Analysis of spatial variability of groundwater quality in different climatic zones of Sri Lanka

By

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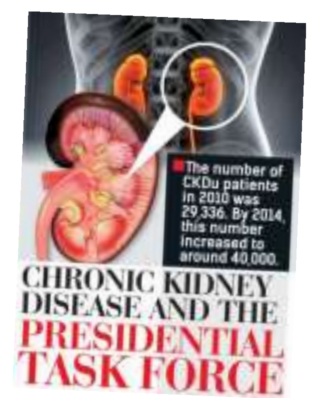
Introduction

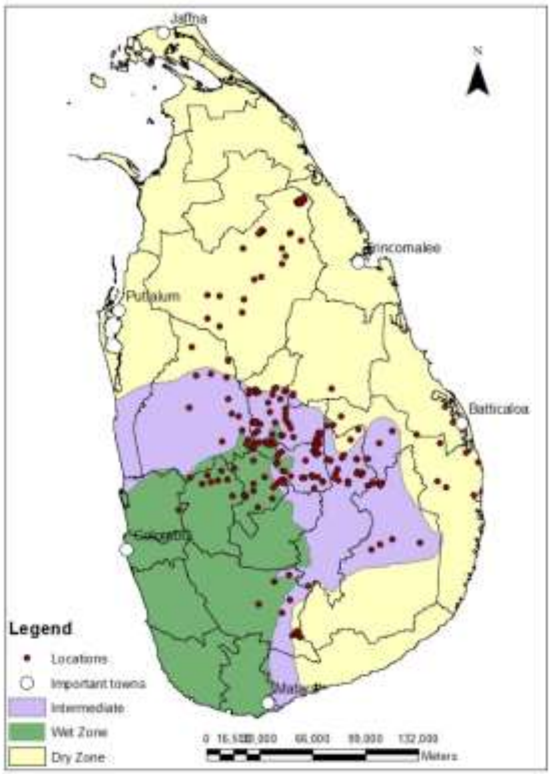
- Wet zone – rainfall > 2500 mm per year
- Dry zone – rainfall <1500 mm per year
- Intermediate zone – 1500<rainfall<2500mm per year

Objective

- Investigate the groundwater composition and calculate Water Quality Index (WQI) that determine the groundwater quality in different climatic zones of Sri Lanka



Ground water sampling locations



Sample strategy	
Sample type	No of samples
Ground water (dug wells)	149
Tube wells	45

Sampling locations were selected depending on the intensively paddy cultivated areas covering the three main climatic zones of Sri Lanka.,

Wet Zone (Kandy,Kegalle, Gampaha)

Dry Zone (Ampara, Auradhapura, Polonnaruwa)

intermediate zones (Kurunegalla,Monaragala,Matale and Rathnapura)

The study mainly focuses on the ground water (dug wells & tube wells) nearby paddy fields

Chemical Analysis in laboratory

Figure : Sample preparation & arrangement for chemical analysis

Measuring major elements using Atomic Absorption Spectroscop y

Measuring other chemical parameters by Hach DR 2700 spectrophoto meter and titrimetric method

pH, EC- Sension+ 150MM portable pH meter

Water Quality Index (WQI) - (Horton 1965) & Brown et al. (1970)

WQI was calculated using pH, Total Alkalinity, Total Hardness, Chloride, Sulfate, Nitrate, Phosphate, Fluoride and major cations.

$$WQI = \sum_{i-1}^{n} w_i\, q_i / \sum_{i=1}^{n} w_i$$

w_i – unit weight water quality for the ith parameter
q_i - the quality rating scale of the ith parameter.

$$w_i = \frac{k}{v_S}\text{-------}(1)$$

$$k = \frac{1}{\sum_{i-1}^{n} v_i}\text{----}(2)$$

$$q_i = \frac{(v_i - v_o)}{(v_S - v_o)}\text{------}(3)$$

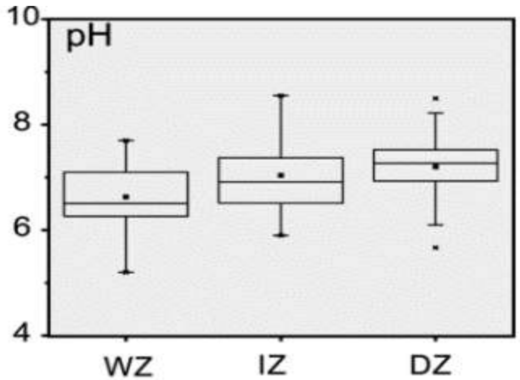
k - proportionality constant
v_i - estimated concentration of the ith parameter in the laboratory analysis,
v_o - real value of the ith parameter in pure water (v_0 = 7 for pH and 0 for other parameters)
V_s – Sri Lankan standard value

Table: Water quality rating as per the weight arithmetic water quality index method

WQI value	Rating of water quality
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for drinking purposes

Climatic Zone	Values	pH	EC µS	TDS ppm	HCO3⁻ ppm	NO_3^- ppm	Hard ppm	PO_4^- ppm	SO_4^{2-} ppm	F^- ppm	Cl^- ppm	Na^+ ppm	K^+ ppm	Mg^{2+} ppm	Ca^{2+} ppm
Wet zone	Minimum	5.2	31.8	38.5	3.6	0.5	5.5	0.05	0.7	<dl	4.75	1.21	0.34	0.55	0.88
	Maximum	7.7	1223	4523	244.3	4.3	279.9	0.4	54.5	1	120	75	6.99	32.3	72
	Average	6.63	273.21	581.51	77.68	1.19	88.7	0.19	8.75	0.33	26.73	13.5	2.4	9.54	19.8
Intermediate zone	Minimum	5.04	0.03	38.5	12	0.21	4	0.02	<dl	<dl	7	17	0.21	0.21	0.87
	Maximum	8.08	964.2	4523	392	11.5	444	5.86	78	2.12	99	150	10.2	41.4	157
	Average	6.84	383.31	581.51	163.5	3.02	152.2	0.9	11.14	0.53	32.68	27.3	1.88	9.81	45.1
		5.67													
Dry zone	Minimum	5.71	90.2	38.5	20	0.5	21.6	0.08	0.1	0.04	4.4	8.49	0.35	0.85	4.78
	Maximum	8.5	3310	4523	787.3	2.6	1123.8	1.46	230	3.9	1001	600	90	121	300
	Average	7.17	1035.5	581.51	218.5	1.02	222.91	0.412	28.33	0.7	185.3	107	5.75	35.1	47.5

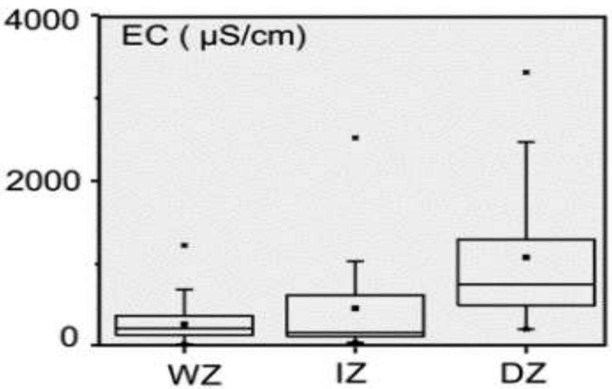
Variation of Groundwater Quality due to agricultural practices



pH

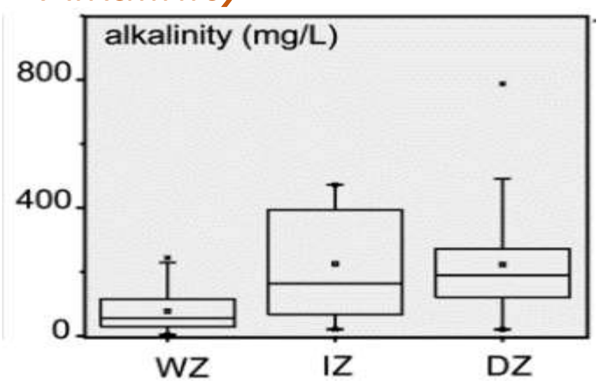
- Groundwater in wet zone showed much acidic nature due to the lateritic soils in the region and/or due to decomposing of organic litters under wet–warm climatic conditions that prevails in the area.
- Over 73% of the groundwater samples from intermediate and dry zone are alkaline in nature.
- Higher evaporation rates under prevailing dry conditions could increase the pH of groundwater in the dry and intermediate zones.

Electrical Conductivity (EC)



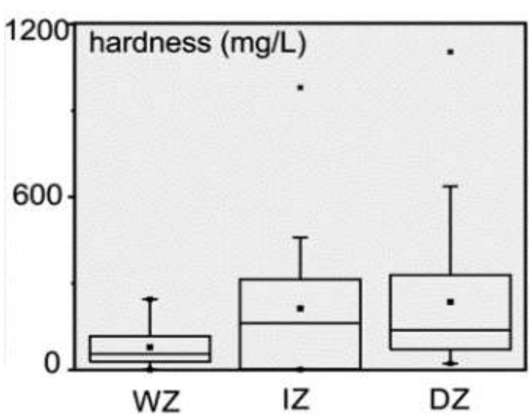
- All wells in the wet, intermediate zone and 77% of the groundwater samples from the dry zone were within the permissible limit of 1500 µS cm^{-1} (Fawell *et al.*, 2003).
- Dry zone characterized by low rainfall and high ambient temperature, groundwater tends to move upward, and more salts can accumulate during evaporation.

Alkalinity



- Alkalinity in the groundwater may be due to hydroxides, carbonates and bicarbonates
- HCO_3^- ion is the main dominant anion in the study area
- The alkalinity of all samples lies between 3.6 and 787 mg L^{-1}
- Bicarbonate ions are the major contributor of alkalinity in ground water

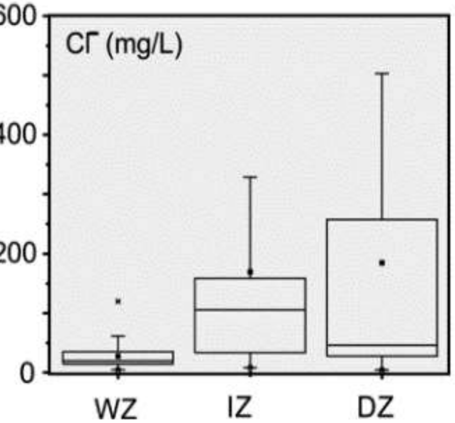
Total Hardness



Total hardness expressed as $CaCO_3$ in the dry zone regions is higher than in wet zone regions

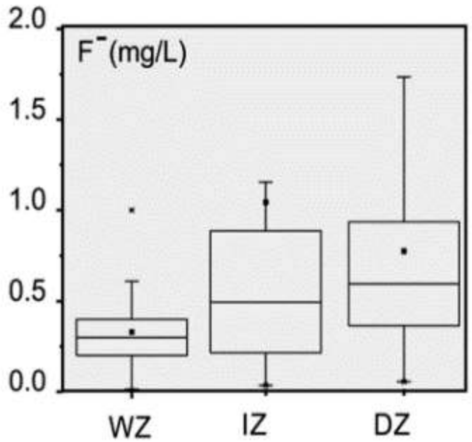
About 30% of wells in the dry zone exceeded the desirable limit of 300 mg L^{-1}, and nearly 10% of the wells exceeded the allowable limit of 600 mg L^{-1}.

Long-term consumption of hard water may increased incidence of some types of cancer, and chronic kidney diseases which widely spread in the dry and intermediate zone in Sri Lanka (Chandrajith *et al*., 2010).



Chloride

- Highly soluble chloride can be leached from agricultural activities such as fertilizer applications, saline water intrusion or due to mixing or groundwater with irrigated water

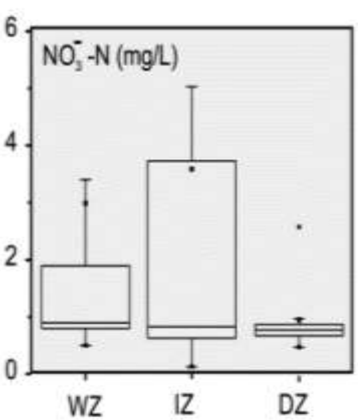


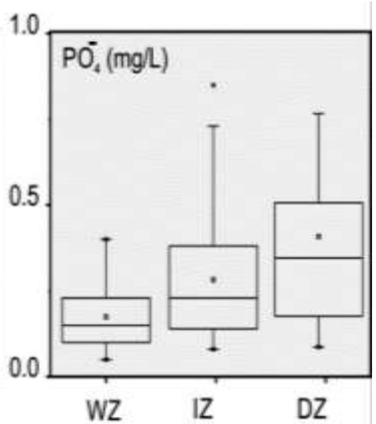
Fluoride

- In intermediate zone, 25% of groundwater and in dry zones, about 49% of the groundwater exceeded the 0.6 mgL^{-1} fluoride, the limit recommended for tropical countries (Status and Use, 1994)

high fluoride concentrations occurs due to - fluoride bearing rock types charnockites, hornblende-biotite gneiss etc.. (Dharmagunawardhane and Dissanayake, 1993)

Consumption of fluoride rich water longer period result - dental diseases (dental mottling and discolouration) and skeletal diseases





Nitrate-N

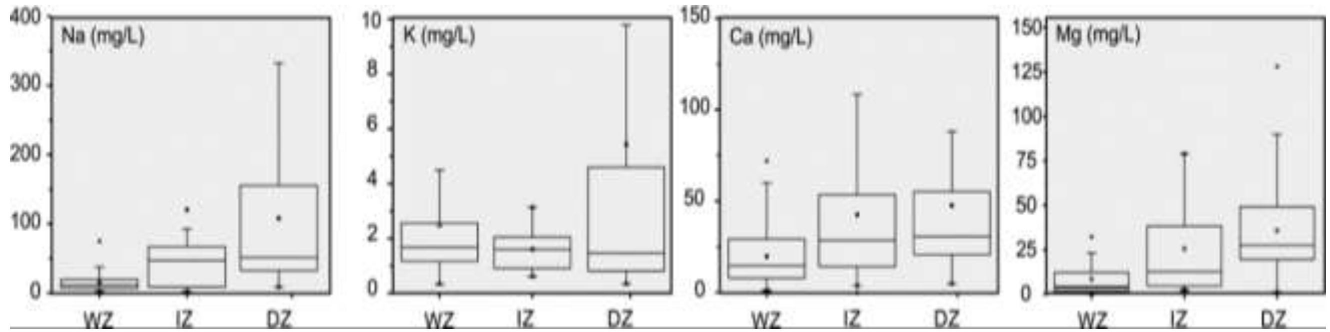
Several wells were exceeded the maximum contamination levels of WHO, 2013(10 mgL^{-1}).

Most of the samples were within the WHO safe level

Phosphate

Phosphate concentrations in groundwater exceeded the WHO maximum contamination limits (0.01 mg L^{-1}) indicating heavy fertilizer applications

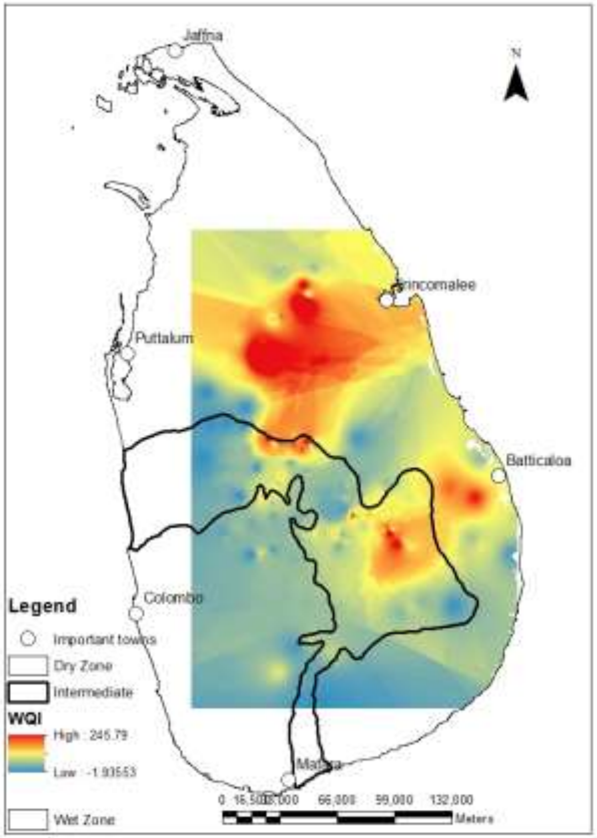
Major Cations in Ground water



Main anions - $HCO_3^- > Cl^- > SO_4^{2-} > F^-$

Main cations – $Na^+ > Ca^{2+} > Mg^{2+} > K^+$

- 12%, and 11% of groundwater samples in intermediate zone and dry zone were exceeded the desirable limit (100 mg L^{-1}) of Ca in groundwater while all samples in wet zone were safe within the limits of the WHO guideline (WHO, 2011).
- Na concentration exceeded the permissible level (200 mg L^{-1}, WHO 2011) in 18% in intermediate zone and 17% in dry zone groundwater.
- 6%, 29% and 48% of Mg content of the groundwater samples were exceeded its permissible limits (30 mg L^{-1}) in wet zone, intermediate zone and dry zone respectively



Water Quality Index (WQI)

WQI value	Rating of water quality	No. of wells		As Percentage, %	
		Dug wells	Tube wells	Dug well	Tube well
0-25	Excellent water quality	52	13	34.9	28.9
26-50	Good water quality	46	10	30.9	22.2
51-75	Poor water quality	30	14	20.1	31.1
76-100	Very poor water quality	8	3	5.3	6.7
>100	Unsuitable for drinking purposes	13	5	8.7	11.1

- WQI values range from 0.27 to 246.7
- 51.1 % of tube wells & 65.7% of dug wells are safe limits for drinking purposes.
- Dug wells water in the area needs treatment before consumption to reduce concentrations of hardness and fluoride

Figure: Spatial Distribution of WQI in groundwater samples

CONCLUSIONS

- Groundwater in intermediate and dry zones need treatment before consumption to reduce concentrations of hardness and fluoride, and need to be protected from the perils of contamination.
- 62.4% water samples are good quality while 15.46% water samples were found very poor and unsuitable category.
- Poor groundwater quality areas (22.7%) are the highest vulnerable areas for CKDu.
- WQI is mainly depend on Fluoride concentration in groundwater between climatic zones
- WQI can be excellent and easy interpretation indicator to detect changes in water quality considering their physio-chemical parameters.

REFERENCE

- Aturaliya, T.N.C., Abeysekera, D.T.D.J. and Amerasinghe, P.H. (2003). Chronic renal failure, towards understanding the current trend, Kandy Society of Medicine Annual SessionsChandrajith, R., Nanayakkara, S., Itai, K., Aturaliya, T., Dissanayake, C., Abeysekera, T., Harada, K., Watanabe, T. and Koizumi, A. (2010) Chronic kidney diseases of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications. Environmental geochemistry and health 33(3), 267-278.
- Dharma-Wardana, M., Amarasiri, S.L., Dharmawardene, N. and Panabokke, C. (2015) Chronic kidney disease of unknown aetiology and ground-water ionicity: study based on Sri Lanka. Environmental geochemistry and health 37(2), 221-231.
- Fonseka,S., Jayasumana, C., Jayalath,K., Amarasinghe, M., Senanayake, K., Wijewardhane, C., Samarasinghe, D., Dahanayake, K., Mahamithawa, P. and Paranagama, P. (2012). Arsenic and hardness in ground water from chronic kidney disease of unknown etiology (CKDu) prevalent areas and non-CKDu prevalent areas in Sri Lanka, Symposium Proceeding, International Symposium on water quality and human health:Challenges Ahead, 22-23 March, University of Peradeniya, Sri Lanka
- Ileperuma, O., Dharmagunawardhane, H. and Herath, K. (2009) Dissolution of aluminium from sub-standard utensils under high fluoride stress: a possible risk factor for chronic renal failure in the North-Central Province. Journal of the National Science Foundation of Sri Lanka 37(3).

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