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Assessment of Groundwater Quality in Jaffna Peninsula for the Establishment of a Long-term Groundwater Monitoring Network

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ABSTRACT

Geology in Jaffna peninsula is comprised with five types of significantly distinguished features. Miocene Limestone and the Red bed cover the top middle part of the peninsula while Dune sand/Beach sand restricted into Eastern costal region and as a thin layer of northern costal from Karainagar side to Point Pedro. Rest of the inland is occupied by Unconsolidated Brownish Gray costal sand and marginal areas covered by Lagoon/Estuarine deposits. It's noted that the groundwater quality is varies and interrelated with these geological setup in the region.

Shallower and deeper aquifers encountered in Jaffna, Nallur, Chavakachcheri & Pachchilaippallai divisional secretaries were studied for the establishment of long term monitoring program which leads to identify Groundwater occurrence & quality distribution. These areas were selected based on the issues identified by available information on groundwater quality. This comprehensive assessment study is provided a platform to acquire sustainable utilization & proper management of Groundwater resources in the Peninsula for future economic and rural development activities. In this study, initial assessment of groundwater occurrence and its physical/chemical quality distribution was carried out for identification of long term monitoring points in the pilot area. In-situ testing for selected parameters and further comprehensive analysis including physical, chemical, bacteriological &heavy metals were performed. Aquifer parameters were estimated based on the analysis results of test pumping carried out at different aquifer types in the area. The hydrogeological condition of the sub-surface was interpreted using 1D & 2D resistivity surveys.

More than 17 Nos. of physical and chemical parameters of groundwater were analyzed for the selection of long term monitoring locations.Out of 92 water samples analyzed, 79% samples in dry season and 84% in wet season are exceeded the desirable level for EC prescribed by the WHO standards. Furthermore, 13% samples of each period is exceeded the permissible level resulting an issue for the dinking purposes of this groundwater. No health-based guideline values are proposed for Na by WHO. However, the Clconcentrations and Na concentrations are observed in excess of about 200 mg/l which may be objectionable toconsumers because of the taste of the water (WHO, 2004). About 15% of studied wells are exceeded their permissible level for hardness of the groundwaterexpressed as mg/l CaCO3 equivalent in each periods while almost half of the samples having higher hardness values than the desirable level. This is mostly the result of Ca and Mg from dissolved limestone.Further, there is a possibility to saline water intrusion in Karaveddi-Chavakachcheri DSD boundary. This indicates by the present groundwater quality of the study area.Based on the all chemical analysis results and identified problems in the different zones of the study area, the monitoring network comprising 38 wells which were selected for the long term groundwatermonitoring.

BACKGROUND OF THE STUDY AREA

The study area (in between 9.518° & 9.765° N of latitudes and longitudes of 79.994° & 80.455°) located in the Northern Province of Sri Lanka. This terrain which existed at the northern most part of the country separated from the mainland forming a peninsula and surrounded by the Indian Ocean and Kilali Lagoon. The Jaffna peninsula has an extent of 260,000 acres with a population of 831,112 (1981, Census). But the study area restricts to only four DS divisions namely Jaffna, Nallur, Chavakachcheri of Jaffna district and Pachchilaippallai of Kilinochchi district. The majority of landuse within the area is occupied home gardens, Palmyra, coconut and paddy lands. However most of lands are still abandoned due to prolong war conflict of the country. Main lagoonal deposits which covered the area is known as Jaffna lagoon, Uppu Aru and Vadamarachchi. The area is almost flat and characteristically associated with marshy lands, lagoonal marshy areas, sand dunes and red earth soil beds covering the underlain limestone layer. The highest elevation is about 12-15masl at Thelippalai area.

The region is in the temperate semi-arid climatic zone of the country and average temperature is 28° - 32° C and does not vary widely throughout the year. The average annual rainfall is 1,543 mm according to the rainfall data collected between year 2000 and 2005. 82% of the total annual rainfall in the Peninsula is received by North east monsoonal period starting from October to December. In general, rest of the year is almost without any significant amount of rainfall. Evaporation is approximately 2250mm per year whereas the corresponding total rainfall is 1150mm. Out of the

total area (1025 km^2) of Jaffna district, the land area is occupied with the extent of 929 km^2 and inland waters with 96 km^2 extent according to the Road and Town Atlas published by the Survey Department of Sri Lanka,. Kilinochchi district is off 74 km^2 inland waters with comparison to the 1279 km^2 of total area.

Highly Karstified Miocene sedimentary Limestone formations encountered within shallow depth in most of the area. All the shallow groundwater found within the cavities originated from the infiltration of rainfall and this shallow groundwater forms mounds or lenses floating over the saline water (Panabokke, Perera). The monsoon rain is the only recharge component to the system. There are four other types of geological basement can be identified originated from sedimentary background; Lagoonal and Estuarine deposits, Unconsolidated Brownish Gray costal sands, Red beds and Dune sands. Since the study area belongs to peninsula separated from the whole island mass, there is no any river basin can be identified. Valuku Aru which traverses South-Eastern from its origin in the central Mallakam area does not reach to the study area. The area is lack of any definitive surface drainage system since no streams network could be identified except scattered small scale pond system in the peninsula which is also effective groundwater recharge source for the region. Therefore approximately 100% of water resources existed in the peninsula could be regarded as off groundwater. Dense network of interconnected caverns, fractures and fissures in the limestone aquifer is the most highly productive aquifer in the region.

The concerned area for this study is of shallower and deeper aquifers encountered in Jaffna, Nallur, Chavakachcheri & Pachchilaippallai divisional secretaries to establish a long term groundwater monitoring network which provided a platform for sustainable utilization & proper management of groundwater resources in the Peninsula for future economic and rural development activities. These areas were selected based on the issues identified by available information on groundwater quality. The activities of this study were basically focused for the initial assessment of water quality in the region spatially as well as temporally which leads to identify quality distribution.

OBJECTIVES

The Main objective is establishment of a monitoring network in the selected pilot area for long term assessment of hydrogeochemistry in the region**.** Specific objectives are determination of groundwater use and identification of the influence of agricultural practices, bacteriological pollution and other factors to the groundwater of the Peninsula and furthermore, to interpret the hydro-chemical evolution of groundwater from the limestone aquifer by determining the chemical characteristics and the most relevant controls on the groundwater composition.

Scope of the work

- To carry out survey related to sanitation facilities available in the Jaffna town area
- Identify appropriate monitoring well locations that will provide necessary data to fulfill the objectives of the monitoring program.
- Propose the frequency of both groundwater level measurements and the water sampling for each well assigned in the network.
- Provide the best information currently available regarding the specific hydrogeologic unit(s) monitored by each well.
- Reference the procedures and associated quality assurance requirements to ensure proper protocol being practiced in the monitoring of quantity and quality of groundwater.

METHODOLOGY

Existing aquifer types and the basic Geology, Structure and topology were studied with the help of previous researches done in the area. There is no any comprehensive study has carried out on the occurrence and quality distribution of groundwater by long term consideration. The preliminary reconnaissance survey including some awareness programs to the stake holders and community was done at the initial stage. This lead to obtain the information on the issues identified and the availability of data at leading government as well as non-governmental organizations. During the initial field inspections, the necessary information on the issues and water resources were gathered. In addition, in-situ tests were performed to analyze pH, EC, TDS, Salinity (using HACH HQd Portable Meters) and Nitrate, Phosphate concentrations (HACH DR/890 Datalogging Colorimeter) of the water samples using Field test kits.

Based on the results of in-situ tests and other issues identified at the area, 52 shallow wells were selected out of 112 visited locations as initial sampling points for chemical analysis during the peak time of the dry season in August 2011. In addition, chemical analysis was done for another 40 shallow wells in the same dry season. Most of these wells are used for drinking purpose while some are only for domestic uses and very few were abandoned at the time of sampling. The analysis included with full chemical analysis, selected heavy metal analysis and bacteriological analysis if required.

After the wet season (December-January) same sampling procedure was followed up for chemical analysis at 68 selected locations out of 92 previously studied wells. Some locations have been omitted due to similarity of the water chemistry and considering the aquifer formations, hydrogeological set up and also due to defense restriction in certain areas.

In advance bacteriological analyses were done in selected 13 shallow wells in Jaffna and Nallur urbanized area with parallel to wet seasonal water quality study. These tests were done at the field itself by a chemist using HACH MEL/MF Portable Incubator Laboratory.

During the sampling procedure, water samples were collected into specifically recommended plastic bottles with air tight capping for the laboratory analysis. Samples for the determination of cations were acidified to pH<2. Concentrations of cations were determined by atomic absorption spectroscopy (AAS). Nitrate and phosphates was preserved by adding conc. H_2SO_4 to the samples. The accuracy of the analysis was estimated from the ionic balance error (Freeze and Cherry, 1979), which is within 5% for all samples.

Geophysical survey done at selected locations to study the sub surface conditions using 1-D resistivity methods by ABEM 1000 Resistivity meter and further 2-D imaging resistivity survey method (*AGI SuperSting R8/IP* 8-channel memory earth resistivity meter) was applied to get subsurface 2D visualization in the important target areas.Test pumping carried out at different aquifer types in the area and the analyses results of those tests were used to estimate the aquifer parameters.

RESULT AND DISCUSSION

Table 1 - Comparison of number of wells exceed the SLS drinking water standards in Dry and Wet periods

Parameter	No of wells Exceed the SLS Standards			
	Dry season (Total No. of wells =88)		Wet season (Total No. of wells =70)	
	MDL	MPL	MDL	MPL
Color	0	0	54	12
Turbidity	2	0	10	3
pH	3	0	3	1
EC	73	12	58	9
Total Hardness	44	14	38	11
TDS	71	16	56	10
Total Alkalinity	82	29	63	19
Fe	1	0	0	0
F	32	6	40	1
Ca	17	8	9	2
Mg	3	3	6	0
Cl	48	8	24	5
SO_4	13	6	3	2
NO3	-	1	-	2
PO4	-	4	-	3

MDL: Max. Desireable Level, **MPL**:Max. Permissible Level

Table 01 are shown the number of wells which exceeded the SLS drinking water standardsfor 15 Chemical/ Physical parameters been analyzed during dry and wet periods. Same sampling locations were used in both periods except some of the wells which have been excluded after dry season analysis results.Most of the variables are skewed positively and include outliers. Therefore the variables were log transformed for improving normality of the variables. Subsequently, all 15 variables were standardized to their standard scores (z-scores) and only 88 wells from dry period were used to statistical analysis.

According to this statistical summary of the analysis, there exists a considerable water quality problem in Electrical Conductivity (EC), total Dissolved Solids (TDS), Total Alkalinity (TA), and Total Hardness (TH) in water for both dry and wet periods. Fluoride, Chloride and Calcium concentrations are being reached to the maximum permissible levels and in contrast less Fluoride content is another water quality issue in some areas in the peninsula.

Table 2 - Summary of water quality analysis in dry period (Aug/Sep 2011)

Parameter	Total Count	Mean	Minimum	Maximum
Turbidity (NTU)	88	0.518	0.060	6.400
pH	88	7.386	6.900	8.100
EC (µS/cm)	88	2142	155	18460
Total Hardness (mg/L as Ca)	88	460.2	68.0	7207
TDS (mg/L)	88	1365	102	12183
Total Iron (mg/L)	88	0.110	0.010	0.400
F (mg/L)	88	0.560	0.00	2.100
Salinity (ppt)	88	1.127	0.100	10.90
PO4 (mg/L)	88	1.032	0.200	8.000
Ca (mg/L)	88	93.60	11.50	1347
Mg (mg/L)	88	54.90	1.200	933.0
Na (mg/L)	88	308.0	30.00	2135
K (mg/L)	88	45.30	2.100	346.0
Total Alkalinity (mg/L)	88	367.0	109.0	735.0
Cl (mg/L)	88	531.0	15.10	7280
SO4 (mg/L)	88	137.7	1.000	2600
NO3 (mg/L)	88	1.726	0.100	26.00

Water quality analysis for dry season hasbeen distinguished several shallow water lenses that createddifferent water quality changes within nearby areas.

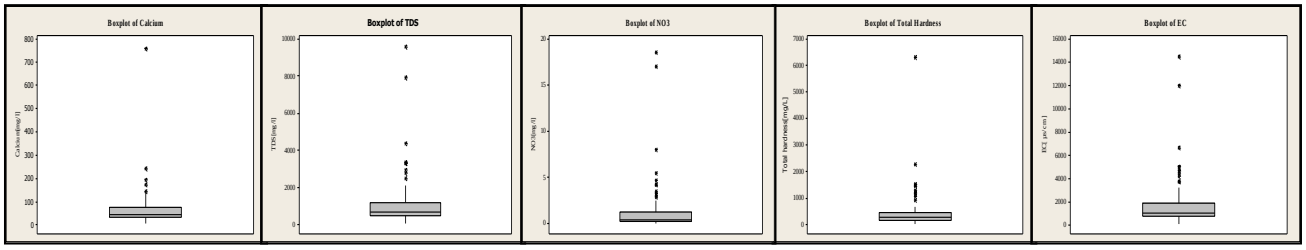


Figure 1 - Water Quality Analysis after Wet Season (Jan/Feb 2012)
(Box plots for shorter range variables of wet seasonal analysis)

Wet season analysis data concludes that TDS has the widest range than other variables. TH, TA, Na and Cl has considerably higher ranges. But Fe, F, Ca, Mg, K, PO_4, SO_4 and NO_3 have shorter ranges. Beside these shorter range variables, again all the variables are positively skewed. One outlier has been identified considering all the parameters and therefore only 69 samples were used to interpret the wet seasonal data.

Table 3 - Statistical analysis data for wet season

	Calcium (mg/L)	TDS (mg/L)	NO_3 (mg/L)	Hardness (mg/L *as Ca*)	EC (µS/cm)
Q1	168.75	33	0.2	538.0	825.0
Median	271.5	44.7	0.4	707.0	1091.0
Q3	461.0	76.275	1.275	1217.75	1912.5
IQ Range	292.25	43.275	1.075	679.75	1087.5
N	70.0	70.0	70.0	70.0	70.0

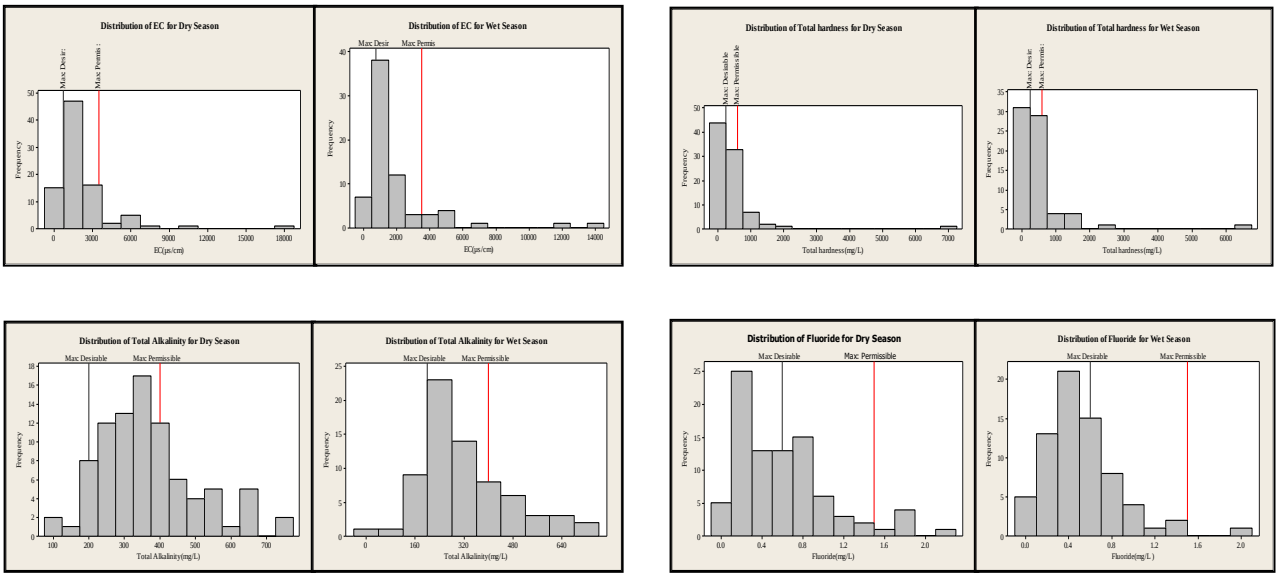


Figure 2 - Graphical representation for seasonal changes in selected parameters
(Comparison of histograms for dry andwet periods)

Groundwater Quality

Nitrate concentration of Groundwater is significantly high in Kondavil-Kopai Red Earth underlying area. High yielding shallow aquifer compare with the rest of the study area may be easily contaminated by excessive application of Agrochemicals. And there is a slight indication of Sea water intrusion in Ariyalai and possibility to development of such a situation in Karaveddi DSD boundary Lagoonal area too. Shallower fresh water lenses created by the fine sand in Iyakachchi area is extended to the South eastern coastal side. HACH portable Bacteriological in-situ field instruments were used to carry out the Bacteriological Analysis. Selected 13 numbers of dug well locations in Jaffna & Nallur town area were not indicated a bacteriological contamination in this particular time period.

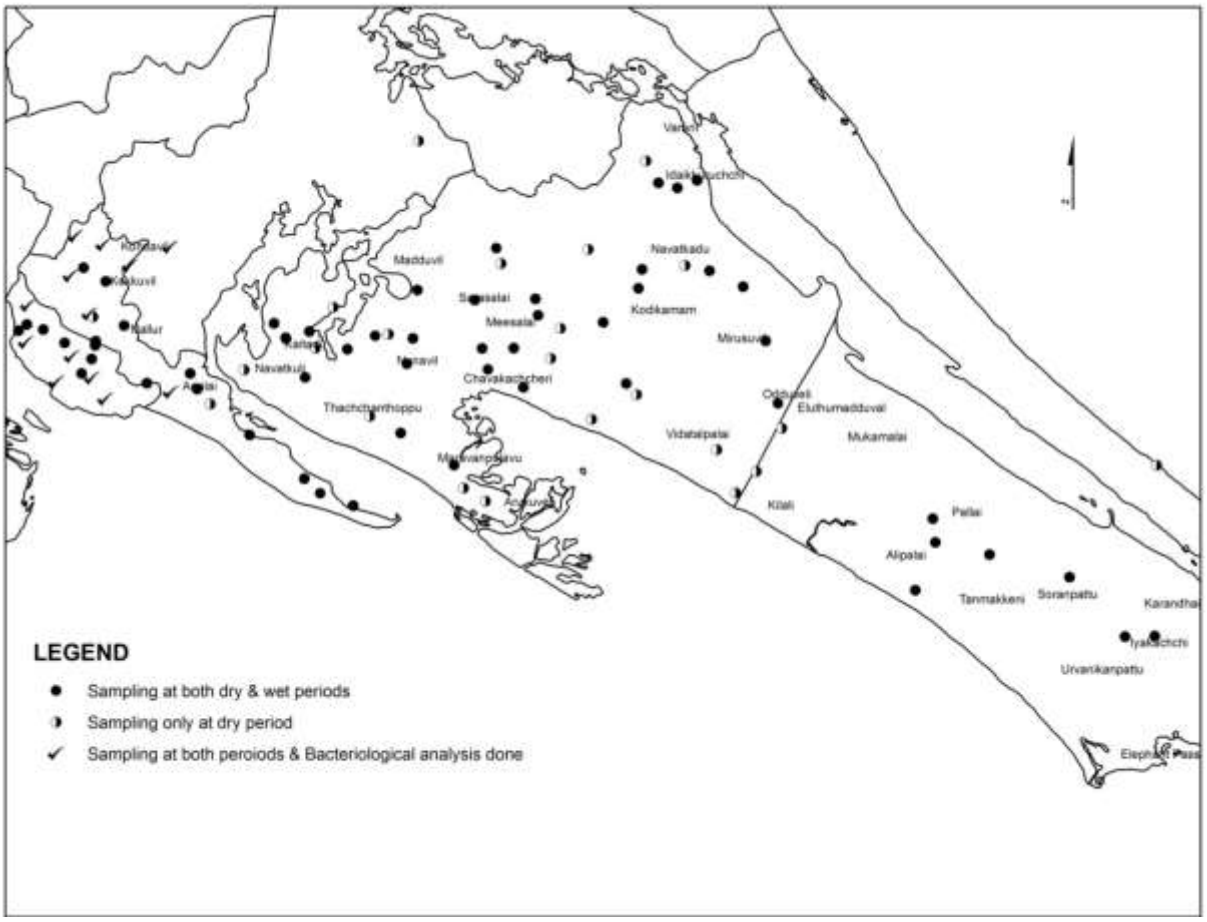


Figure 3 - Spatial distribution of the groundwater quality in dry and wet periods

Table 4 - Bacteriological in-situ analysis results after wet season (Feb2012)

Well No.	Location	pH	PO4 (mg/L)	NO3 (mg/L)	Total Coliform	E-Coli
JS31	Kopai South	7.7	0.6	3.5	Nil	Nil
JS49	Jaffna	7.5	0.6	0.5	Nil	Nil
JS50	Thirunelvely	7.6	0.6	2.9	Nil	Nil
JS51	Kondavil	7.5	0.6	4.7	Nil	Nil
JS55	Iruvalai Road	7.6	0.3	3.3	Nil	Nil
JS57	Kondavil	8.0	0.6	0.8	Nil	Nil
JS60	Kurunagar	7.6	8.0	5.5	Nil	Nil
JS62	Chundikuli	8.2	1.0	3.0	Nil	Nil
JS63	Koddady	7.2	0.9	0.2	Nil	Nil
JS65	Oddumadam	7.3	0.7	18.5	Nil	Nil
JS72	Pasiyoor	8.2	1.1	0.3	Nil	Nil
JS73	Maniyamthottam	8.1	0.5	0.3	Nil	Nil
JS76	Kokuvil East	7.8	0.7	0.4	Nil	Nil

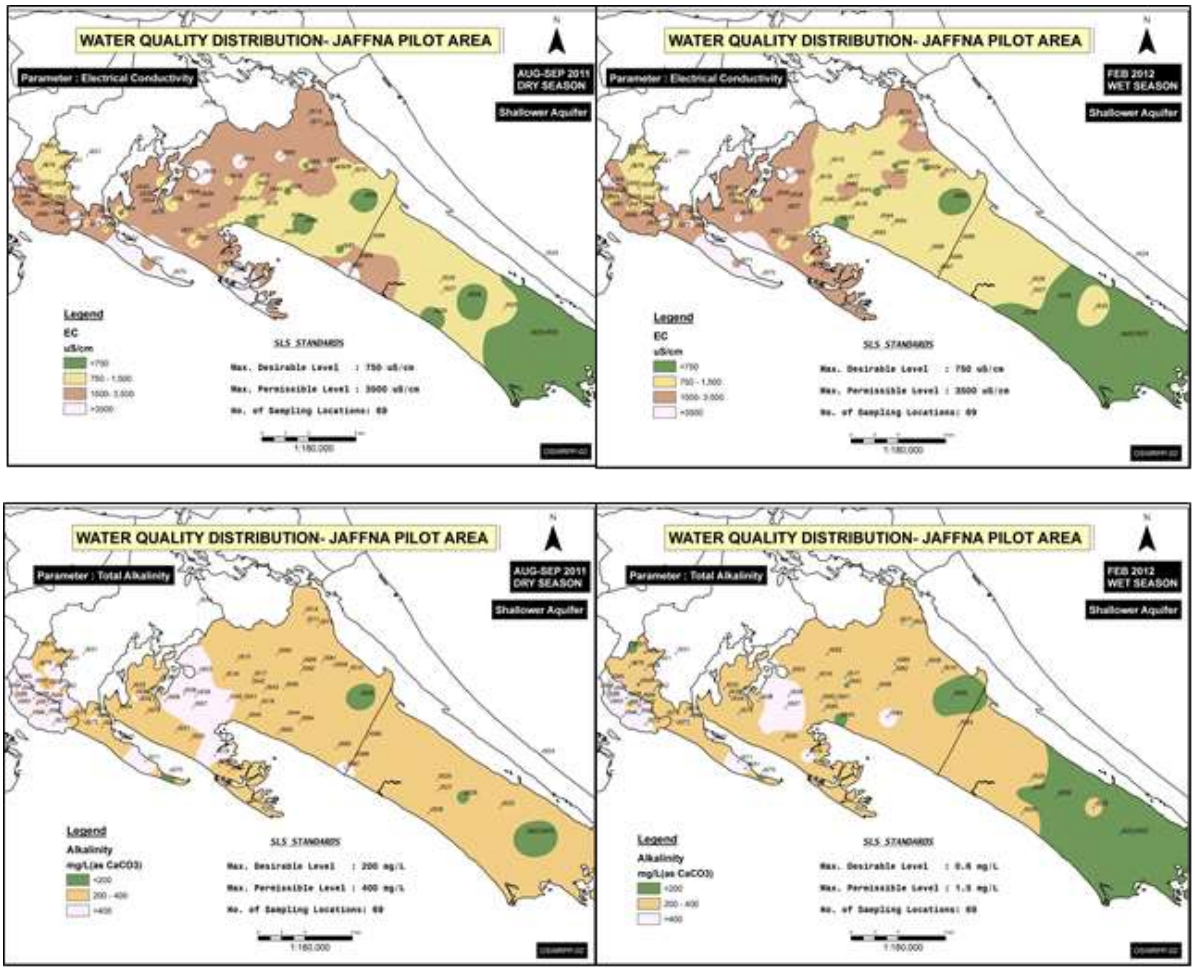


Figure 4 - Seasonal changes in EC and alkalinity quality distribution in shallow groundwater of study area

Interpolated spatial distribution of the Groundwater quality in each sampling periods (by Inverse Distance Weighted method using ArcGIS 10 software) implies that temporal variations of quality distribution patterns and shown in above figures.

Subsurface condition

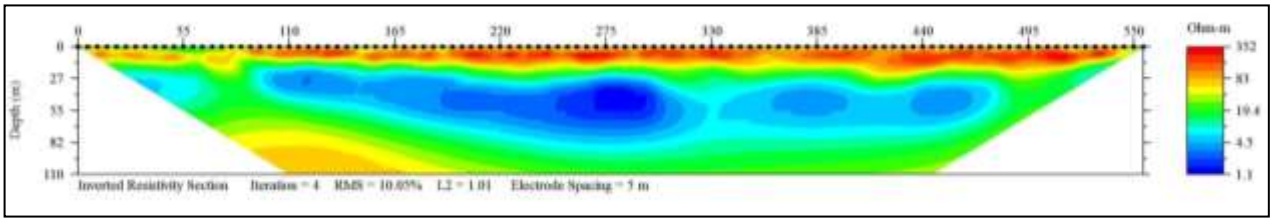
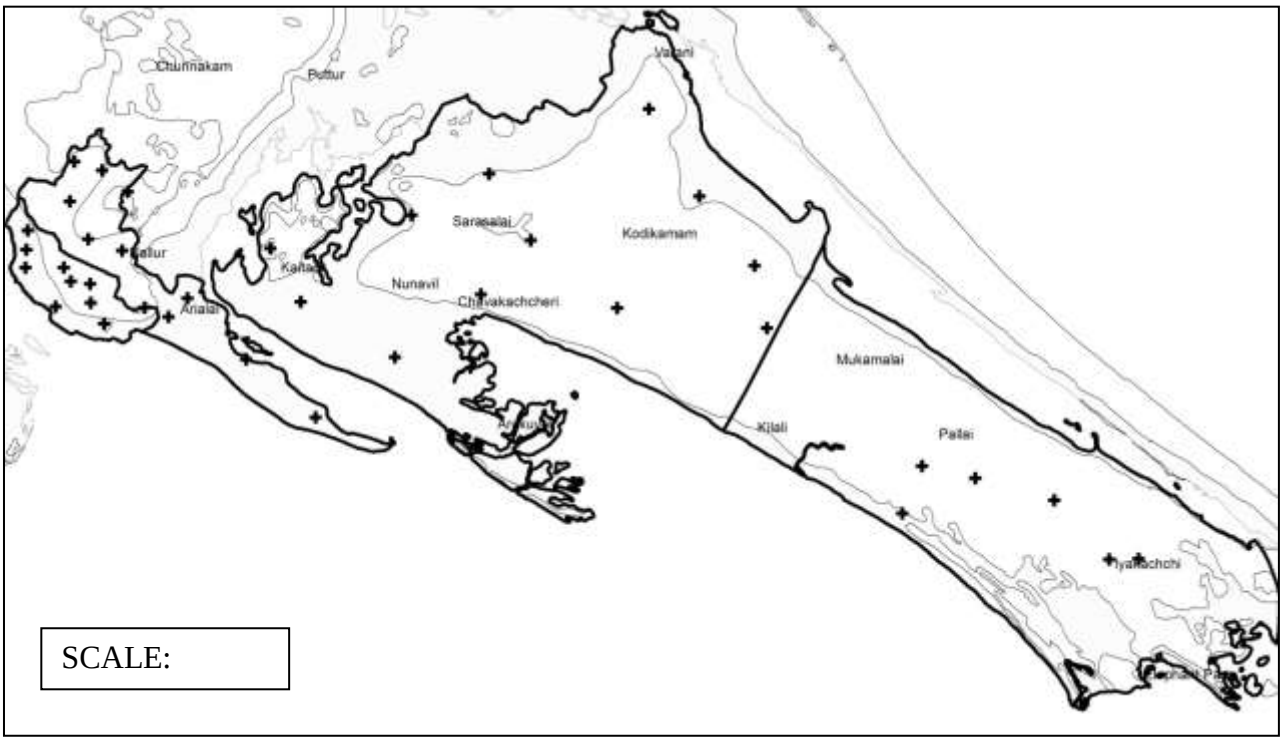


Figure 5 - Different sub surface layers identified by 2D Resistivity Survey done at Kondavil

The area is underlain by comparatively high resistive top soil (Red earth) formations and then the karstified Limestone which is more than 100m thick. 1D resistivity survey carried out in different geological natures in the area implies the deeper (>20m-30m) Groundwater quality may be objectionable to the consumers because of the taste.

Proposed Long-Term Shallow Groundwater Monitoring Network



Fiure 6 - Spatial map for selected GW monitoring network

LIMITATIONS RELATED TO FIELDWORK

One of the major limitations to the fieldwork in the study area was the lack of enough Hydraulic head data and water quality analysis data in the limestone aquifer due to the lack of monitoring boreholes. Therefore study was mostly restricted to shallow aquifer system.

Some high security zones cannot be accessed and sampling was not done in those particulararеas for this quality assessment.

RECOMMENDATIONS

The proposed Monitoring Network is comprised of 38 shallow wells and it is recommended tomonitor the water level and water quality on quarterly basis. This could be carried out at peak time of the dry period, after the infiltration of rain water and in between these two seasons.

In the case of Nitrate issue in Red bed areas, it is recommended to monitor the Nitrate levels on monthly basis at the selected wells.

It is also recommended to control the excessive applications of agrochemicals in high sensitive areas of the Groundwater contamination through awareness and guidance by the relevant Governmental or Non-Governmental agencies.

Further, it is observed that the Nitrate in groundwater sources utilized for the most of water schemes are indicated higher level thus require a mechanism such as lowering the NO3 levels by mixing better quality water sources which are required to be explored in the region.

ACKNOWLEDGEMENT

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REFERENCES

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- Groundwater quality in the Valigamam Region of the Jaffna Peninsula, Sri Lanka. Rajasooriyar L., Mathavan V., Dharmagunawardhane A. & Nandakumar V. *GeologicalSociety, London, Special Publications*; 2002; v. 193; p. 181-197;DOI: 10.1144/GSL.SP.2002.193.01.14
- Nagarajah, S., Emerson, B.N., Abeykoon, and Yogalingam, S. 1988. Water quality of some wells in Jaffna and Kilinochchi with special reference to nitrate pollution. Tropical Agriculturalist, Vol. 144, 61–78.
- B. A. Adelekan and K. D. Abegunde.Heavy metals contamination of soil and groundwater atautomobile mechanic villages in Ibadan, Nigeria.
- Carmelita Nishanthiny,Thushyanthy,T. Barathithasan and Saravanan. Irrigation Water Quality Based on Hydro Chemical Analysis, Jaffna, Sri Lanka. American-Eurasian J. Agric. & Environ. Sci., 7 (1): 100-102, 2010
- Arumugam, S. 1974. Geology and Groundwater Resources in Northwest Ceylon:Studies on Groundwater in Sri Lanka (Ceylon). Water Resources Board, Colombo.36p.
- Nanthani T, Mikunthan T and Vijayaratnam R. Some Physio-chemical characters of groundwater in some (selected) water supply wells in the Jaffna peninsula. J.Natn.Sci.Foundation Sri Lanka 2001 29(1&2):81-95
- Balendran, V.S., Sirimanne, C.H.L. and S. Arumugam. 1968. Groundwater in Jaffna.Water Resources Board, Colombo. 35p.
- Sri Lankan Standards 614: part 1(1983). Specification for potable water physical and chemical requirements. p:5-10
- World Health Organization (1984). Guidelines for drinking water quality Vol.1: Recommendations. Geneva. p:79