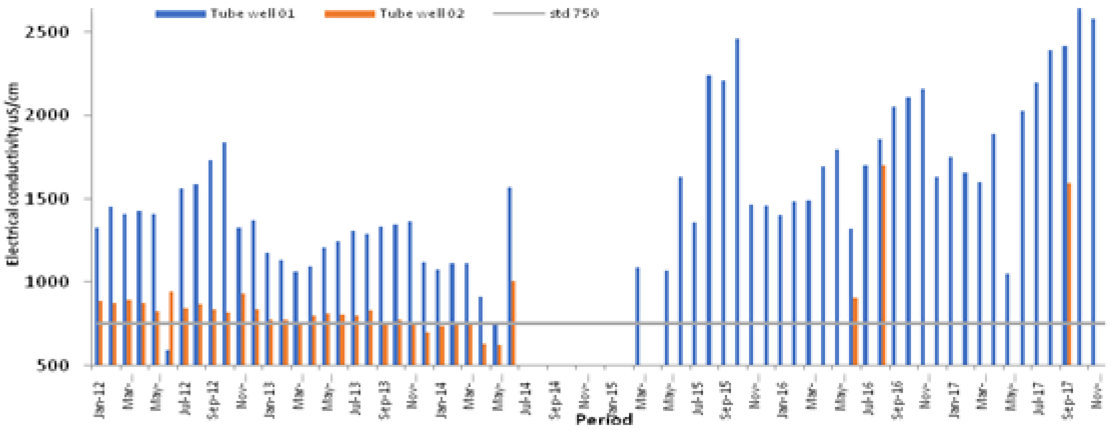

Fig.1. Variation of electrical conductivity in Vermpirai intake wells (CHA 1 & 2)

3.1.3 Total Hardness

The concentration of hardness is very high in these wells, all the period it is showing higher concentration than the maximum permissible level of 250 mg/L (SLS 614:2013) after May 2015. The concentration showing periodical increase also may be due to the dissolution of the rocks with the extraction. Overall average concentration was 376 mg/L in tube well 01 and after 2016 the average was 431 mg/L it is clearly showing the increasing trend in the Water supply scheme. Tube well 02 was not in the continuous operation but that well also showed higher concentrations after 2016.

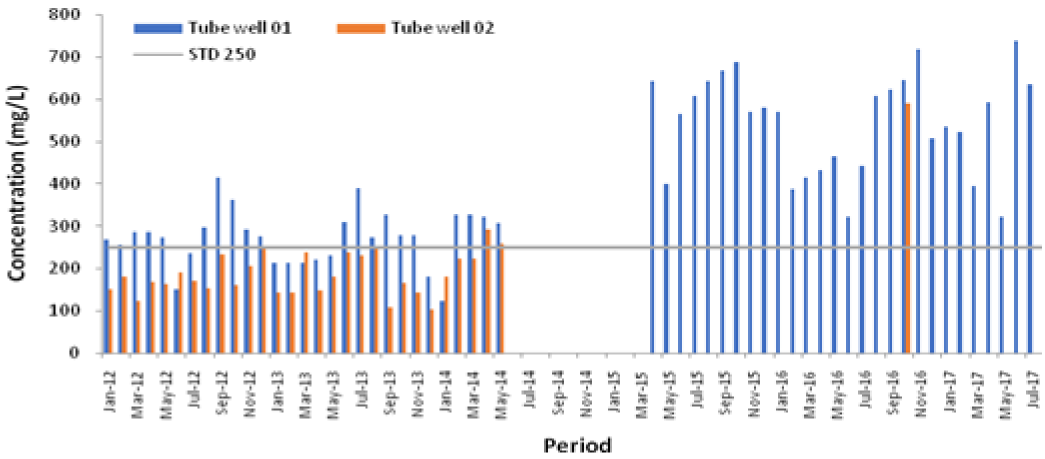

Fig.2. Variation of Chloride ions in Intake wells

3.1.4 Total Alkalinity

The concentration of total alkalinity is very high in these wells, for most of the period it is showing higher concentration than the maximum permissible level of 250 mg/L (SLS 614:2013). The overall average concentration was 332 mg/L in tube well 01 and 251 mg/L in tube well 02 but tube well 02 was not in continuous operation so we are unable to predict the effect of extraction.

The concentration of the minor anions such as phosphate, nitrate, nitrite, and fluoride are below the SLS 614:2013 maximum permissible levels, only in January 2016 the phosphate showed comparably higher concentration, it also may be due to the runoff water contamination or leaching in the rainy season.

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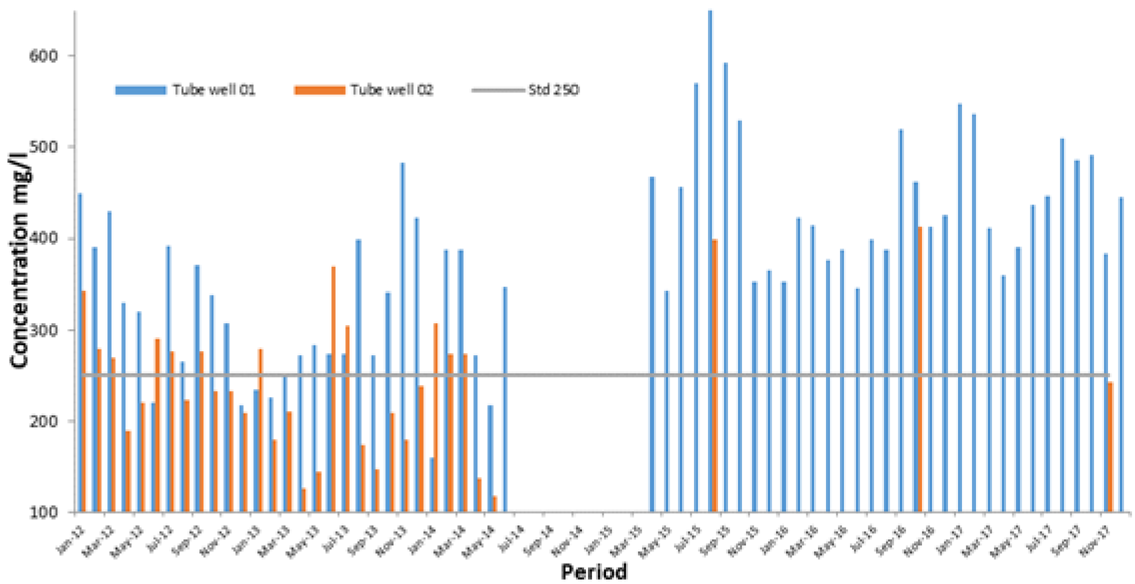


Fig.3. Variation of Total Hardness in Intake Wells

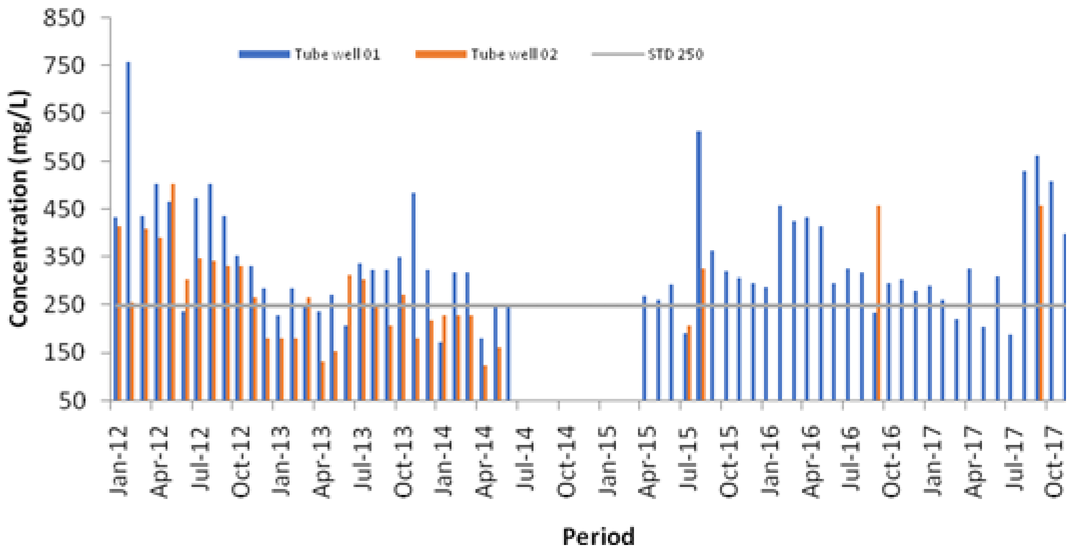


Fig.4. Variation of alkalinity in intake wells

3.2. Hydro Geochemical characteristics

3.2.1 Piper diagram for Vermpirai

According to Fig.s 5 and 6, all the wells are located in the sodium-calcium chloride sulphate type water including control wells in both diamonds, only control well CHA 03 is located in the mixed type of water in both months. Sodium, and calcium Chloride sulphate water was changed with the season and sodium chloride type water, commonly chloride ion influence is increasing in the dry season. There is a possibility of the influence of Vadamarachchi Lagoons' saltwater intrusion with the extraction (Table 4).

The anion triangles also are showing the same characters, intake wells are shifted towards chloride type from April to August 2018.

According to Table 3, more than 1000 µS/cm electrical conductivity contains wells showing high chloride concentration influences, those wells were changed to sodium chloride type water in the dry season. CHA 3 not showing significant changes with the season.

Table 4 Water type changes with the season in the Thenmaradchi aquifer in the months of April and August 2018

Well	EC (µS/cm)	Apr-18	EC (µS/cm)	Aug-18
CHA 1	1070	Na-Ca-Cl-SO4	1440	Na-Cl
CHA 2	2070	Na-Ca-Cl-SO4	2890	Na-Cl
CHA 3	714	Na-Ca-Cl-HCO3	607	Na-Ca-Cl-HCO3
CHA 4	2250	Na-Ca-Cl	3100	Na-Ca-Cl
CHA 5	4090	Na-Ca-Cl	5550	Na-Cl

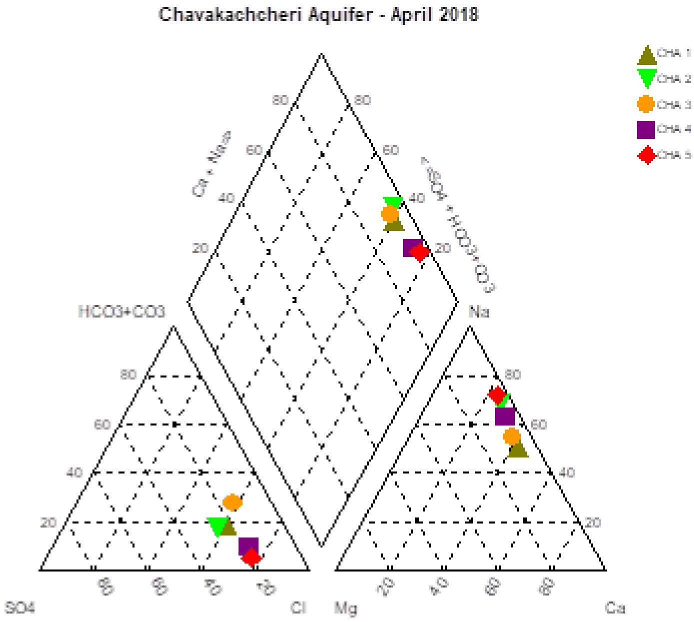


Fig. 5. Piper diagram for Vermpirai, the month of April 2018

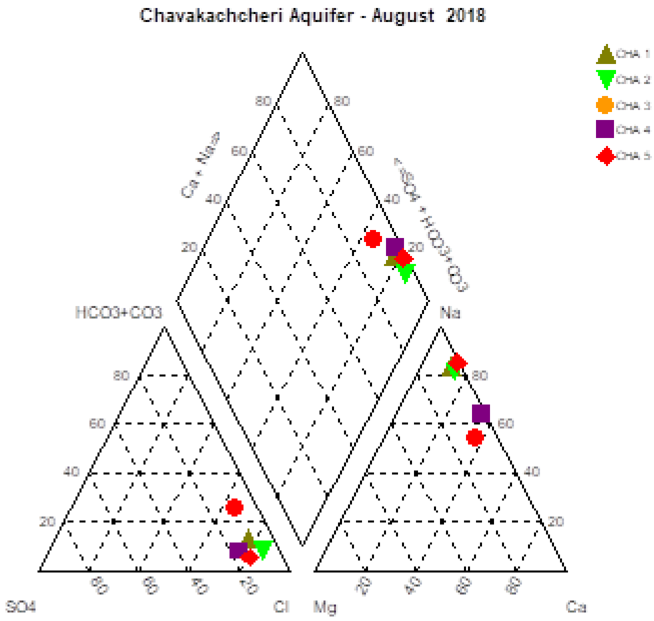


Fig. 6: Piper diagram for Vermpirai, the month of August 2018

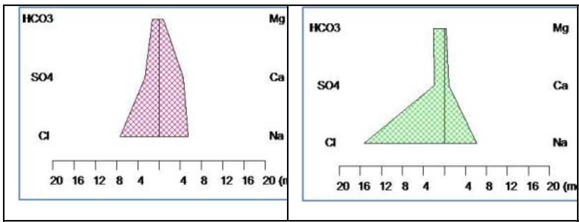
3.2.2 Stiff diagram

Stiff diagrams are commonly used for displaying major-ion compositions of groundwater. The shape of the diagram indicates the relative proportion of different ions and the size indicates total concentrations. Developed stiff diagrams are shown in Fig. 7 and the geochemical domination pattern in different seasons is summarized in Table 5.

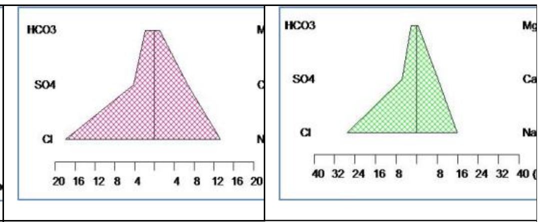
The intake wells only showed a prominent chloride ion increase in the dry season, it may be due to saltwater intrusion caused by the continuous extraction. Two Control tube wells did not show a similar pattern and did not show any significant pattern changes with the season. All the wells are showing an increasing trend in the total ions.

3.2.3 Gibbs diagram

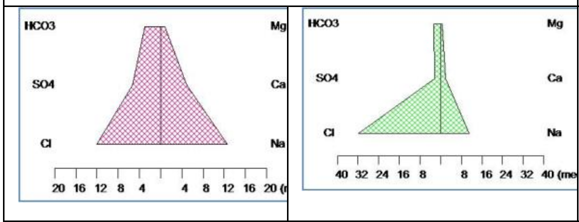
The Gibbs diagram is widely used to establish the relationship between water composition and aquifer lithological characteristics (Gibbs 1970). According to Fig. 08, Sodium ion domination is increasing in all the wells, and all are moving toward the Evaporation zone except CHA03. According to Fig. 09, Chloride ion domination is increasing in all the wells, and no movements was observed from zone to zone, rock domination is high in both season.



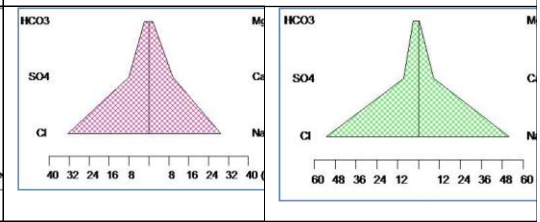
Stiff diagram for CHA 1 , month of April and August



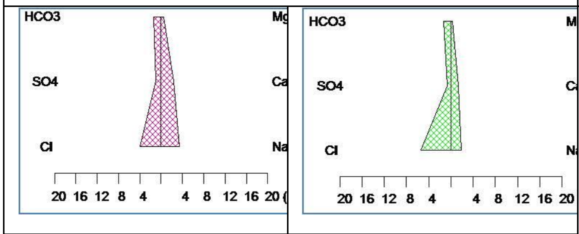
Stiff diagram for CHA 4 , month of April and August



Stiff diagram for CHA 2 , month of April and August



Stiff diagram for CHA 5 , month of April and August



Stiff diagram for CHA 3 , month of April and August

Fig. 7: Stiff Diagram for CHA 01,02,03,04& 05, Months of April and August 2018

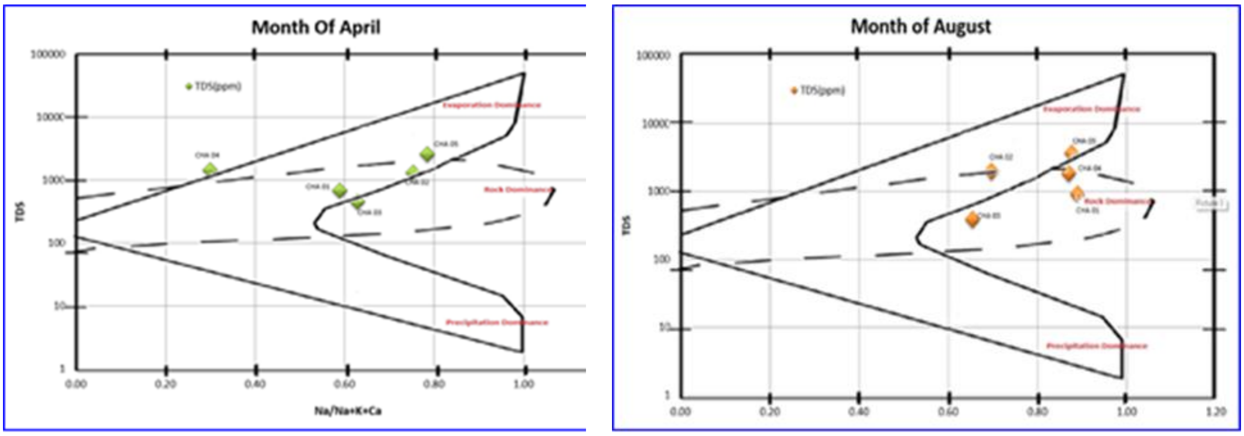


Fig.8. Gibbs diagram of (Na/Na+K+Ca) for CHA 01, 02, 03, 04 & 05, Month of April and August

Table 5 Geochemical domination pattern with dry and wet seasons in 2018

Well No	Character
CHA 01	Calcium ion was the dominant species in cations in the wet season, the sodium ion domination is increasing in the draught, and chloride ion was the dominant anion species and showed an increasing trend with the dry season
CHA 02	Sodium and chloride ions are dominant species in the well and chloride ion is showing a significant increasing trend with the dry season
CHA 03	No prominent domination and no significant seasonal fluctuation in the geochemical parameters. Slightly increasing chloride ions
CHA 04	Sodium and chloride ions are dominant, with no significant ion domination with the season, and the total ion concentration is creasing in the dry season.
CHA 05	Well is showing sodium chloride-type water and no significant seasonal ion fluctuation, only showing the increasing trend in the ion concentration.

4 CONCLUSION

In Vermpirai WSS, Chloride ions showed a periodical increasing trend with time: and it decreased in the wet season and increased during the dry season. There was a sudden increase in chloride concentration after May 2015 similar to that of electrical conductivity. It might be due to heavy extraction. The Chloride concentration increased significantly in all these intakes, hence chloride ion was the major contributory factor for this quality deterioration. The concentration of total hardness and total alkalinity were very high and exceeding the maximum permissible level of SLS 614:2013, it may be due to the possible dissolution of the rocks during the extraction. Minor anions such as Nitrate, Phosphate, Fluoride, and Iron were always lower than SLS 614:2013 maximum permissible level and not shown seasonal fluctuation. Vermpirai intakes showed high deterioration than the control wells.

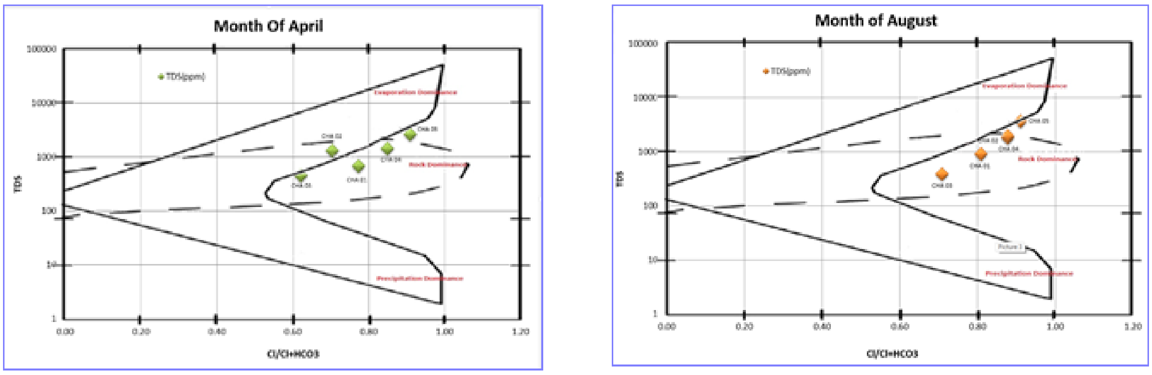


Fig. 9: Gibbs diagram of (Cl/Cl+HCO3) for CHA 01, 02, 03, 04 & 05, Month of April and August

According to the Piper diagram, in Thenmaradchi Aquifer all the tested wells were observed as the Sodium Calcium Chloride Sulphate type water including control wells. Only one control well was found to be with the mixed type of water in both seasons. These wells have changed with the season to Sodium Chloride type water. This was confirmed with the anion triangles.

According to Stiff diagrams of the Thenmaradchi Aquifer, only intake wells showed a prominent chloride increase in the dry season. Both control tube wells showed different water quality characteristics, but they did not show any significant fluctuation with season.

According to the Gibbs diagram, sodium and chloride domination is increasing in all the wells, and rock domination also was high in both seasons. Chloride ion was increased prominently in the scheme, it may be due to the seawater intrusion.

Vermpirai Intakes have comparably low-quality water, those showed higher concentrations of chloride and total hardness. Geochemical parameters profiled with high sodium and chloride ions influences other than the geological influences such as calcium and bicarbonate. Based on this, it can be concluded that the Vermpirai WSS aquifer is vulnerable to saltwater contamination. Therefore, additional water sources need to be identified to meet the increasing consumption and demand. Further, if the same wells are used for a long time, it may affect the entire aquifer. Therefore, it is advisable to look for additional sustainable water sources or alternative water sources in these areas.

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