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Drinking Water Quality on Chronic Kidney Disease of Unknown Aetiology (CKDu) in *Ulagalla* Cascade, Sri Lanka

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Abstract

Chronic Kidney Disease of unknown aetiology (CKDu) is one of the major health issues in Northern part of Sri Lanka that recorded highest mortality and morbidity rates. The main responsible reason for the CKDu has not yet been identified and hence many scientists have suggested number of certain risk factors where the CKDu-mfo (CKDu multi-factorial origin) term derived. However it relates with certain drinking water quality parameters strongly. This study was focused on evaluating the drinking water quality of *Ulagalla* cascade in Anuradhapura district with admiration to CKDu. Thirty wells and twenty tanks were selected as sampling locations for groundwater (GW) and surface water (SW) respectively from the cascade. Water quality parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, Sodium (Na^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Potassium (K^+), Arsenic (As^{2+}), Lead (Pb^{2+}), Cadmium (Cd^{2+}), Ammonium Nitrogen (NH_4^+-N), Nitrate Nitrogen (NO_3^- -N), alkalinity, Sulphate (SO_4^{2-}, Chloride (Cl^-) and Phosphate (PO_4^{3-}) were analysed and observed parameters were compared with drinking water quality standards. In GW turbidity, Mg, Cl^- and Cd were not significantly different from the maximum permissible level ($p>0.05$) while SW has shown significant difference only for the turbidity ($p>0.05$). Both well and tank water samples from *Thodamaduwa* were polluted by Cd which exceeded the maximum permissible level standards. It was recorded as averages of 0.15, 0.13 and 0.019 ppb for 3 identified polluted wells in GW and 0.01ppb in tank water. Accordingly the study it can be suggested that cumulative levels of heavy metals (such as Cd) may be aggravating the CKDu in the Northern Central Parts in Sri Lanka.

Key words: Chronic Kidney Disease of unknown aetiology, Surface water, Ground water, Drinking water quality, Drinking water quality standards

Introduction

The dry zone of Sri Lanka is well-known as the cradle of island's hydraulic civilization with the foremost kingdom, Anuradhapura. The adjustable environmental conditions with land availability in dry zone have become the key reasons to this agricultural extent throughout the area. Average annual rainfall in the dry zone is generally 1000mm mostly from October to December and has a dry period from late May to September [Burt & Weerasinghe, 2014]. The tank cascade system (TCS) is the most advanced water conveyance mechanism developed to overcome water scarcity problems in dry zone from the ancient irrigation history [Mahatantila *et al.*, 2008]. Water in tanks is generally used for agricultural and domestic purposes including drinking [Jayawardena, 2015]. As TCS is a connected series of tanks organized within a micro catchment, the head water tank is principally nurtured from rainfall and river conversion while the irrigation channels distributing water through downstream [Bandara, 1985]. Tail end tank of TCS may significantly polluted as a result of intensive application of agrochemicals in paddy fields that were not evident in ancient time [Kumari *et al.*, 2013]. As a result of polluted water intake, there is some health concerns reported from the people inhabited in the dry zone.

With reporting huge number of patients with a diseased kidney due to non-recognized reasons and by extending that statistic drastically during past two decades, the dry zone gained more advertence of government, public and private and academic organizations. It is been suggested that CKDu can be oriented through very long agricultural history of the dry zone as it is very common farmers or agricultural labourers.

Chronic Kidney Disease of unknown aetiology (CKDu) is one of the greatest problem in north central province (NCP) which recorded highest mortality and morbidity rates and recognized reasons were unknown [Ratnayake *et al.*, 2012, Noble *et al.*, 2014]. CKDu is very aggressive disease with absence of certain responsible causes and very common among men (proportion of male: female is 3:1) who are in approximately the age of 40-60 years, and most of them are farmers or agricultural labourers. Dialysis or kidney transplant are the only medical solutions for this disease. The cost of dialysis of CKDu patients has become a severe problem on the government health authorities [Chandrajith *et al.*, 2011a]. Consequently, nearly 80% of these patients ultimately die from kidney failure within the first two years [Misra & Saxena, 2012].

During last two decades, mortality and morbidity rates have been increasing progressively, due to kid-

Table 1: WHO (fourth edition) and SLS standards for drinking water

Parameter	Maximum per-missible level WHO (Fourth edition 2011)	Maximum per-missible level SLS (614: 2013)	Maximum per-missible level (Accepted)
pH	6.5 -8.5	6.5 -8.5	-
Electrical Conductivity (μS/cm)	-	-	1500*
Total Dissolved solids (mg/L)	600	500	-
Turbidity NTU	-	2	5
Alkalinity (mg/L)	500	200	
Calcium (mg/L)	100**	100	
Magnesium(mg/L)	30	30	
Sodium (mg/L)	200	200	
Chloride (mg/L)	250	250	
Phosphorus (mg/L)	5	2	
Nitrate Nitrogen (mg/L)	50	50	
Ammonium Nitrogen (mg/L)	0.5	0.2	
Sulphate (mg/L)	250	250	
Arsenic (mg/L)	0.01	0.01	
Cadmium (mg/L)	0.003	0.003	
Lead (mg/L)	0.01	0.01	

*EC is not interpreted for drinking water in WHO or SLS standards. Hence the study used the standard value from http://www.google.lk/url?sa=t&source=web&rct=j&url=http://mrccc.org.au/wp-content/uploads/2013/10/Water-Quality-Salinity-Standards.pdf&ved=0ahUKEwiqn9Xy-bTbAhVJhbwKHRfOCpoQFggkMAE&usg=AOvVaw3GBXHTkDWptYNh3HeDHIxT
** Interpreted as Hardness of water in WHO fourth edition.

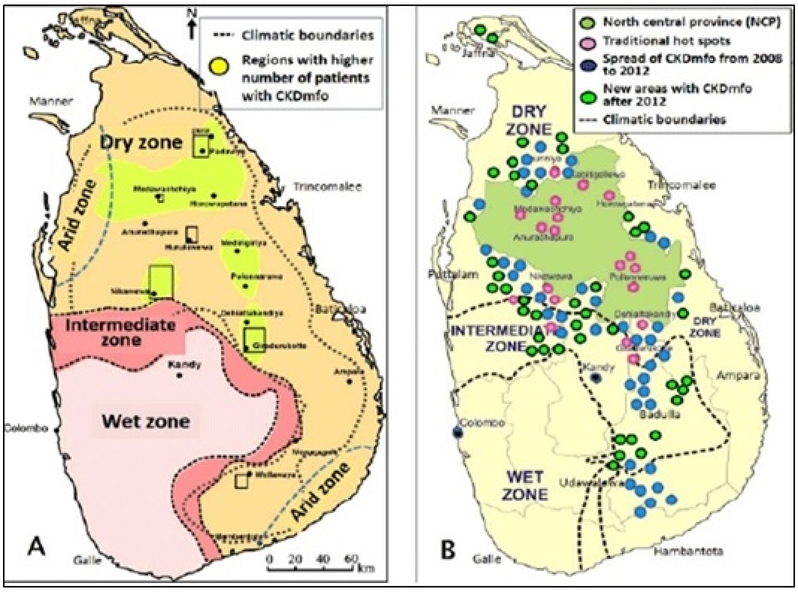

Figure 1: Prevalence of CKDu in Dry zone (1A: Regions where recorded patients with CKDu, 1B: Traditional hotspots and the spreading of CKDu with time.

Table 2: Sampling locations for SW

Tank No.	Name
T1	Thodamaduwa
T2a	Ulagalla
T2b	Ulagallamahawewa
T3	Manakkulama
T4	Wagayakulama
T5	Karabayagama
T6	Pudukkulama
T7	Diwulwewa
T8	Periyakulama
T9	Athiniwetunuwewa
T10	Ulankulama
T11	Itikattiya
T12	Ihalawewa
T13	KudaItikattiya
T14	Maradankadawala
T15	Halmillewa
T16	Settikulama
T17	Heenukgama
T18	Galwiharawewa
T19	Pahalawewa

ney related diseases in dry zone. Dry zone has been reported highest prevalence rates in North Central Province, Eastern Province and Uva province. When counting on the reasonable causes for CKDu, several studies have proven that there should be a profound relationship between drinking water quality and CKDu [Wanigasuriya, 2012, Chandrajith *et al.*, 2011a]. People from dry zone mainly acquire water from tanks and dug wells for agricultural issues for their domestic and agriculture purposes. *Ulagalla* is a small cascade that extended in Maradankadawala and Thirappane areas with 20 small tanks and 1100 farming families. They are acquiring drinking water from tanks/reservoirs (1%), shallow dug wells (92%) mostly as well as tube wells (7%) in some circumstances [Jayasekara *et al.*, 2013]. The population is vulnerable to unknown diseases as the area is being used for agricultural practices with heavy use of agrochemicals and fertilizer which is being transporting through those water resources for hundred years. So the water quality should be checked for the potential of CKDu of that area.

Ulagalla cascade is one of the prominent cascades in Anuradhapura district with twenty small tanks highly utilizing for agricultural purposes and still no any study has been conducted to evaluate water quality in the cascade with relevant to CKDu. Hence the present study has been conducted to characterize the surface water (SW) and ground water (GW) quality with CKDu in mentioned cascade. The aim of the study was to evaluate the GW and SW quality parameters and its subsequent comparison with World Health Organization, [WHO, 2011] and Sri Lankan Standards for potable water (SLS 614, 1983) related to CKDu in "*Ulagalla* Cascade" in Anuradhapura district, North Central Province, Sri Lanka.

Even if numerous studies have been conducted in Sri Lanka, the main responsible reason for CKDu is not yet identified. Hence many of the scientists and researchers have suggested number of certain risk factors where the CKDu-mfo (CKDu multi factorial 3 origin) term derived. CKDu-mfo described combination of two or more of risk factors and its synergistic effect could be accountable for CKDu [Wimalawansa, 2015]

Kidney disease with recognized causes are absent is named 'Chronic Kidney Disease of Unknown aetiology' (CKDu) and believing it is due to two or more factors, CKDumfo term is being using for this disease. Especially the areas such as Medawachchiya, Padaviya, Kebitigolawa, Medirigiriya (North Central Province), Nikawewa (North Western Province), Dehiattakandiya (Eastern Province) and Giradurukotte (Uva Province) were highlighted as threatened areas [De Silva *et al.*, 2011]. Among two districts of NCP (Anuradhapura and Polonnaruwa) Anuradhapura has affected more and the disease is on the increase [Abeygun. & Wick., 2014]. In 2012 the number of patients has further increased to 8000 [WHO, 2012]. In Anuradhapura District alone 18,000 cases of CKDu were reported with over 200 deaths recorded annually [Abeygun. & Wick., 2014]. For Anuradhapura, Polonnaruwa and the whole country in 2007, CKD had been the 1^{st}, 2^{nd} and 9^{th} leading cause of death respectively [Fernando, 2011].

Figure 1 shows the prevalence of CKDu in Dry zone area, regions with highest number of patients and newly recognized hotspots of that critical issue. The affected area covers around 17,000 km^2 and with a population of near 2.5 million in which over 95% live in rural areas [Wimalawansa, 2014].

Several risk factors were suggested during the last decade, to assume the occurrence and aetiology of the CKDu in the NCP [Wanigasuriya, 2012], but origin of the disease is still in problem and in the search [Gunatilake *et al.*, 2014]. Causes such as overuse of pain killers, use of cheap aluminium cookware, habit of illegal drugs and alcohol, leptospirosis, smoking, petrochemical contamination, unsafe working conditions, longterm consumption of contaminated water and food, genetic susceptibility, lack of safety measures when using agrochemicals, Ayurveda medicines, and previous inci-

Table 3: Monitored water quality parameters and methods of analysis

Parameter	Method of analysis
pH and Electrical Conductivity (EC)	Multi parameter analyser (HACHHQ40d)
Total Dissolved Solids (TDS)	Multi parameter analyser (EUTECH PCD650)
Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, As^{3+}, Pb^{2+}, Cd^{2+}	ICP-OES(Thermo ICAP 7400)
Ammonium nitrogen	4500NH F phenate method(APHA 1998)
Nitrate nitrogen	Salicylic acid method(APHA 1998)
Alkalinity	Acid base titration(APHA 1998)
Phosphate	Ascorbic acid method (APHA 1998)
Turbidity	Turbid meter (EUTECH TN-100)

dents of snake bites were reported [Wanigasuriya, 2012, Wimalawansa, 2014]. Harmful agricultural practises, including excessive and indiscriminate use of toxic agrochemicals (fertilizers, pesticides, and weedicides), lack of safety measures when using agrochemicals, intake of contaminated water from paddy fields and from contaminated ground water wells, have led to the increase of this widespread disease in NCP [Wimalawansa, 2014, Chandrajith *et al.*, 2011a, Chandrajith *et al.*, 2011b, Daily mirror, 2013]. Regardless of this deadly disease, many farmers in NCP practised to use excessive amounts of agrochemicals long term to get higher yields [Wimalawansa, 2014]. Hardness or high amount of fluoride in water, use of cheap aluminium cookware, ionicity in drinking water are suggested as multi factorial causes for this disease [Kumari *et al.*, 2016]. Among these factors drinking water related factors were discussed and argued by literature .

Drinking water quality parameters are apparently related with the occurrence of the CKDu [Kumari *et al.*, 2016, Abeygun. & Wick., 2014]. Most of the agrochemicals (weedicides, insecticides, and fungicides) contain very high concentrations of Cadmium (Cd^{2+}), Arsenic (As^{3+}) and other heavy metallic substances [Keil, 2011, Illeperuma, 2000]. Through the studied which have been conducted in dry zone, Sri Lanka, Cd^{2+} and As^{3+} were supposed as risk factors for CKDu [Mendis, 2011]. Drinking water and rice contaminated with As^{3+} has been identified as the key motives for CKDu and through the theory, As^{3+} is being bio-accumulating in human bodies [Dharmawardana *et al.*, 2015]. Water hardness plays a great role to support heavy metals by cation exchange capacity while fertilizer runoff has increased the ionicity of ground water (Wanigasuriya, 2012). Toxins ingested from food and water, direct absorption of toxins due to uncaring management of agrochemicals, extended exposure to toxins and pollutants from drinking water are assumed as most reasonable risk factors [Dharmawardana *et al.*, 2015] .

The quality of drinking water is powerful environmental factor that determine the health of human. Therefore, the WHO and various national agencies have introduced drinking water quality standards that specify the permissible chemical, microbial and radiological characteristics of safe water (Table 1). Major drinking water sources of NCP people are 92% shallow dug wells, 7% tube wells, 1% reservoirs [Jayasekara *et al.*, 2013]. Most of the tested drinking water quality parameters are higher than the WHO recommended levels in NCP. However, within the NCP, small compartments of CKDu non-prevalence sectors also exists [Wanigasuriya, 2012].

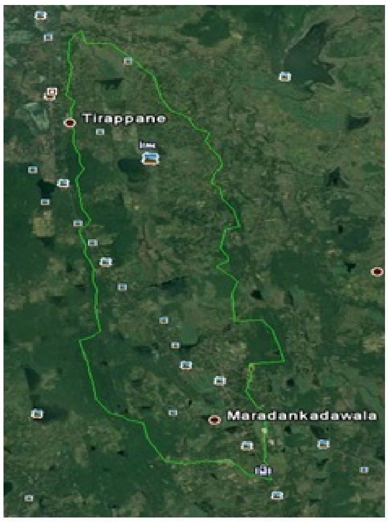

Figure 2: Study Area-*Ulagalla* cascade

Methods

Ulagalla cascade is a prominent cascade located in Anuradhapura district with twenty small tanks and highly utilizing for agricultural purposes [Kumudumali *et al.*, 2016]. It is located in DL1b agroecological region (Dry zone Low country) of Sri Lanka. Total number of farm families living in the study area was approximately 1100 and the total land area is about

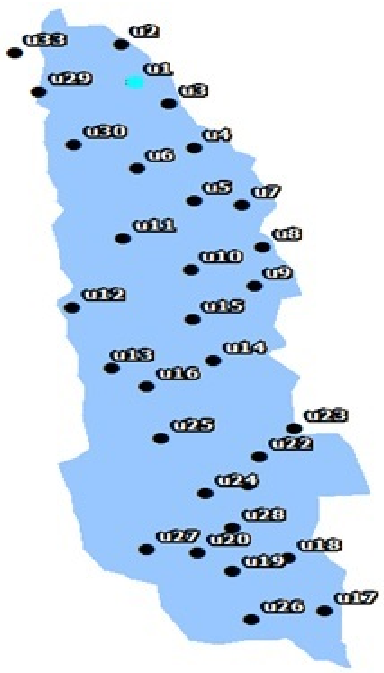

Figure 3: Sampling locations for ground water

25km^2 . Maradankadawala and Thirappane (figure 2), areas of *Ulagalla* cascade were selected for the sampling locations for both GW and SW.

Water samples were collected from all the 20 tanks (Table 2) for SW (T) and randomly selected 30 GW wells (Figure3) for ground water (U) in *Ulagalla* cascade in Anuradhapura.

The total area of the cascade was divided into 1 km^2 grids and one well to represent each grid was purposely selected from above mentioned villages to evaluate the quality of GW (thirty wells located in uplands). Availability of GW was assessed by measuring the depth to GW and the depth of well from the surface during three months of period.

The water samples were transferred into 250 mL clean polyethylene bottles after rinsing three times with the water to be sampled and labelled. Two water samples were collected from each sampling points once a month during three months (July, August and September). These bottles were tightly closed, labelled and transported to the Laboratory of soil and water science, Department of Agricultural Engineering and Soil Science, Faculty of Agriculture, Rajarata University of Sri Lanka. All the samples were stored below 40C temperature in a refrigerator.

All the water samples were filtered by using number 01 Whatman filter papers for further chemical analysis to evaluate all the cations, anions and heavy metals. Samples were stored below 40C and Table 3 shows the analysis methods for selected water quality parameters.

Geographical Information System (GIS) has been used for the study as a tool for storing, analysing and displaying spatial data. Once the input data was imported as a point layer into ArcGIS 10.1, geo-database was created to generate the maps of spatial distribution of selected ground water quality parameters. Interpolation is the process of predicting unknown values using the known values in the vicinity. Point based Inverse Distance Weighted (IDW) interpolation method was used to produce spatial distribution of GW quality variables. GIS is helpful to developing solutions for water resources problems for assessing water quality, determining water availability, preventing flooding, understanding the natural environment and mapping water resources on local or regional scale [Ferry *et al.*, 2003].

To evaluate measured drinking water quality parameters of GW and SW t test (one sample t test and two sample t test) was performed by using Minitab statistical software package.

Results and Discussion

Water quality parameters have been tested for both GW and SW in the *Ulagalla* cascade and recorded in Table 4. Obtained results had been comparatively discussed with the results obtained from previous studies to the dry zone by analysing same parameters in Kumari *et al.* (2016) and Chandarjith *et al.* (2011b). pH in GW has varied between the range of pH 6.7 8.7 and in the SW it was 5.8-8.2. When compared with the drinking water quality guideline values [SLS 614, 2013, WHO, 2011] 96.66% of GW wells and all the SW bodies (100%) were below the maximum permissible level, yet suitable for drinking purpose. Significant difference from one sample t test was observed for GW and SW ($p<0.05$).

Electrical Conductivity (EC) in drinking water is related to the presence of water salinity and ion (both cations and anions) content. Water hardness can be the reason for highest EC in water. EC in GW has varied from 427.10 μS/cm to 2590.67 μS/cm and EC of SW has varied from 94.25μS/cm to 806.33μS/cm in *Ulagalla* cascade. Based on world accepted standards for EC, 16.66% of GW wells and none of SW tanks were exceeded the maximum permissible level, then not suitable for drinking purpose. Obtained p values for one sample t-test of the recorded p value and SLS standards were 0 for both GW and SW. Kumari *et al.* (2016) reported the highest average EC values of GW in CKDu non prevalent areas. According to the Kumari *et al.* (2016) EC in GW were varied from 131.4μS/cm to 556 μS/cm in dry zone. Their maximum EC value of GW was below than the maximum EC value of GW in *Ulagalla* cascade. Chandarjith *et al.* (2011b) were documented highest average GW EC value as 3400 μS/cm thus, that value was comparatively higher than the average GW EC of *Ulagalla* cascade. According to the Kumari *et al.* (2016) average EC of SW was varied from 96.2 μS/cm to 299.0 μS/cm.

Water has the ability to dissolve a wide range of in-

Table 4: Recorded values for each parameter

Parameter	Observed values (GW)	Observed values (SW)	Maximum permissible level(MPL) for drinking water (WHO, 4*th* edition)	MPL for drinking water (SLS 614:2013)	Wells that recorded as not suitable for use	Tanks that recorded as not suitable for use
SO_4^{2-}	1.3370	116	250	250	All wells were below the MPL (Highest U13)	All tanks were below the MPL (Highest T3)
As^{3+}	0.030.44	0.020.19	10	10	All wells were below the MPL (Highest U1)	All tanks were below the MPL (Highest T12)
Pb^{3+}	1.768.85	0.592.8	10	10	All wells were below the MPL (Highest U13)	All tanks were below the MPL (Highest T5)
Cd^{2+}	U180.15; U190.13; U200.01	T10.01	3	3	All wells were below the MPL, however U18, U19 & U20 have reported Cd.	All tanks were below the MPL, however T1 has reported Cd.
PO_4^{3-}	0.181.05	0.080.18	5	2	All wells were below the MPL	All tanks were below the MPL
Alkalinity	33.33162.5	10.4270.83	200	200	All wells were below the MPL	All tanks were below the MPL
NO_3^-N	0.078.35	0.121.97	10	50	All wells were below the MPL (Highest U17)	All tanks were below the MPL (Highest T19)
NH_4^+-N	0.070.13	0.070.24	0.5	0.2	All wells were below the MPL (Highest U6)	All tanks were below the MPL (Highest T19)

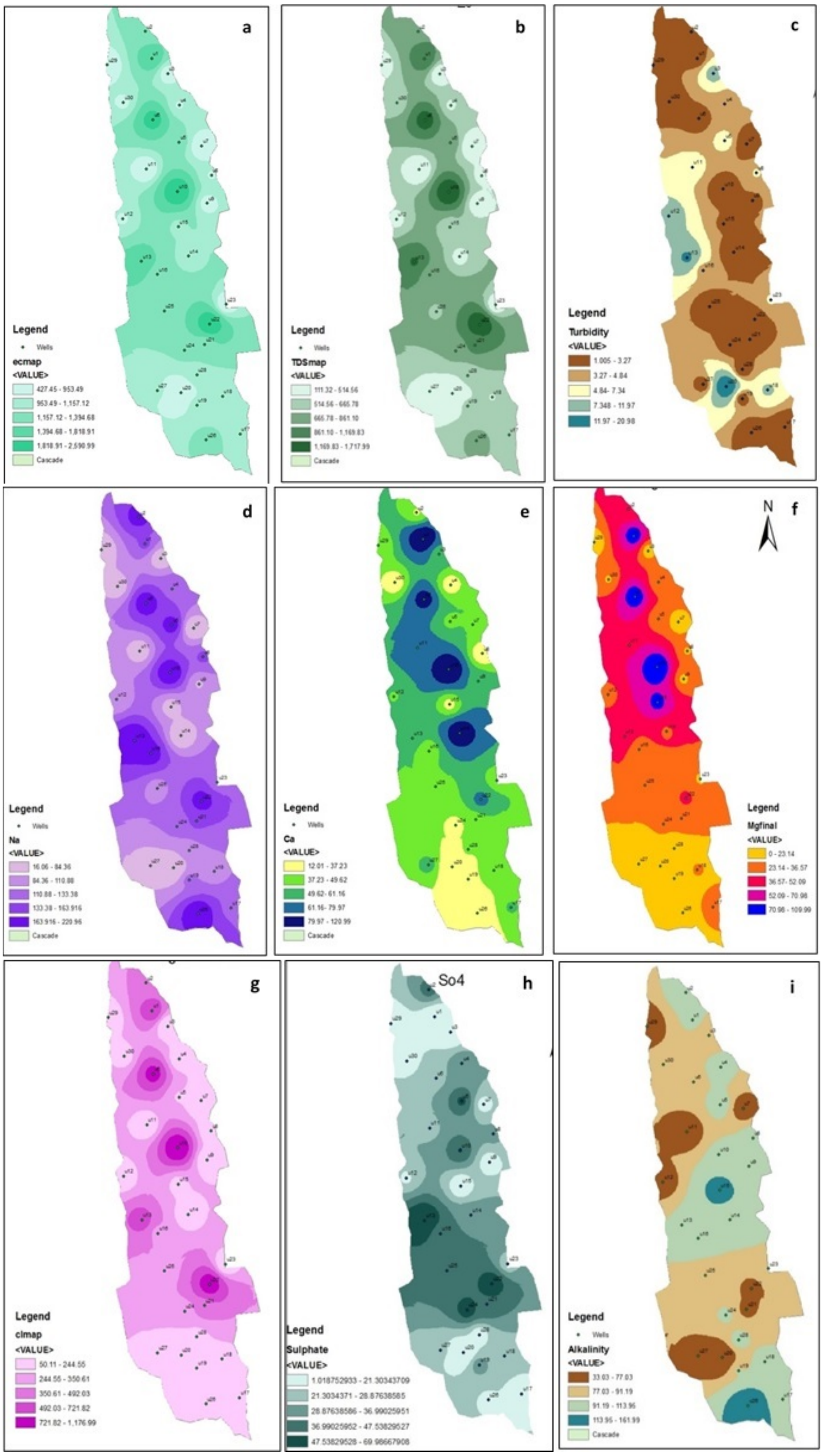

Figure 4: Spatial distribution of several parameters of GW in Ulagalla cascade. a-EC variation, b- TDS, c- Turbidity, d- Na^{+}, e= Ca^{2+}, f= Mg^{2+}, g= Cl^{-}, h= SO_4^{2-}, i= Alkalinity

organic and some organic minerals or salts such as K^{+}, Ca^{2+}, Na^{+}, HCO_3^{-}, Cl^{-}, Mg^{2+}, SO_4^{2-} etc. These minerals produced undesirable taste and diluted colour in the appearance of water. In *Ulagalla* cascade average TDS values of GW was varied from 111.43 mg/L to 1718.33 mg/L. According to the drinking water standards, 43.33% wells were exceeding the MPL while 60% of wells including U10 (highest), U1, U6, U13 and U22 exceeding MPL for SLS standards. According to the Kumari *et al.* (2016) from a different previous study for same catchment, TDS in GW was varied from 65.9 mg/L to 311 mg/L and average TDS in SW was varied from 40.2 mg/L to 141.53 mg/L. The maximum TDS values reported in Kumari *et al.* (2016) were below than the maximum TDS values of our study for GW and SW in *Ulagalla* cascade. According to their study all the sampling locations were below the safe limit thus, suitable for drinking purpose. Therefore, these results were not accordance with the present results from our study for *Ulagalla* cascade. In *Ulagalla* cascade significant difference (GWp=0.026 and SWp=0) has observed between GW and SW ($p<0.05$).

Turbidity is the relative clarity of the water that reduces the transmission of light. Turbidity of GW in *Ulagalla* cascade was varied from 0.92 NTU to 20.85 NTU and in the SW it was varied from 1.62 NTU to 313.19 NTU (p for GW=0.305 and p for SW=0.063 for SLS standards, 2 NTU). According to the SLS drinking water quality guideline value 50% of GW locations and 95% of SW tanks were exceeded the maximum turbidity level. Based on world acceptable laboratory guideline values 26.67% of GW locations and 53.33% of SW tanks were exceeded the maximum permissible turbidity level. Thus, doubtful for drinking purpose. Significant difference was not observed between GW and SW.

In *Ulagalla* cascade, observed Na^+ concentration was varied from 16.42 mg/L to 221.41 mg/L in GW and from 7.51 mg/L to 81.54 mg/L in SW. Based on the WHO and SLS guideline values 13.33% of GW locations were exceeded maximum permissible Na^+ value while all the SW locations were below the safe limit. In *Ulagalla* cascade highest average Na^+ concentration was noted in GW while lowest average Na^+ concentration has recorded in SW. There was a significant difference between standards and observed values of GW and SW ($p<0.05$) as p for GW=0 and p for SW= 0). According to the Kumari *et al.* (2016) average Na^+ concentration in GW was varied from 11.39 mg/L to 38.18 mg/L. Highest Na^+ concentration value of their study was almost less than the average Na^+ concentration in *Ulagalla* cascade. Thus this result was not accordance with Kumari *et al.* (2016). Chandrajith *et al.* (2011b) has been reported 1910 mg/L in their study. It was almost higher than the average Na^+ concentration of GW in *Ulagalla* cascade. According to the Kumari *et al.* (2016) average Na^+ concentration in SW was varied from 10.54 mg/L to 27.85 mg/L in their study. It is almost lower than the average Na^+ concentration in SW of *Ulagalla* cascade.

Ca ions (along with Mg ions) create the hardness of water, though no health-based guideline standards are interpreted for drinking water. However, the public acceptance for hardness is 100-300 mg/L and generally accepted as 100 mg/L by considering other dependable factors such as pH and alkalinity [WHO, 2011]. The Ca^{2+} concentration in GW of *Ulagalla* cascade was varied from 12.27 mg/L to 120.76 mg/L (average= 50.49 mg/L) and in SW Ca^{2+} concentration was varied from 8.86 mg/L to 41.25 mg/L (average= 25.68 mg/L). According to SLS guideline value, 10% of GW locations and based on the WHO guideline, 13.34% of GW locations were exceeded the maximum permissible levels respectively (p for GW= 0 and p for SW= 0). There was a significant difference between GW and SW ($p<0.05$). According to the Kumari *et al.* (2016) Ca^{2+} concentration in GW of their study was varied from 10.3 mg/L to 30.54 mg/L. That value was lower than the observed values in *Ulagalla* cascade. In addition, they have recorded high Ca^{2+} concentration in the GW of CKDu non prevalent areas. Based on the both SLS and WHO guideline value, all the SW bodies were below the maximum permissible Ca^{2+} concentration level hence, suitable for drinking purpose. According to the Kumari *et al.* (2016) Ca^{2+} concentrations was varied from 9.12 mg/L to 30.79 mg/L. Maximum average Ca^{2+} a concentration of their study was lower than the maximum average Ca^{2+} concentration value of *Ulagalla* cascade.

Mg^{2+} concentration in GW of *Ulagalla* cascade was varied from 2.9 mg/L to 110.05 mg/L. Based on the observed values 33.33% of GW were exceeded the WHO and SLS maximum permissible levels (p for GW=0.468 and p for SW= 0). According to the Kumari *et al.* (2016) Mg^{2+} concentration in GW locations of their study was varied from 2.63 mg/L to 23.43 mg/L. These values were lower than the maximum Mg^{2+} concentration value of *Ulagalla* cascade. Furthermore, Chandrajith *et al.* (2011b) has recorded average Mg^{2+} concentration in GW of their study as 1280 mg/L and it was very higher than the *Ulagalla* cascade value. In the SW of *Ulagalla* cascade Mg^{2+} concentration was varied from 1.39 mg/L to 23.55 mg/L. Based on the SLS and WHO guideline values all the sources were below than the maximum level hence all were suitable for drinking. According to Kumari *et al.* (2016), Mg^{2+} concentration in GW locations of their study was varied from 2.95 mg/L 14.98 mg/L. These values were lower than the maximum Mg^{2+} concentration value of *Ulagalla* cascade.

Cl^- concentration in GW of *Ulagalla* cascade was varied from 50 mg/L to 1176.67 mg/L. Based on the guideline values 33.33% of GW locations were exceeded safe limit. According to the Kumari *et al.* (2016) Cl^- concentration in GW of their study was varied from 15 mg/L to 53.33 mg/L. These values were lower than the highest Cl^- concentration value in GW of *Ulagalla* cascade (p for GW= 0.411 and p for SW= 0). Also Chandrajith *et al.* (2011b) were recorded the average Cl^- concentration in GW of their study was 688 mg/L. Cl^- concentration in SW was varied from 20 mg/L to 280 mg/L. 5% of SW locations were exceeded the safe limit. Kumari *et al.* (2016) have reported the Cl^- concentration in SW was varied from 13.33 mg/L to 25.0 mg/L respectively.

These values were almost lower than the average Cl^- concentration values of *Ulagalla* cascade. There was a significant difference between GW and SW ($p<0.05$).

SO_4^{2-}concentration in GW of *Ulagalla* cascade was varied from 1.33mg/L to 70mg/L and SO_4^{2-}concentration in SW of *Ulagalla* cascade was varied from 1mg/L to 16mg/L (p for GW=0 and p for SW=0). In *Ulagalla* cascade PO_4^{3-} concentration in GW was varied from 0.18 mg/L to 1.05 mg/L and PO_4^{3-} concentration in GW was varied from 0.08 mg/L to 0.18 mg/L. There was a significant difference between standards and observed values of GW and SW ($p<0.05$) as p for GW was 0 and p value for SW was 0. Alkalinity in GW was varied from 33.33 mg/L to 162.5mg/L, while the average alkalinity in SW was varied from 10.42 mg/L to 70.83 mg/L (p for GW= 0 and p for SW= 0). Based both guideline values, all the GW locations and SW bodies were below the maximum permissible levels of SO_4^-2, PO_4^{3-} and alkalinity. There was a significant difference between GW and SW ($p<0.05$) for SO_4^-2, PO_4^{3-} and alkalinity respectively.

Observed NH_4^+-N concentration in GW was varied from 0.07 mg/L and 0.13 mg/L and in the SW it was varied from 0.07 mg/L to 0.24 mg/L (p for GW= 0 and p for SW= 0) in the *Ulagalla* cascade while the average NO_3^- -N concentrations of GW was varied from 0.07 mg/L to 8.35 mg/L and average NO_3^- -N concentrations of SW was varied from 0.12 mg/L to 1.97 mg/L (p for GW= 0 and p for SW= 0). Based on the WHO and SLS guideline values all the GW locations and SW bodies were below the maximum permissible levels of NH_4^+-N and NO_3^- -N.

Pb^{2+} concentration in GW of *Ulagalla* cascade was varied from 1.76 μg/L and 8.85 μg/L and Pb^{2+} concentration in SW of *Ulagalla* cascade was varied from 0.59 μg/L and 2.80 μg/L (p for GW= 0 and p for SW= 0). All the GW and SW locations were below the maximum permissible levels of SLS and WHO drinking water quality guideline values. Chandrajith *et al.* (2011a) have observed 0.957 μg/L of average Pb concentration in their study. Pb^{2+} concentrations in *Ulagalla* cascade were higher than that literature results. Surface and groundwater contamination by Pb^{2+} can be happened due to excessive use of agrochemicals [Katz *et al.*, 1999]. In some fertilizers and weedicides that have been using in agriculture, reported maximum dangerous levels of Cd^{2+}, As^{3+} and Pb^{2+}. *Ulagalla* cascade area is a highly agriculture area and ensured for using those agrochemicals for higher harvest. In addition, it is important to mention that As and Cd excretion in urine were significantly higher in healthy people living in the CKDu endemic area however, Pb^{2+} was significantly lower [WHO, 2012]. However, it can concentrate in human tissues and bones through bio-accumulation.

In *Ulagalla* cascade Cd^{2+} has detected in three wells (U18, U19 and U20) and one SW tank T1 (Thodamaduwa). Cd^{2+} concentrations of these water bodies were 0.15 μg/L, 0.13 μg/L and 0.01 μg/L in U18, U19 and U20 respectively. In T1 tank average Cd^{2+} concentration was 0.01 μg/L. All these observed values were below the maximum permissible guideline values. One sample t test results were given as p value for GW was 0.285 and p value for SW was 0.

As^{3+} concentration in GW in *Ulagalla* cascade was varied from 0.03 μg/L and 0.44 μg/L and As^{3+} concentration in GW and SW in *Ulagalla* cascade was varied from 0.02 μg/L and 0.19 μg/L (p for GW= 0 and p for SW= 0). All the sources were below the maximum permissible level of SLS and WHO drinking water quality guidelines. There was no significant difference of the As^{3+} concentration between GW and SW. Long term ingestion of arsenic contaminated drinking water may effect to peripheral vascular diseases and to peripheral nervous system (Gunathilake *et al.* 2014). Jayasumana *et al.* (2011) has strongly argued that As^{3+} in pesticides can be combined with the hardness in water to form the calcium arsenate and when calcium arsenate transported to kidneys, it can cause severe kidney damages. Wasana *et al.* (2016) have suggested total As^{3+} in water cannot be considered as the causative factor for the incidence of CKDu though they have observed As levels below the maximum permissible levels of SLS and WHO guidelines.

Observed measurements were graphically analysed by using ArcGIS and the GIS maps were prepared for spatial distribution of water quality parameters. Figure 4 will represent those GIS maps for each parameter throughout the area.

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