Application of home remedial techniques to reduce hardness and Assessment of Variation of physical and chemical parameters of well water in Vadamaradchi.

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Abstract

Vadamaradchi aquifer is considered to be the best ground water source in Jaffna peninsula. Therefore, some wells in Vadamaradchi are used as collector wells which supplies water to fulfil domestic water requirements of the residents in Jaffna peninsula. The present study was conducted with the objectives of assessing physical and chemical parameters of water in selected wells in Vadamaradchi and to identify suitable home remedial techniques to treat the increased hardness of water. Variation of physical and chemical parameters of water collected form 10 collector wells in Vadamardchi aquifer were analyzed and were compared with those parameters in bottled drinking water (Knuckles brand) and with SLSI drinking water quality standard. Along with that the replicate water samples collected were subjected to boiling at 100^0C for 10 minutes, filtration through commercial mineral filter and *Moringa oleifera* leaf powder filter. Total hardness (254.4 mg/L) of the collector wells exceeded the SLSI drinking water standards. Filtration through *Moringa oleifera* leaf powder filter significantly increased TH and filtration through commercial mineral filter did not caused a significant reduction in TH. However, boiling water at 100^0C for 10 minutes significantly reduced TH accounting for 16 % reduction.

Keywords - Collector wells, drinkability, *Moringa oleifera*, mineral filter,

1.0- INTRODUCTION

The prime natural water source in Jaffna peninsula is ground water in the limestone aquifer due to lack of major water supply schemes, absence of rivers and rain water harvesting systems (Panabokke, 2005). In this region of the country, there is a considerable variation in the quality of groundwater and these variations can be related to variations of the geological setup in the area.

There are four main types of aquifer systems in Jaffna peninsula, namely, Chunnakam, Thenmaradchi, Vadamaradchi and Kayts. It is recorded that the best groundwater source is located in sand dune aquifer and the importance of protection of this aquifer from pollution and over extraction is highlighted by several researchers (Hidayathulla, 2011).

However, it is believed that Vadamaradchi aquifer to be the best ground water source in Jaffna peninsula. Therefore, some wells in Vadamaradchi are used as collector wells which supplies water to fulfil domestic water requirements of the residents in Jaffna peninsula. Salt water intrusion due to over extraction of groundwater and sewage contamination due to improper construction of soakage pits, high nitrate concentrations and high hardness water are become major concerns regarding the quality of available groundwater in this part of the country.

The Total Hardness (TH) is relatively high in ground water in Jaffna Peninsula compared to other regions in the country (Kumara, 2013). High amounts of calcium and phosphate in the drinking water may accelerate stone formation in the bladder (Sivarajah, 2003). Long-term intake of drinking water harder than 500mg/L may cause higher local blood supply in the kidneys and subsequent adaptation of the filtration and resorption processes in the kidney (Kožíšek, 2003; WHO, 2011).

The remedial actions to make the contaminated water to a potable condition are a widely researched area in the world. Ion exchange technology, reverse osmosis can be used to soften the water and boiling water also helps to precipitate calcium as calcium carbonate to reduce the hardness (WHO, 2011).

However, no recent studies have conducted to study the water quality in these supply wells located in Vadamaradchi. In addition the application and feasibility of home remedial methods to treat hard water in this area is also poorly researched. Thus it become vital to suggest cheaper, feasible and efficient home remedial methods for the local people to purify the water collected from the domestic wells of the area.

The objectives of the present study was to assess the physical and chemical water quality parameters in selected domestic wells, which also serve as collector wells in Vadamaradchi and to compare these parameters with same parameters measured in bottled drinking water and Sri Lanka Standards Institution Standards (SLSI) for safe drinking water. In addition the efficacy of boiling,

filtration through commercial mineral filter and filtration through *Morings oleifera* leaf powder filtrate was to treat the increased hardness of water was also studied.

2.0- METHODOLOGY

2.1- Study area

This study focused ten water collector wells fed by Vadamaradchi aquifer in Jaffna Peninsula and is considered as the most uncontaminated aquifer in Jaffna Peninsula. The locations of the sampled wells are given in the map shown in Figure 1. The Study was carried out from April to September 2016.

2.2- Sample collection and treatments

Three replicate water samples were collected from each well and preserved in accordance with APHA, 1998. These water samples collected from these wells were subjected filtration through a commercially available mineral water, filtration through *Moringa oleifera* leaf powder filter and were boiling at 100º C for 10 minutes and the water quality parameters before and after treatment were measured.

2.3- Water quality analysis

The temperature, salinity, pH, Electrical Conductivity (EC), Dissolved Oxygen (DO) concentration, and Total Dissolved Solids (TDS) of each water sample were measured using pre-calibrated multi-parameter water quality checker (HACH model: H940). The water samples were preserved in accordance with APHA, 1998, and were transported to the laboratory of the Department of Zoology and Environmental Management, University of Kelaniya, Sri Lanka. In the laboratory Chemical Oxygen Demand (COD), nitrate-N concentration, Total Phosphorus (TP) concentration, Total Hardness (TH) and Total Solids (TS) were measured following the methodologies described in APHA, 1998.

2.4- Comparison with SLSI drinking water quality standards

The recorded values of measured physicochemical parameters were compared with SLSI 614, 2013 drinking water quality standards.

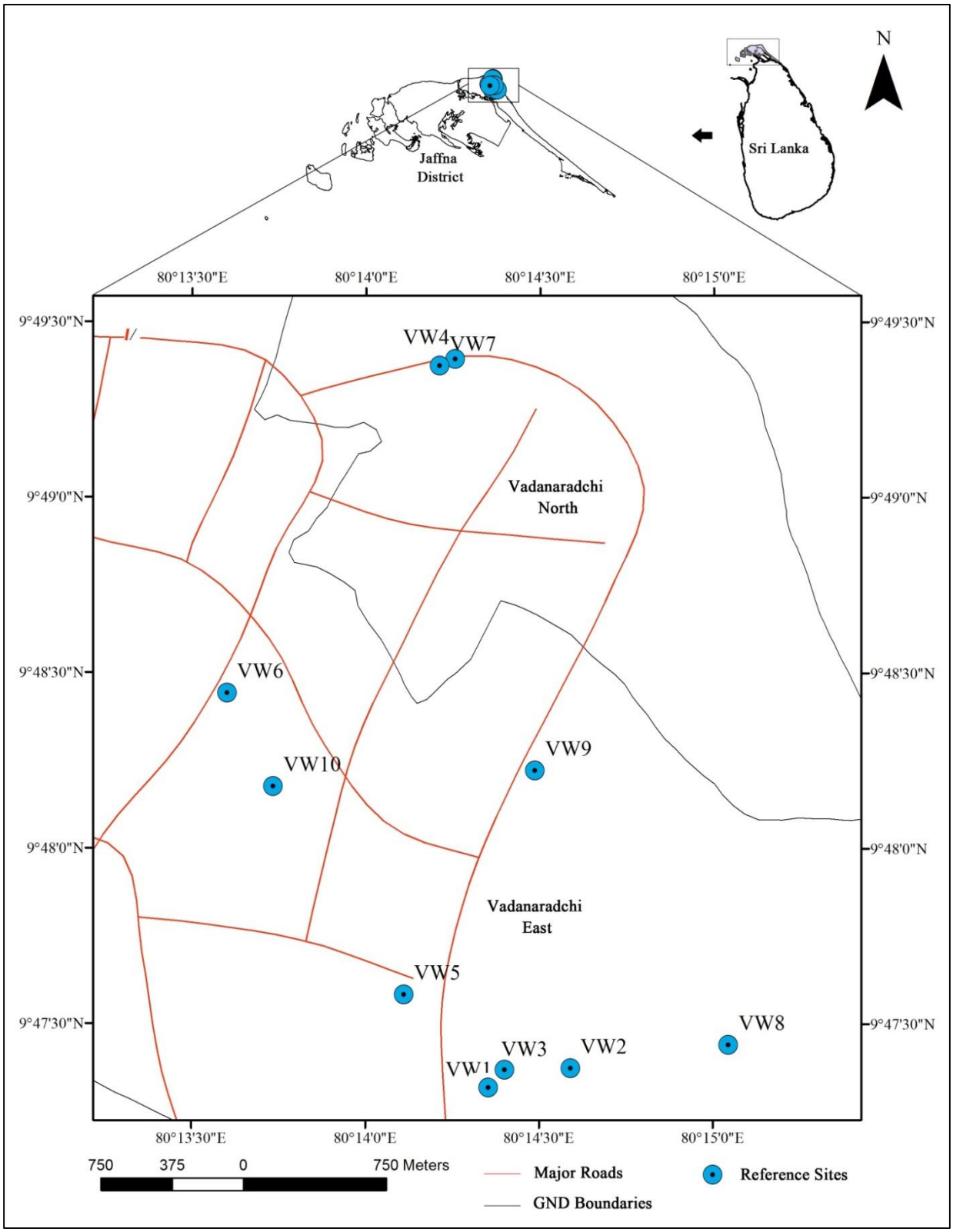

Figure 1: Map of the study areas

2.5- Comparison with water quality parameters in bottled drinking water

The water quality parameters before application of water treatments were compared with same water quality parameters measured in replicate samples of bottled drinking water (Knuckels brand). The water quality measurements were performed in accordance with the methodologies described in APHA, 1998.

2.6- Statistical analysis

Student t-test was used to analyze the variation in-between bottled drinking water and sampled domestic well water while paired t-test was used to compare the water quality parameters of treated water with raw water MINITAB 14 statistical software package was used for statistical analysis. Principal Component Analysis (PCA) was performed considering all the physicochemical parameters for control and sampling sites using Primer version 5.0 software package to identify the characterized physicochemical parameters of each sites and control.

2.7- Application of ArcGIS 10.2.2, for spatial interpolation

Spatial distribution of TH was analyzed using Spatial Analyst Tool of ArcGIS 10.2.2 software.

3.0- RESULTS & DISCUSSION

Spatial and temporal variation of water quality and comparison with SLSI drinking water quality standards and bottled drinking water

Comparison of the physico-chemical parameters of water from the collector and domestic wells in Vadamaradchi area with that of the bottled drinking water (Knuckles brand) and with the drinking water standards established by the Sri Lanka Standards Institution (SLSI 614, 2013) and the percentage of sampled wells exceeding SLSI drinking water standards are given in Table 1. The pH total dissolved solids (TDS), electrical conductivity (EC), total solids (TS), salinity, total hardness (TH), chemical oxygen demand (COD) and nitrate N of the well water were significantly higher than that of the bottled drinking water (Table 1). Mean TH of the sampled well were higher than the SLSI drinking water standards, while other parameters were within the SLSI drinking water standards (Table 1). There were no significant difference in dissolved oxygen concentration (DO), temperature and total phosphorous concentration (TP) of the well water and bottled drinking

water. The total hardness in well water in Jaffna Peninsula is comparatively higher than in other areas of the country due to the presence of calcium, magnesium, chloride and sulfate ion (Mikunthan, 2008). Thus, weathering of rock and the leaching of salts with rainfall and high permeability of soil causes rapid movement of ions which may be resulted high EC, TDS, TH, TS and salinity compared to bottled water.

Table 1: Compaison of Mean values ± SEM of physico-chemical parameters of well water collected from Vadamaradchi with bottled drinking water(Knuckles brand) and SLSI drinking water standards. For each parameter, mean values indicated by different superscript letters at each row are significantly different from each other ($p<0.05$)

Parameters	Vadamaradchi (Water collector wells)	Bottled water (Knuckles brand)	SLSI drinking water standards
pH	7.93 ± 0.08^a	7.12 ± 0.03^b	6.5-8.5
DO (mg/L)	7.27 ± 0.25^a	7.57 ± 0.02^a	Not mentioned
EC (µS/cm)	824.2 ± 68.8^a	58.1 ± 1.9^b	Not mentioned
TDS (mg/L)	405.6 ± 34.7^a	27.3 ± 0.8^b	500
Salinity (‰)	0.37 ± 0.03^a	0.03 ± 0.00^b	Not mentioned
Temperature (◦C)	29.82 ± 0.06^a	29.60 ± 0.14^a	Not mentioned
TS (mg/L)	568.0 ± 53.5^a	60.0 ± 1.1^b	Not mentioned
TH (mg/L,$CaCO_3$)	254.4 ± 14.6^a	56.60 ± 0.2^b	250
COD (mg/L)	7.55 ± 0.51^a	2.76 ± 0.10^b	10
Nitrate- N (mg/L)	1.69 ± 0.46^a	0.112 ± 0.001^b	11.2
TP (mg/L)	0.090 ± 0.005^a	0.091 ± 0.002^a	2.0

The results of the principal component analysis based on the physical and chemical parameters of well water of collector wells in Vadamaradchi areas and bottled drinking water is given in Figure 2. The eigenvalues of the first two principal components, eigenvectors of the water quality parameters and the principal component scores for the study sites are given in Table 2. Two principal components displaying a cumulative variance of 71.9% were obtained after

applying PCA on water quality parameters (Table 2). According to the results of the PCA on water quality parameters, the bottled drinking water, VW8 and VW2 were categorized together and were characterized by high DO. The wells VW1, VW3, VW4 and VW5 were characterized by high pH, COD and TP. VW7 and VW10 were characterized by high TH, TDS and conductivity (Figure 2, Table 2).

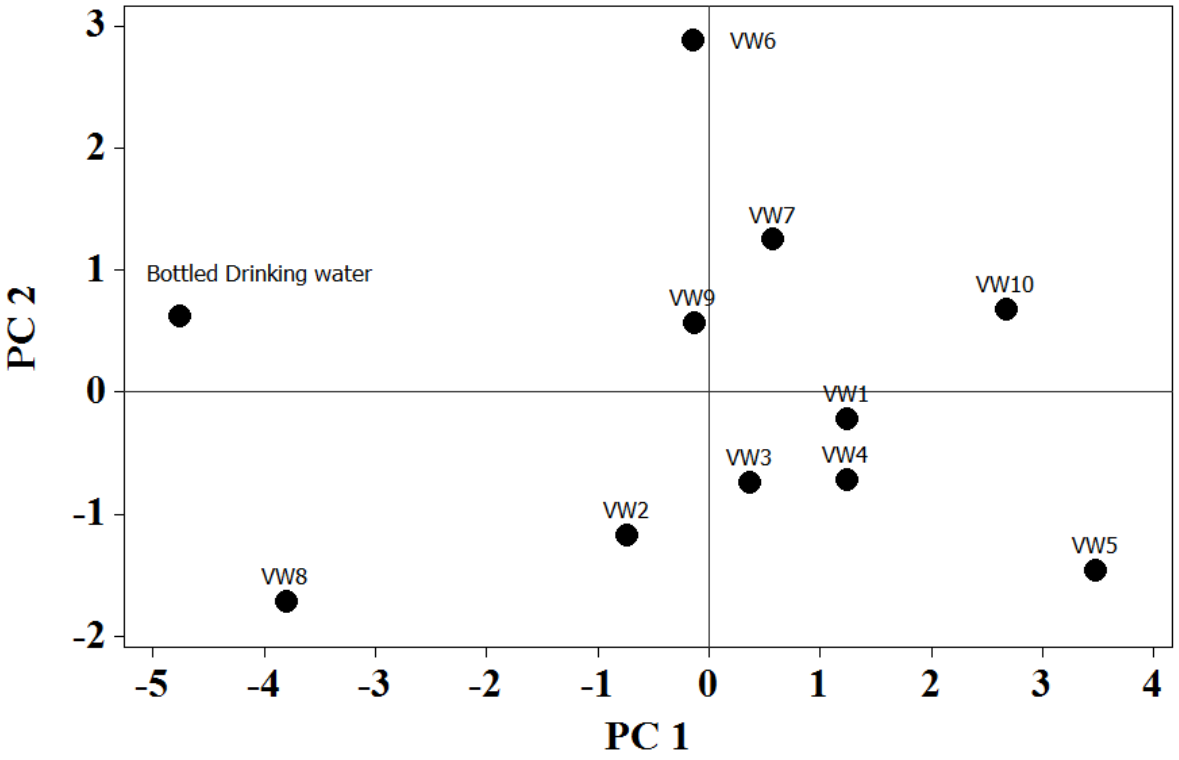

Figure 2: Ordination of the ten wells and the bottled water of PC1 and PC2 scores of Principle Component Analysis based on physico-chemical parameters

Table 2: Summary of the PCA of physico-chemical parameters of water sampled from the collector wells in Vadamaradchi areas. Cumulative % variation of only the PC1 and PC2 are shown. A high cumulative percentage as high as 66.2 % of the total variation among physico-chemical parameters are explained by PC1 and PC2 axis

Eigen values

PC	Eigenvalues	%Variation	Cumulative %Variation
1	6.05	55.0	55.0
2	1.86	16.9	71.9

Eigen vectors
(Coefficients in the linear combinations of variables making up PC's)

Variable	PC1	PC2	PC3	PC4	PC5
pH	0.182	-0.465	0.311	0.101	0.616
DO (mg/L)	-0.248	-0.224	0.487	-0.526	0.054
Conductivity (µS/cm)	0.383	0.126	0.158	-0.035	-0.220
TDS (mg/L)	0.335	0.212	0.301	-0.101	-0.090
Salinity (‰)	0.396	0.098	0.004	-0.169	-0.027
Temperature (°C)	0.216	-0.467	0.045	-0.389	-0.431
TS (mg/L)	0.394	0.046	0.110	0.020	-0.195
TH (ppm, CaCO3)	0.386	0.100	-0.013	0.259	0.110
COD (mg/L)	0.346	-0.221	-0.149	0.037	0.373
Nitrate- N (mg/L)	0.055	0.537	-0.118	-0.600	0.430
Total phosphate (mg/L)	0.125	-0.308	-0.707	-0.303	0.010

Spatial interpolation of total hardness in the study area in May, July and September 2016 are given in Figure 3. In this study period, May, 2016 was inter monsoonal with heavy storm and July and September 2016 were dry period. The maps generated from ArcGIS 10.2.2 showed the area with higher TH was increasing from May to September. However, VW8 was within the lowest TH level throughout the study period (Figure 3). This temporal variation of TH during the study period may be resulted due to the declining of shallow fresh water lens in the study area thereby concentration Ca^{2+} over time (Panabokke, 2007).

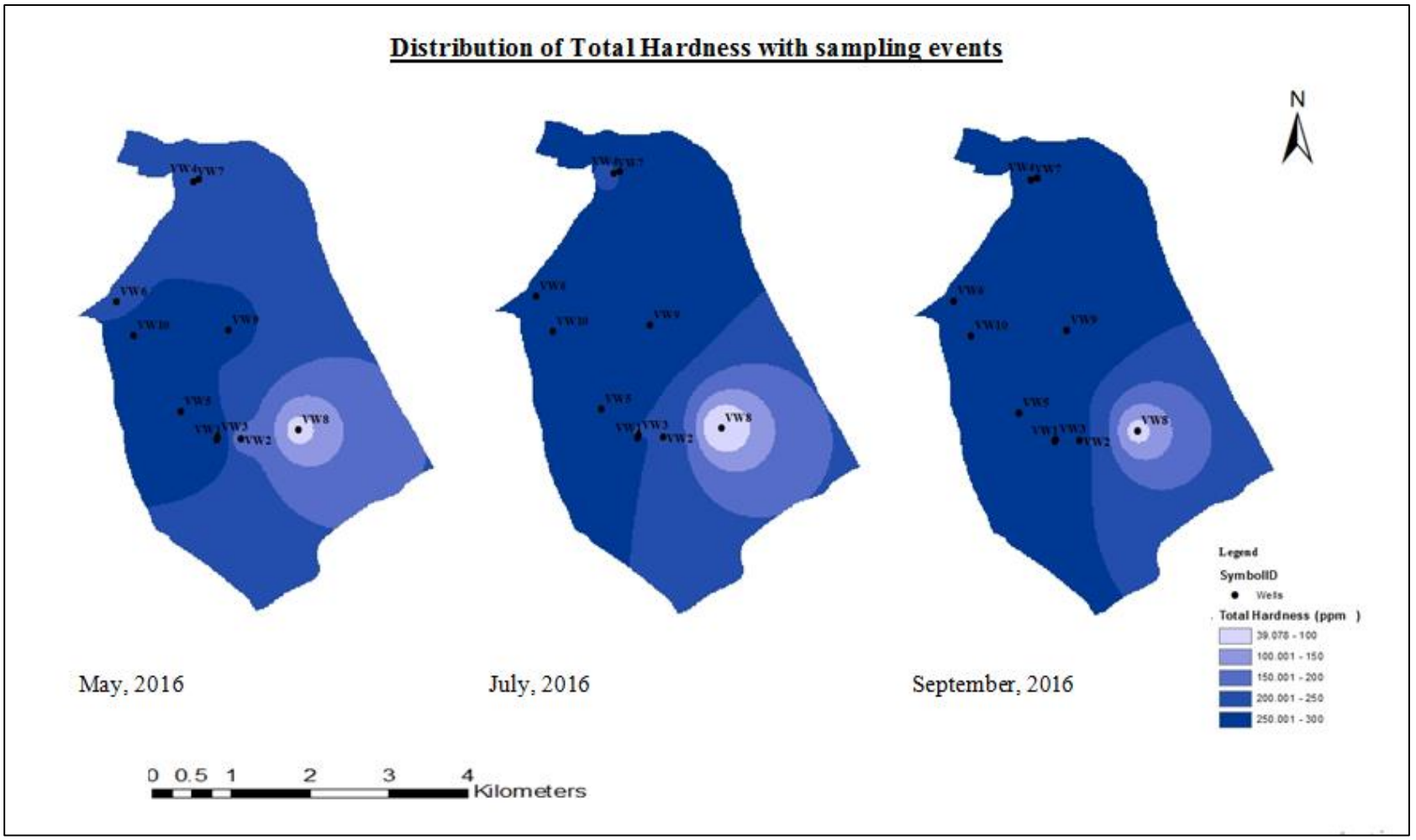

Figure 3- Spatial interpolation of total hardness in the study area in May, July and September 2016.

Home remedial methods for higher TH

The SLSI standard of TH for safe drinking water is 250 mg/L (SLSI 614, 2013). According to WHO standards, there is no observed impact due to TH up to 500mg/L (WHO, 2011). However, the residents of Jaffna Peninsula consume waters with high levels of TH exceeding SLSI standards, but less than 500mg/L over the decades. Water exceeding the drinking water standards cannot be recommended for consumption without treatment. This may cause formation of bladder stones with the higher phosphate concentration. In addition to health effects precipitation within the plumbing and pipes may occur and also soaps and detergents are not readily dissolvable in hard water (WHO, 2011). The variation of Mean±SEM of total hardness, of water after each treatment are given in Table 3.

The filtration through commercial mineral filter did not reduce TH significantly. However, the frequent changing of the mineral stones of the filter may help to increase the TH reduction ability. Filtration through *Moringa oleifera* leaf powder caused a significant increase of TH in the water samples. *Moringa oleifera* leaf powder have been successful in treating water with high nitrate concentrations (Wijeyaratne and Suvendran 2017). But the present study indicates that it cannot be successfully used in treating hard water. *Moringa* leaf powder is rich with freely available Magnesium and Calcium (Gopalakrishnan, 2016). This may be a possible reason for a significant increase in TH after filtration. However, boiling water at 100^0C for 10 minutes significantly reduced TH. The boiling of water caused approximately 16 % reduction of total hardness (Table 3). Therefore, boiling can be recommended as a suitable home remedial technique to reduce TH.

Table 3: Mean ± SEM of total hardness before and after each treatment. The mean values indicated by different superscript letters at each row are significantly different from each other (paired t test, $p<0.05$)

Treatment	Raw water	Treated water
Filtration by commercial mineral filter	235.4 ± 23.3^a	239.7 ± 19.2^a
Filtration by *Moringa olifera* leaf powder	258.8 ± 31.1^a	315.3 ± 23.0^b
Boiling at 100ºC for 10 minutes	269.0 ± 22.0^a	226.5 ± 15.2^b

4.0- REFERENCES

APHA. (1998). Standard methods for the examination of water and wastewater (19th Ed.). American Public Health Association, American Water works Association, Water Environment Federation Publication. Washington D.C.

Gopalakrishnan, L., Doriya, K. and Kumar, D.S. 2016. Moringa oleifera: A review on nutritive importance and its medicinal application. Food Science and Human Wellness, 5(2), pp.49-56.

Hidayathulla, M.S.M. and Karunaratna, G.R.R. (2013). Assessment of Groundwater Quality in Shallow Aquifers in Jaffna Peninsula, In Proceedings to 29th Technical Sessions of Geological Society of Sri Lanka, Vol. 109, p. 113.

Kožíšek, F. (2003). Health significance of drinking water calcium and magnesium. National Institute of Public Health Czech Republic, pp.1-29.

Kumara, I., Rathnayaka, S., Mayadunne, M. and Rajapakse, R. (2013). Assessment of groundwater quality in Jaffna peninsula. Journal of Geological society of Sri Lanka, Vol 15, pp.137-146.

Mikunthan, T. and De Silva C.S. (2008). Vulnerability assessment for shallow aquifers using chemical quality of groundwater: a case study from Thirunelvely and Kondavil in Jaffna district. Tropical Agricultural Research, vol. 20, pp.303-312.

Panabokke, C.R. and Perera, A.P.G.R.L. (2005). Groundwater resources of Sri Lanka. Water Resources Board, Colombo, Sri Lanka. 28p.

Panabokke, C.R.(2007). Groundwater conditions in Sri Lanka. National Science Foundation of Sri Lanka. 149 p.

Sivarajah, N. (2003). Health related problems of water pollution in Jaffna. International workshop on environmental management in north- east Sri Lanka. 1st - 4 th December, 2003. Thirunelvely, Jaffna, Sri Lanka. pp 89-94.

Sri Lankan Standards 614: 2013. Drinking water standard - First Revision, 2013.

Sri Lankan Standards 614: part 1,1983. Specification for potable water physical and chemical requirements. p. 5-10, 1983.

WHO (2011). Guidelines for drinking water quality. 4th edition. World Health Organization-2011, Geneva.

Wijeyaratne, W.M.D.N and Suvendran S. (2017). Assessment of the Efficacy of Home Remedial Methods to Improve Drinking Water Quality in Two Major Aquifer Systems in Jaffna Peninsula, Sri Lanka. Scientifica, vol. 2017, Article ID 9478589, 6 pages, 2017. doi:10.1155/2017/9478589.