Characterization and seasonal variation of intake wells for drinking water at Vadamarachchi Aquifer of Jaffna District in Sri Lanka

Saravanan Suntharalingam
National Water Supply and Drainage Board

Christina Shanthi De Silva
The Open University of Sri Lanka

(Mrs.) Thushyanthy Mikunthan
University of Jaffna

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S. Saravanan[1], C. S. De Silva [2*], T. Mihunthan[3]

[1]National Water Supply and Drainage Board, Vavuniya
[2]Department of Agricultural and Plantation Engineering, The Open University of Sri Lanka, Nawala, Nugegoda, Sri Lanka.
[3]Department of Agricultural Engineering, University of Jaffna

*Corresponding Author: email: csdes@ou.ac.lk, Tele: +94112881323

Abstract: *Jaffna peninsula is depending on groundwater for their entire water requirement. Seasonal variation of groundwater quality is a matter of serious concern for Jaffna. Groundwater quality becomes crucial during dry periods. There is a tendency for increased concentration of geo chemical parameters in groundwater. The intake wells, which are used for water supply activities are comparably used for extracting more water during the whole year in the identified aquifers. They can easily respond to the seasonal impacts and over extraction than domestic wells.This paper discusses the characteristics and suitability of the water supply in the identified aquifers by analyzing the seasonal water quality and geochemical parameters. Secondary Water quality data of intake wells from 2013 to 2017 and the seasonal and periodical variation of geochemical parameters intake wells and control wells of the aquifer water were analyzed. All intakes are showing periodical degradation due to the seasonal impacts and increased consumption rate. Comparably the control wells are showing less quality variation with the season. Prominently chloride ion is increasing in the intake wells; it may be due to the influence of sea water. The aquifers are adjacent to salty water area, in these sand dune aquifers and there is a high possibility of the salt water intrusion. Geochemical parameters have shown sea water influences other than the geological influences. Therefore, all the aquifers are vulnerable to sea water contamination. Point Pedro scheme needs additional water sources to meet the increasing consumption*.

Keywords: *Ground water, Geochemistry, Intake well, seasonal variation, Water quality*

1. INTRODUCTION

Water is the most important resource for humans. It forms 50 to 60% of body weight and play an active role in all the vital processes of our body. The global water consumption is doubling every 20 years and is more than twice the rate of population increase (Clothier, 2007). By 2030, more than half the world population will face a shortage of water (Winblad and Hebert, 2004).Approximately 25% of the world's population has no access to clean and safe drinking water. Even though freshwater is available in most parts of the world, many of these water sources contaminated by natural means or through human activity. With the population boom and industry expansion, the demand for potable water is ever increasing, and freshwater supplies are being contaminated and scarce (Wimalawansa, 2013).

Groundwater is one of Sri Lanka's most precious natural resources. The estimated groundwater potential of Sri Lanka is 780,000-hectare meters per annum (Panabokke and Perera, 2005).A large number of people depends on it for their sustenance with no expense to the State. When compared with surface water, groundwater is a hidden resource, which is more reliable and also less subject to the type of year-round variation as in the case with surface streams and rivers. 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. Main towns in Jaffna, Batticaloa, Mannar, Puttalam, and Vavuniya depend almost 90 % on the groundwater supply (Panabokke, 2007).

There are two types of groundwater, one is renewable source which is associated with near surface hydrological processes and will be affected by climate change and another one is non-renewable which is deposited long time ago in deep sediments and less susceptible to climate change (Mawilmada *et al*, 2010). 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 ground water shows a negligible variation with time for a given aquifer (Dissanayake, 1985).

1.1. Geology in Jaffna Peninsula

Jaffna peninsula is underlain by three formations: the pre-Paleozoic basement rocks, Mannar sandstone and the Jaffna limestone. 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 rock is overlain by the quarzitic sedimentary deposits, the Mannar sandstone formation of early tertiary up to Miocene age.

The Jaffna limestone is the main aquifer of the Peninsula, the entire groundwater is generated almost entirely from percolated rainfall and it forms a fresh water lenses beneath the Peninsula (Figure 1). It has been found, that the fresh water lenses do not extend below the base of the limestone. Among the different types of aquifers in Sri Lanka, the Karst limestone aquifer is present in Jaffna peninsula, regarded as the richest sources of ground water (Panabokke and Perera, 2005).

Surface water and groundwater are the main water resources of Sri Lanka (Cooray, 1984). 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 purposes. Hence the attention has to be paid to protect and conserve the existing good quality water. Groundwater has been mainly confined to the sedimentary Miocene formation in the Jaffna Peninsula and the North West area in Sri Lanka(Panabokke and Perera, 2005)

1.2 Hydro geochemistry

Hydro geochemistry is helping to determining the time and source of groundwater recharge, estimating how long water has been in an aquifer, identifying mineral makeup of aquifer materials, examining how water from different sources mix and interact and evaluating what types of (bio)geochemical processes have occurred during the water's journey through the system.The hydro chemical study reveals the quality of water and its suitability for drinking, agriculture and industrial purposes. Presence of excessive quantities of salts in groundwater is one of the major constrains in well farming in Jaffna Peninsula. Irrigation with poor quality waters may bring undesirable elements to the soil in excessive quantities affecting its fertility. Research studies have shownthat the bicarbonate hazard as major hazard which is due to the influence of carbonate rock dissolution in Jaffna peninsula (Nishanthiny*et al*,2010).

1.3 Groundwater Resources in Jaffna Peninsula

In Jaffna mainly four groundwater aquifers are available for water consumption depends on the water capacity and quality of the water. Those four aquifers are Vadamarachchi-east aquifer, Chavakachcheri aquifers, Chunnakamaquifers and Kayts aquifers. Of these four aquifers Chunnakam aquifer contains the highest capacity of water. In Jaffna Peninsula, the occurrence of the fresh water is typical of that of any small island with the groundwater lenses (Figure 2) floating over the sea water, the thickness and the uniformity of these freshwater lenses would be greatly affected by the cavernous limestone found in the area (Figure 3). Recent information on the number of wells existing in the Jaffna Peninsula is unavailable. About 100,000 to 84,000 shallow wells with depths ranging from 5 m to 10 m would have been used to draw water for various purposes (Nagarajah*et al*., 1998). Nagarajah*et al* (1998) also reported that about 100,000 wells were in use to extract water out of which 20% of these wells are farm wells. For the agriculture purposes 25,256agro wells, 2,433 ditches, 1,084 ponds are used in Jaffna in 2012 (By the estimate of Department of Agrarian development, Jaffna).

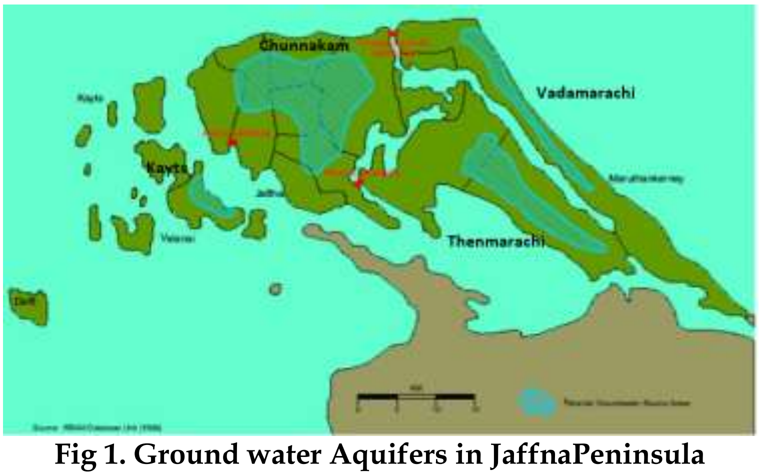


Fig 1. Ground water Aquifers in JaffnaPeninsula

(Source: Market Town water supply 1985 and Jaffna Feasibility Report, 2006-NWS&DB)

The Jaffna peninsula is underlain by Jaffna limestone of early Miocene age. The limestone is typically a compact, hard, partly crystalline rock. It is massive in places but some layers are fossiliferous and weathered into a honeycombed mass (Coorey, 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 the vertical thickness of at least several hundred feet, and at one drilling site in the southeastern part of the peninsula at Palai it was found to be (270 ft) 90 m thick and underlain by a thick sandstone formation overlaying the Precambrian basement.

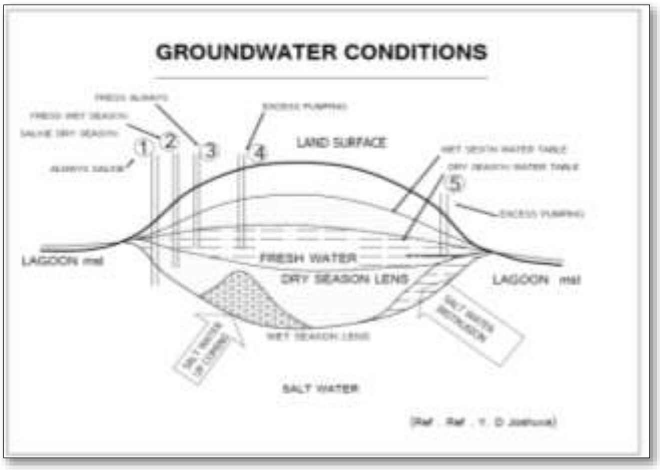


Fig. 2: Floating pattern of fresh water lens in Jaffna (Source: Joshuva, 2013)

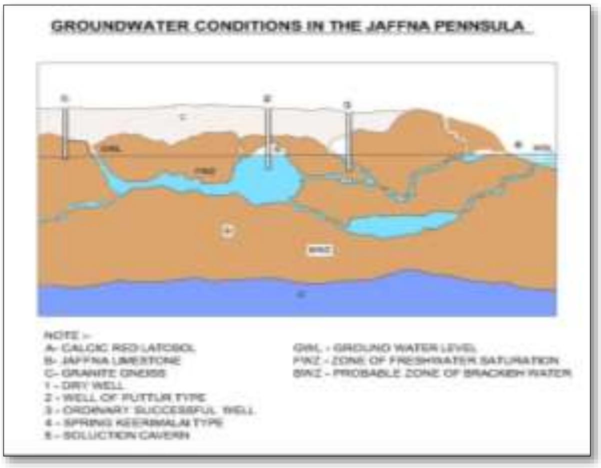


Fig. 3: Groundwater condition in Jaffna peninsula (Srimanne, 1952)

1.4 Water Quality Variation

The qualities of groundwater resources vary naturally and widely depending on climate, season, and geology of bedrock as well as anthropogenic activities. In addition to the natural sources of constituents acquired by water during its interaction with atmosphere and rocks, various human activities such as industrial, sewage and domestic waste disposal, fertilizers, pesticides etc. also contribute chemical constituents to water. Therefore, a regular check of its chemical quality is required for assessing its suitability for different purposes and for quantitatively monitoring any future change. Over pumping of aquifers, discharge of toxic chemicals and contamination of water bodies with substance that promote algae growth are major cause for water quality degradation and also the pollution of the groundwater happens mostly due to percolation of pluvial water and the infiltration of contaminants through the soil under waste disposal site (Humbarde *et al*., 2014).

The environmental impact of human activity on the groundwater is considered as one of the major hazard in the modern days. Rapid Urbanization and increased agricultural activities has resulted in the degradation of the water quality. Unused fertilizers, pesticides, effluents discharged from industries and sewage water are the main contaminants of the groundwater. The chemical budget of major ions and heavy metals are important in determining the quality of groundwater (Fares Howari, 2005).

TDS values are considered important in determining the usage of water and groundwater with high TDS values are not suitable for both irrigation and drinking purposes (Ayers, 1985).Study of chemical budget of the major ions gains importance since it explains the origin of the ions in groundwater and the level of the contamination by natural as well as anthropogenic sources (Woo *et al.,* 2000).

The well water columns also showing quality variation due to the density effects, during the wet season the water quality parameters were nearly same at bottom and the surface of the well water but during the dry season those parameters show significant variation between the bottom and surface of the well water. Bottom quality values were higher than the surface values (Saravanan*et al*., 2014).The annual recharge of groundwater was 0.57 MCM from April 2007 to March 2008 and annual average withdrawal was 0.66 MCM resulting in a deficiency of 0.09 MCM in the water balance leading to water storage or depletion of water and over exploitation of the groundwater aquifer. Therefore, it is imperative to introduce a groundwater regulatory framework to control the deterioration of available groundwater resources in Jaffna peninsula (Thushyanthy and De Silva, 2012).

1.5 CLIMATE

The climate of the Jaffna peninsula is determined by the monsoon that forms a distinct wet and dry season. The mean annual precipitation of Jaffna peninsula is 1200 mm with a mean variation of 30 mm. The mean annual temperature is 27.6^{o}C (Statistical Hand book, Jaffna 2018).The lowest average monthly rainfall of 14.8 mm occurs in June and the highest average monthly rainfall of 363.2 mm in November. There is a pronounced wet season lasting from October to December. Evaporation exceeds rainfall in the dry season months from February to September by a considerable margin with the largest deficits occurring in June and July with 117 mm and 114 mm respectively. The average yearly evaporation of the Peninsula is 1234 mm (Punthakey and Gamage,2006)

1.6 POINT PEDRO WATER SUPPLY SCHEME

The Point Pedro water supply scheme (WSS) of Vadamarachchi aquifer was constructed in 2012 with the assistance of Asian Development Bank, and operation commenced from end of 2014. All the intake wells of the water supply scheme were located in the Vadamarachchi sand dune aquifer, and around 1.2 to 1.4 Km away from the seashore. All the intake wells were connected with two 150 m lateral pipes in north south direction to increase the yield capacity of the wells. According to the Figure 4, number of water supply connections increased by 2.66 times and consumption also increased by 4.1 times within this period.

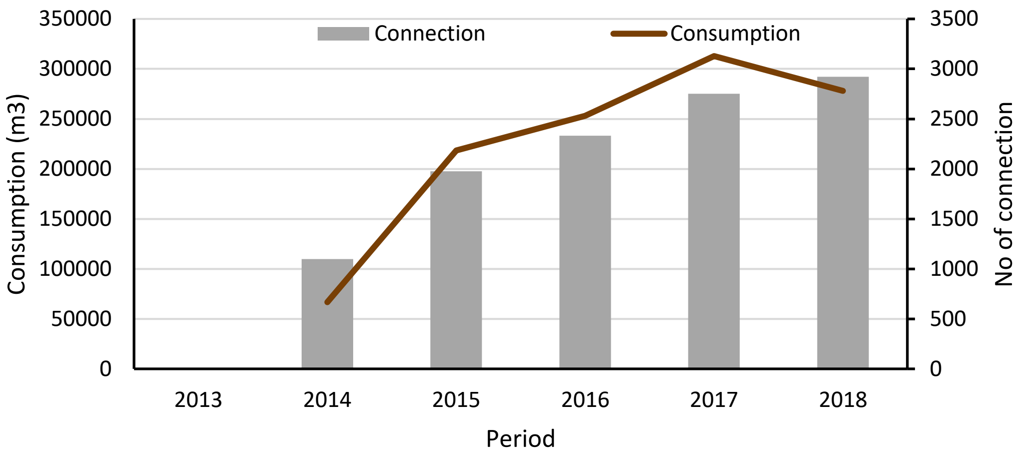


Fig. 4: Consumption and number of connections of Point Pedro WSS

1.7 Justification for the Study

The National Water Supply and Drainage Board, Jaffna is supplying drinking water to the identified area. There are 16 water supply schemes running at present under the NWS&DB in Jaffna Region. Around 20,000 people are estimated to be getting safe water supply in the Jaffna District, it is less than 4% of the total population of the Jaffna Peninsula. The daily production of the schemes is about 52,000 m^3.

Jaffna peninsula is depending with groundwater for their entire water requirement. Seasonal variation of groundwater quality is a matter of serious concern for Jaffna. Groundwater quality becomes crucial during dry periods. There is a tendency for increased concentration of geo-chemical parameters in ground water. The intake wells, used for water supply activities are comparably extracting more water and they are in active operation in the whole year in the identified aquifers. They can easily respond the seasonal impacts and the over extraction than domestic wells. Long term secondary data and the geochemical analysis in the two seasons may help to identify the aquifer behavior and suitability of the intakes for a long run. Therefore this research project is designed to study the characteristics and suitability of the water supply in the Vadamarachchi aquifers with the analysis of seasonal water quality data and geochemical parameters to recommend suitable measures.

2. METHODOLOGY

2.1 Location

The Jaffna peninsula is situated at a longitude of 79^0 45′ - 80^0 20′and east latitude of 9^0 30′- 9^0 50′. It is in the extreme north of dry zone of Sri Lanka and has been surrounded by the sea on its western, northern and eastern sides and by the Jaffna lagoon in the south. The topography is low and flat, the highest elevation is only +10 m from MSL. The peninsula is split in to three parts by lagoons which are connected to the sea. The Elephant pass Lagoon separates the peninsula from the mainland, the Vadamarachchi Lagoon separates the peninsula in western and eastern part and the Upparu Lagoon separates the northern from the western and eastern parts.

2.2 Secondary Data Collection

Water quality data of the production well were collected from Regional Laboratory of National Water Supply and Drainage Board for past five years from 2014 to 2017 as secondary data and analyzed to see the seasonal and periodical variation of geochemical parameters.

2.3 Primary Analysis

Also, seasonal water quality analyses were carried out for wet and dry seasons in the same wells and adjacent wells from the same aquifer to see the variation of geochemical characteristics of the aquifer.

2.4 Sample collection and Analysis

Water samples were collected fromfour production wells and six domestic wells in Vallipuram sandy aquifer. Six domestic wells were selected as control points but proper spatial sampling points were not maintained due to the unavailability of the wells.
Samples were collected in the around 10 cm below the surface and 20 cm above from the bottom of the dug wells with help of specific samplers and samples were collected by pumping from the tube wells (Table 1).

Table 1:Sampling location of Point Pedro aquifer with its sample code

S/No	Sample Location *Point Pedro Aquifer*	Sample point	Sample Code
1	Vallipuram Intake Well 01	Top	PP 01
2		Bottom	PP 02
3	Vallipuram Intake Well 02	Top	PP 03
4		Bottom	PP 04
5	Vallipuram Intake Well 03	Top	PP 05
6		Bottom	PP 06
7	Vallipuram Intake Well 04	Top	PP 07
8		Bottom	PP 08
9	Vallipuram Control well 01	Top	PP 09
10		Bottom	PP 10
11	Vallipuram Control well 02	Top	PP 11
12		Bottom	PP 12
13	Vallipuram Control well 03	Top	PP 13
14		Bottom	PP 14
15	Vallipuram Control well 04	Top	PP 15
16		Bottom	PP 16
17	Vallipuram Control well 05	Top	PP 17
18		Bottom	PP 18
19	Vallipuram Control well 06	Top	PP 19
20		Bottom	PP 20

In total 20 water samples from 10 locations were collected for the analysis. Two sets of water samples were collected from each location in April and September to represent the different wet and dry seasons.

Geochemical parameters were analyzed for 50 samples from each set with the triplicate. Table 3 shows the parameter analyzed and method of analysis. All the analysis were carried out according to the 21st edition, Standard method of water and waste water analysis, American Public Health Association's publication

Table 2: Methodology used for Analysis

S.No	Parameter	Method of Analysis
1	Electrical conductivity	APHA 2510 B
2	pH	APHA 4500- H^+
3	Chloride	APHA – 4500 Cl^- B
4	Calcium	APHA, 3500 - Ca B
5	Magnesium	APHA 3500-Mg B
6	Carbonate	APHA , 2320 B
7	Bicarbonate	APHA , 2320 B
8	Sodium	AAS – 3500 Na B
9	Potassium	AAS – 3500 K C

3. RESULTS AND DISCUSSION

3.1 Rainfall

According to the Figure 5, Jaffna was receiving considerable amount of rainfall from October to February (*Maha* Season) and in 2013 and 2016 the annual average rainfall was comparably less than the average (1011mm and 1033mm) of annual rainfall of Jaffna.

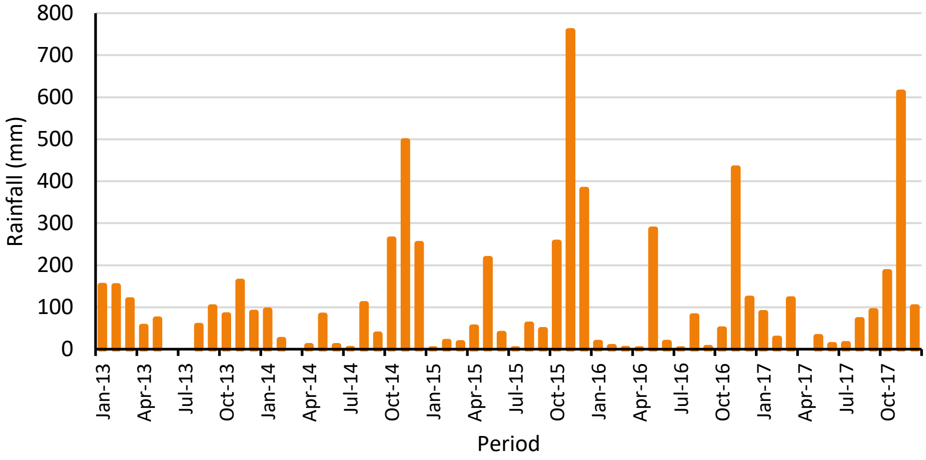


Fig. 5: Rainfall variation in Jaffna peninsula from 2013 to 2017

3.2 Seasonal variation of the general water quality parameters

Average water quality parameter values of the top and bottom of the wells were used to interpret the Vallipuram intake water quality variation.

3.2.1. Electrical Conductivity

Figure 6 shows, the fluctuation of the electrical conductivity of the four intake wells. Electrical conductivity of all intake wells was fluctuating highly with the season. Annually the lowest values were obtained in December to January and highest values in September to October period because these are the dry and wet period in Jaffna respectively.

Not only the season but also the anthropogenic activity also influencing the quality verification, Electrical conductivity values were increased in the well 02 and 04 immediately after the commencement of pumping, because these two wells were located closer to the sea than the other two wells (well no 1 and 3). It may be due to the salt water intrusion.Well 1 showed less fluctuation than other wells and showed slow periodical degradation.During June 2015 to October 2015 the wells 02, 03 and 04 showed rapid increase in EC than other years, it may due to uncontrolled extraction of the water from the wells. After April 2016, all the intake wells electrical conductivity was higher than SLS 614:2013 standard of 750 µS/cm.

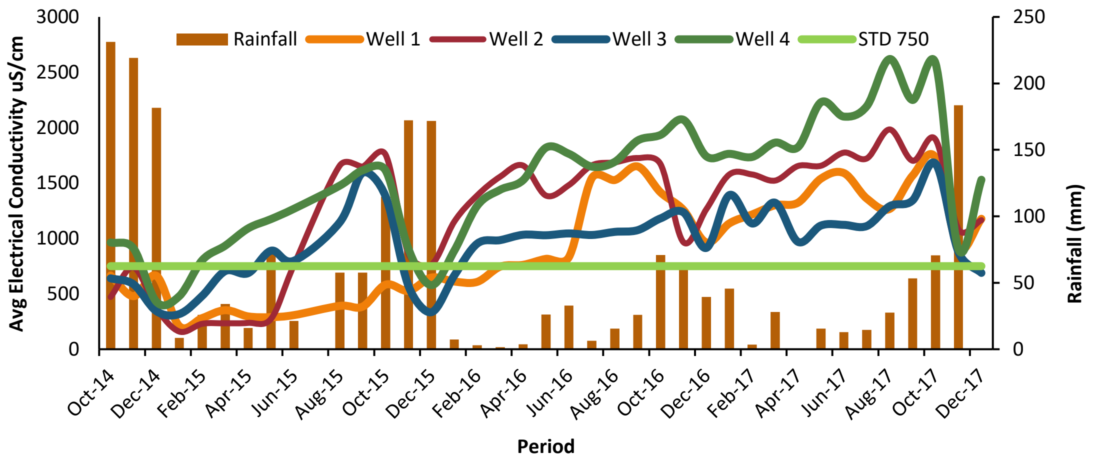


Fig. 6: Electrical conductivity Variation in Vallipuram Intake wells from 2014 to 2017

3.3.2 Chloride Concentration

Figures 7 show that the Chloride concentration of all the wells was fluctuating highly with the season. The lowest values were observed in November to January during wet season may be due the dilution effect. The highest values were observed in September and October 2014 to 2017 towards the end of dry period as electrical conductivity.Chloride concentration of the well 03 and 04 are showing the rapid increase than well 01 and 02. During June 2015 to October 2015 the wells 02, 03 and 04 showed rapid increase than other years, it may be due to uncontrolled extraction of the water from the wells. Well no 01 showed smooth pattern and low concentration below the standard of 250 mg/l till March 2016, it may due to the no operation or minimum pumping from the particular well. The high concentration of chloride indicates the saltwater intrusion and contribution of irrigation return flow (Jeevanandam*et al*., 2007). Over abstraction of groundwater leads the up coning of the salt/freshwater interface and saline intrusion (Rajasooriyar, 2002).

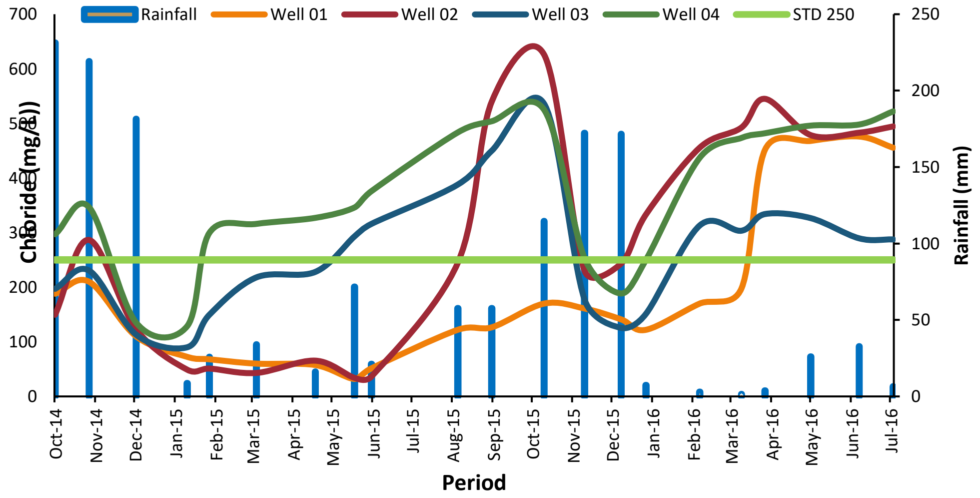


Fig. 7: **Chloride Variation in Valliupuram Intake wells from 2014 to 2017**

3.3.3 Total hardness (mg/l)

Figure 8 shows that the total hardness of all the wells also was highly fluctuating with the rainfall. All the wells were showing lowest values in December - January due to dilution by the annual rainfall and highest values in September October during dry period as electrical conductivity. Total Hardness concentration of the well no 02 and 04 was shown the high periodical increase than in wells no 01 and 03. Before June 2015 these wells showed hardness concentration less than SLS 614 standard (250mg/l), after the June 2015 it increased more than the SLS limits in well 02, 03 and 04. According to the NWSDB pumping records,till 2015 the well no 01 was not used or under minimum operation hours. After 2015 December it exceeded the limits because of extraction. This clearly showed that theextraction is causing quality degradation.

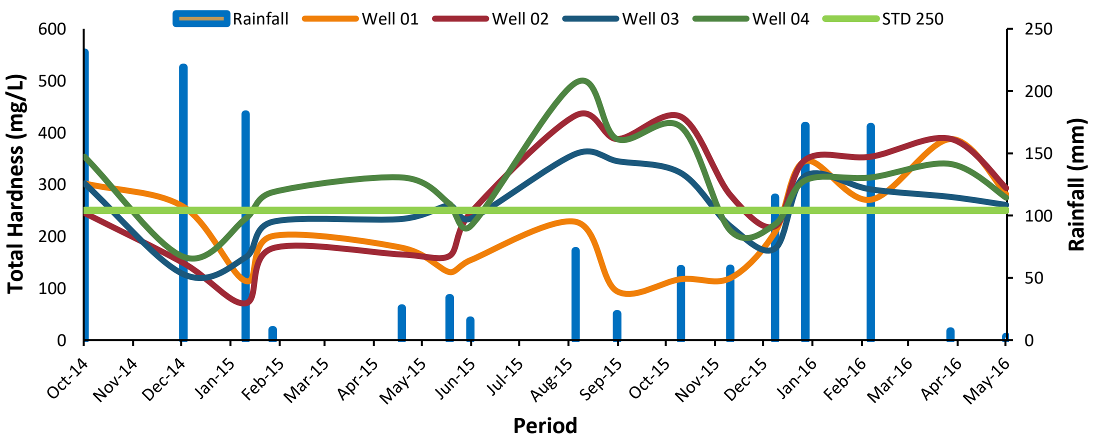


Fig.8 : Total Hardness Variation in Vallipuram Intake wellsfrom 2014 to 2017

3.3.4. Sulphate

Figure 9 shows that the Sulphatesconcentration varies with rainfall as similarin other parameters, but the variation was within the maximum permissible level of the SLS 614 (200 mg/L). Well 01 showed low concentration of Sulphates in June 2015 to September 2015 and other wells showed comparably higher concentration in the same period in 2015. This is due to water stagnation in the well no1 due to the non-pumping from the well during that period.

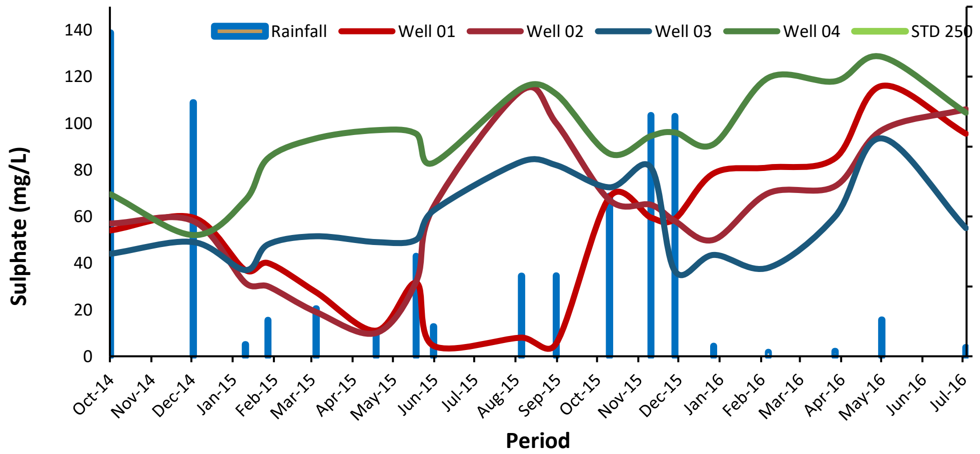


Fig. 9: Sulphates concentration in Vallipuram Intake wells form 2014 to 2017

3.3.5. Total alkalinity

All the wells were showing increasing trend of alkalinity (Figure 10). Seasonal variation pattern of total alkalinity is almost same like other geochemical parameters. After March 2016, the alkalinity was significantly in increasing trend, it may be due to more extraction than in the previous years and exceeding the SLS 614:2013 standard 250 mg/L. Mostly alkalinity is coming from bicarbonate rocks, so it may be dissolution of rocks in the particular aquifer due to the continuous pumping of these wells.

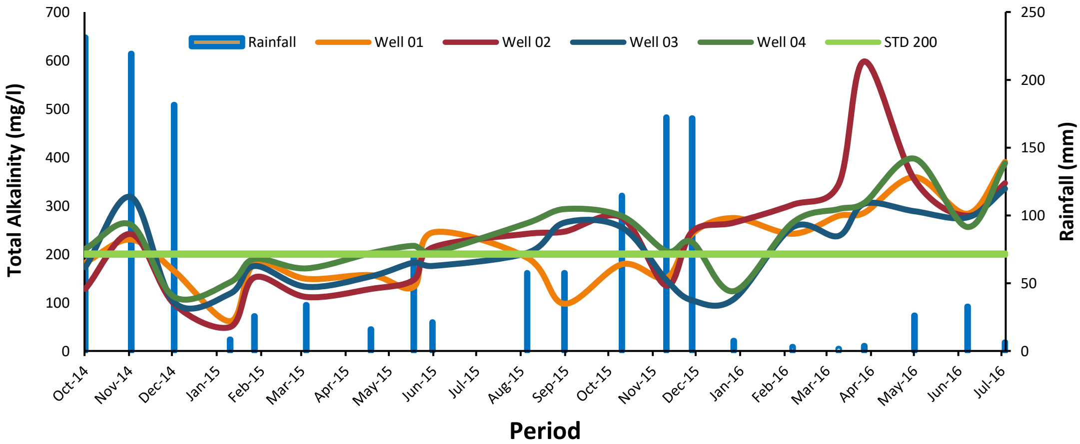


Fig.10: Alkalinity Variation in Vallipuram Intake wells from 2014 to 2017

3.3.6. Phosphate, Nitrate and Fluoride

These parameters were found in very much less concentration than the SLS 614:2013 acceptable level and has not responded to the seasonal variations (Table 4, 5 and 6).

Table 4. Nitrate concentration in the point Pedro WSS intakes

Concentration (mg/L)	PP 01	PP 02	PP 03	PP 04	PP 05	PP 06	PP 07	PP 08
Maximum	1.4	1.4	3.7	2.2	2.1	1.6	1.6	1.1
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	0.6	0.4	0.5	0.5	0.3	0.4	0.4	0.4

Table 5.Phosphate concentration in the Point Pedro WSS intakes

Concentration (mg/L)	PP 01	PP 02	PP 03	PP 04	PP 05	PP 06	PP 07	PP 08
Maximum	0.43	0.62	0.96	0.75	0.63	0.86	0.69	2.11
Minimum	0.09	0.12	0.06	0.07	0.12	0.09	0.10	0.08
Average	0.19	0.26	0.24	0.27	0.25	0.29	0.24	0.38

Table 6. Fluoride concentration in the point Pedro WSS intakes

Concentration (mg/L)	PP 01	PP 02	PP 03	PP 04	PP 05	PP 06	PP 07	PP 08
Maximum	0.27	0.23	0.28	0.27	0.35	0.33	0.23	0.26
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average	0.09	0.09	0.12	0.10	0.11	0.11	0.13	0.12

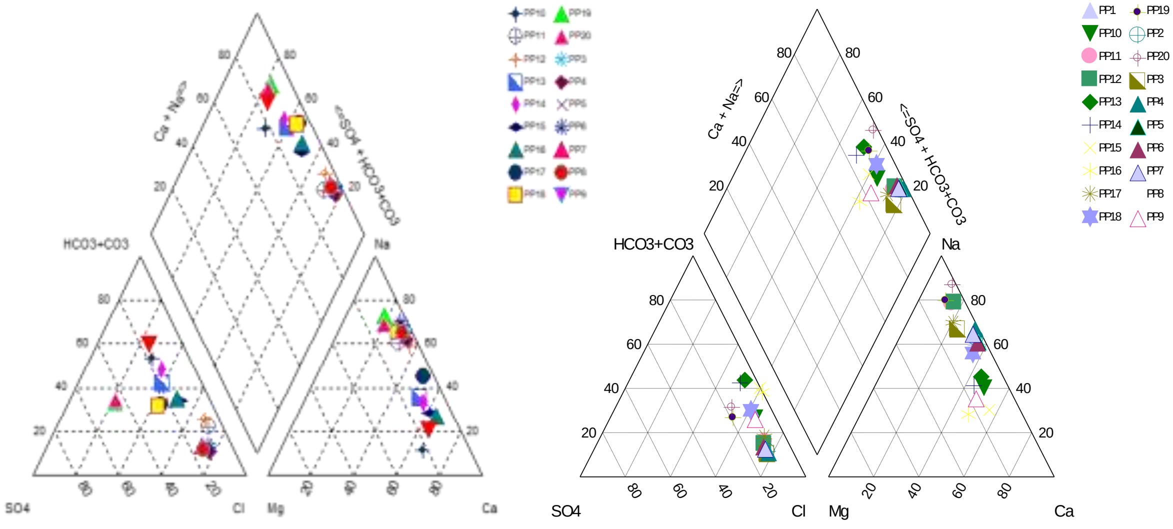
These wells are located in the sand dune area, and the Agricultural and the industrial activities are very less in the adjacent locations, it may be the reason for the lesser concentration of the above parameters in the well water quality.

3.4 Hydro Geochemical characteristics

3.4.1 Piper diagram for Vadamarachchi Aquifer

Figure 11 shows the piper diagram of Point Pedro in Vadamarachchi aquifer in April and August (2018). In the both diamonds all the intake wells are already in the sodium chloride type water and most of the control wells are located in the calcium chloride type water, only PP 11 and PP 12 are in sodium chloride type in both months. PP 11&12may be in the boundary line of the aquifer area and near by the Vadamarachchi salt water lagoon; it may be the reason for the sodium chloride concentration.

All the wells are moving towards the sodium chloride type from April to August 2018. Intake wells are shifted towards chloride type from April to August 2018 in anion triangle, shifted towards sodium type in cation triangle. According to the Table 7, Well water electrical conductivity valuesare higher than 1000 µS/cm, are belong to sodium calcium chloride or sodium chloride type water, 500 - 1000 µS/cm electrical conductivity value water are belong mixed type water. Less than 500 µS/cm values are belong calcium type water.

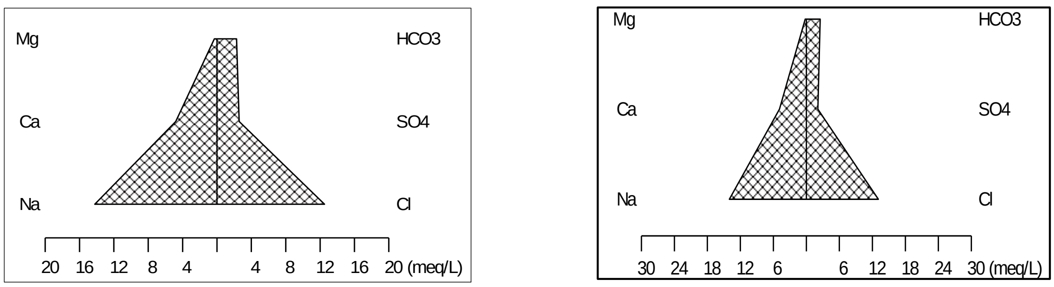


(a) **(b)**

Fig. 11: Piper diagram, during the month of (a) April and (b) August 2018

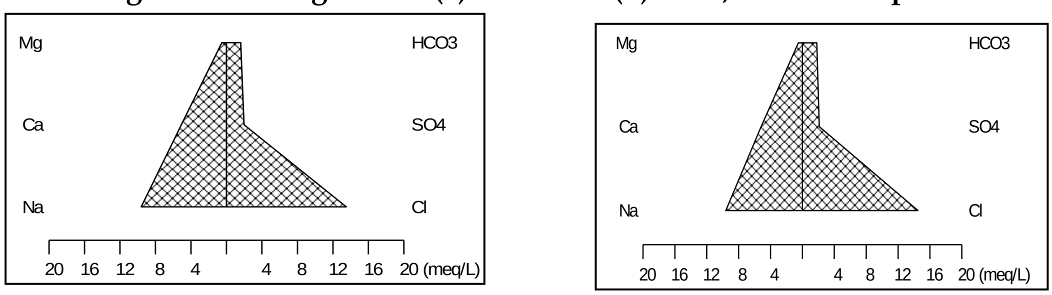
3.4.2. Stiff diagram of Vadamarachchi Aquifer

Stiff diagrams are commonly used for displaying major-ion compositions of ground waters. The shape of the diagram indicates the relative proportion of different ions and the size indicates total concentrations. Stiff diagrams are plotted on a site map, and their shapes visually compared to decipher the flow direction of groundwater in the region Fig 12 and 13). Similarities within the chemistry of ground waters collected from different locations of a geological region can then be determined and groundwater with similar flow histories can be identified (Singh and Gewali, 2010).



(a) **(b)**

Fig. 12: Stiff diagram for (a) PP 01 and (b) PP02, month of April 2018



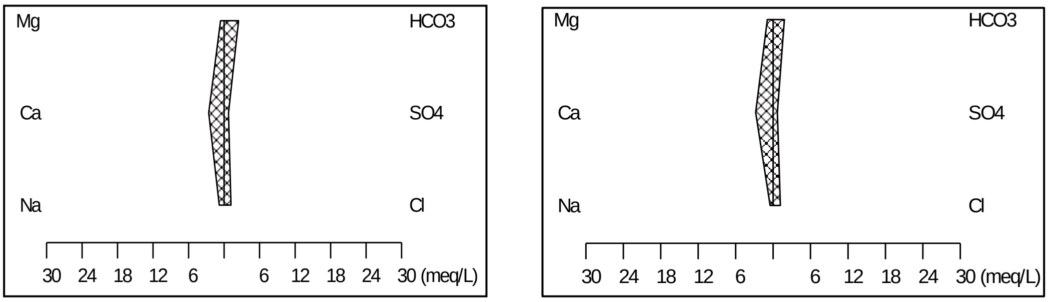
(a) **(b)**

Fig.13: Stiff diagram for (a) PP 01 and (b) 02, month of August 2018

Table 7. Seasonal changes in the water type

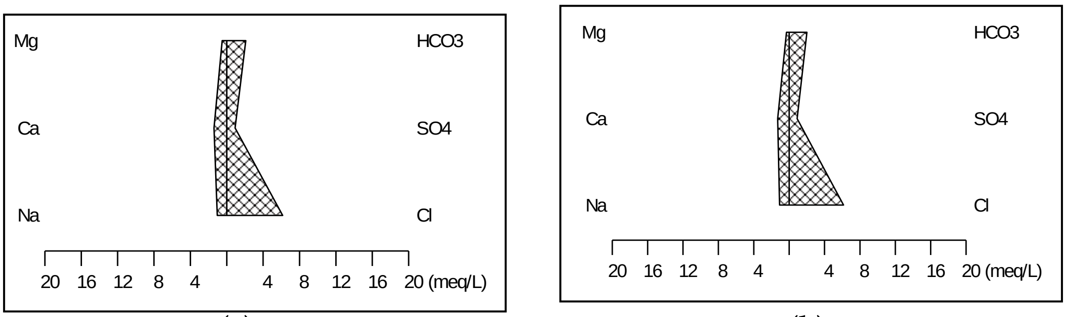
Sample Code	*Type of wells*	*EC – April(µS/cm)*	*Water Type*	*EC - August(µS/cm)*	*Water Type*
PP 01	Intake 01 - surface	1890	Na-Ca-Cl	1632	Na-Ca-Cl
PP 02	Intake 01 - Bottom	1987	Na-Ca-Cl	1720	Na-Ca-Cl
PP 03	Intake 02 - surface	1330	Na-Ca-Cl	1767	Na-Ca-Cl
PP 04	Intake 02 - Bottom	1632	Na-Ca-Cl	1845	Na-Ca-Cl
PP 05	Intake 03 - surface	1020	Na-Ca-Cl	1310	Na-Ca-Cl
PP 06	Intake 03 - Bottom	1310	Na-Ca-Cl	1390	Na-Ca-Cl
PP 07	Intake 04 - surface	2145	Na-Ca-Cl	1376	Na-Ca-Cl
PP 08	Intake 04 - Bottom	2650	Na-Ca-Cl	1429	Na-Ca-Cl
PP 09	Control 01 - Surface	437	Ca-HCO3-Cl	598	Ca-Cl-HCO3
PP 10	Control 01 - Bottom	475	Ca-Mg - HCO3-Cl	606	Ca-Cl-HCO3
PP 11	Control 02 - Surface	913	Na-Cl	1278	Na-Cl
PP 12	Control 02 - Bottom	940	Na-Ca-Cl-HCO3	1286	Na-Cl
PP 13	Control 03 - Surface	467	Ca -Na-Cl-HCO3	426	Na-Ca-Cl-HCO3
PP 14	Control 03 - Bottom	471	Ca-Na-Cl-HCO3 - CO3	441	Ca-Na-Cl-HCO3
PP 15	Control 04 - Surface	510	Ca-Na -Cl-HCO3	404	Ca-Cl-HCO3
PP 16	Control 04 - Bottom	512	Ca-Na -Cl-HCO3	419	Ca-Cl-HCO3
PP 17	Control 05 - Surface	548	Ca-Na-Cl-HCO3 - SO4	610	Na-Cl
PP 18	Control 05 - Bottom	778	Ca-Na-Cl-SO4- HCO3	695	NA-Cl-HCO3-SO4
PP 19	Control 06 - Surface	628	NA-SO4-Cl-HCO3	798	NA-Cl-SO4-HCO3
PP 20	Control 06 - Bottom	673	NA-SO4-HCO3-Cl	865	NA-Cl-HCO3-SO4

According to the stiff diagram (Fig 12 and 13), Sodium and chloride are dominant ion in PP 01 and 02, and calcium concentration is prominently increasing in PP 01 and PP 02 in August 2018. The similar patterns were observed in all other three Intake wells. According to the Fig14 and 15, Calcium and Bicarbonate ions are slightly higher and no prominent domination in PP 09 and 10, chloride concentration is increasing in August 2018.Similar patterns were observed in other control wells too.



(a) **(b)**

Fig 14 : Stiff diagram for (a) PP 09 and (b) 10, month of April 2018



(a) **(b)**

Fig 15: Stiff diagram for (a) PP 09 and (b) PP10, month of August 2018

According to the all diagrams the chloride concentration is increasing in dry season, it may be due to the sea water influences. Sodium chloride concentration is prominently increasing in the intake wells in dry season and total Salt concentration and seasonal fluctuation is comparably higher in intake wells than control wells, it may be due to the continuous pumping of considerable quantity.

4. CONCLUSION

Vadamarachchi sand dune aquifers are surrounded by salt watertherefore; there is high possibility of the salt water intrusion. 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 aquifer is vulnerable to sea water contamination. Point Pedro water suPPly scheme has shown high potential for salt water contamination. Therefore, additional water sources need to be identified to meet the increasing consumption and demand.

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