Water quality and agricultural activities related to CKDu

S. Sadushan, T. Venkadeswaran, G.B.B. Herath

Abstract: Over the past two decades, Chronic Kidney Disease of unknown aetiology (CKDu) has been increasing rapidly in dry zone of Sri Lanka. Male farmers are the most affected population by this CKDu. There is a strong evidence from the past researches that CKDu has a profound relationship with drinking water quality and socio economic parameters. The study was conducted by analysing water quality parameters from random samples and socio economic parameters were analysed from the information collected from the questionnaire survey conducted in both CKDu prevalent and non-prevalent areas. Target area for the study of CKDu prevalence was Medawachchiya and CKDu non prevalent areas were selected from GN divisions in Vavuniya district. From the analysis of water quality, it showed that hardness and fluoride contents were high compared to the standards. Significant amount of the water samples exceeded SLS 614-highest desirable limit for potable water and WHO drinking water quality standards in CKDu endemic areas, but they were comparable with the CKDu non prevalent areas as there were no significant differences found. So, Hardness and Fluoride can't be considered as sole factors contributing to CKDu. Analysis of questionnaire survey showed that CKDu is correlated to farmers aged above 50 years old and to those whose water consumption was less than 1.5 Litres per day. Further multi variable analysis is highly recommended to correlate the water quality parameters with socio economic factors for the occurrence of CKDu.

Keywords: CKDu, Medawachchiya, Vavuniya, Male farmers, Drinking water quality, Socio economic parameters, Random samples, Hardness, Fluoride, Questionnaire survey, Prevalent and non-prevalent areas, Significant differences, Multi variable analysis

1. Introduction

Over the past two decades Chronic Kidney disease of unknown aetiology (CKDu) is increasing rapidly in the dry zone of Sri Lanka. Medawachchiya is one of the CKDu endemic regions. Here, young male farmers are mostly affected by this CKDu. There is a strong evidence that CKDu has a profound relationship with drinking water quality and socio economic parameters.

Sri Lanka is an agricultural based country. Several chemicals may influence the water quality due to the application of fertilizers, pesticides and weedicides. Therefore, increase of water hardness and concentration of heavy metals can be observed. The complex compounds formed by the application of these chemicals like glyphosate metal complexes have adverse effect on kidneys. [1].

There were several studies conducted related to CKDu to find the causative factors. In those research studies they mainly focused on water hardness, ionicity in water, high fluoride content in drinking water, Nephrotoxic elements and genetic factors. In these studies, researchers were unable to get clear conclusions. As it shows that rather than single cause, multi causative factors are involved in the CKDu.

Considering the past literatures, this study focused on water quality parameters and socio-economic conditions related to CKDu, mostly in farming communities to find the causes of this issue. In this regard the Medawachiya area in North central province is selected as the CKDu prevalent area and Vavuniya is selected as the non CKDu prevalent area with the same socio economic background.

Study hypotheses were based on the past research outcomes such as high hardness and high fluoride content in drinking water, low water consumption among the farmers in the dry zone, low consumption as a result of high hardness, causing taste issues and long working duration of people causing severe dehydration and development of heat stress.

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2. Objective

Analyse the water quality parameters and the socio-economic conditions related to water and agricultural activities to identify the effective causative factors for CKDu by comparing it with the CKDu non-prevalent areas

3. Past Studies

There were considerable number of studies carried out regarding the CKDu issue. As this study mainly focused on CKDu related with water quality and agricultural activities, literatures summarized were regarding ionicity in water, hardness in water, Nephrotoxic contaminants in drinking water, farming communities in CKDu areas, CKDu with glyphosate, Drinking water quality parameters related to CKDu, Influence of heavy metals to CKDu and Heat stress related to CKDu

3.1 Ionicity with respect to CKDu

High risk of CKDu due to the exposure to agro-chemicals and contamination of toxins in drinking water. Commonly suggested reasons for CKDu are fluoride, cadmium, arsenic glyphosate genetic risk factors, and hardness of drinking water. [2].

Regarding ionicity, it was found that Fluoride incidence overlaps the presence of fluoride but the presence of fluoride does not imply CKDu.

Studies relating CKDu with ionicity showed that Cadmium was found below the WHO max limit of 0.005 mg/l suggesting no role for Cd causing CKDu in Sri Lanka, Arsenic Biopsy data of CKDu patients showing elevated arsenic levels but water analysis of the WHO study do not find elevated as in soil or water. Also, Glyphosate has no significant presence in water.

From the WHO study no Significant Difference in Urine-arsenic And Lead in CKDu prevalence areas compared to non-prevalence areas. [2].

3.2 Nephrotoxic contaminants with respect to CKDu

Drinking water is considered to be a major source of nephrotoxic contaminants such as Cd, As, Pb, and U that cause CKDu. The concentration of nephrotoxic elements such as, Cd, Pb and U in the drinking water sources of CKDu endemic areas were below the SLS standards for drinking water. Nephrotoxic Contaminants in drinking water sources seems doubtful to be the sole cause for CKDu due to the lack of correlation between the levels of heavy metals in water and urine samples in the CKDu endemic regions. [3].

Amount of water consumption per day, use of Agro-chemicals and food consumption behaviour were estimated from the data collected through household survey. It was found that most of the CKDu patients used tube wells or dug wells as a primary drinking water sources and there was no significant correlation found with Agro-chemicals and the presence of CKDu. [3].

3.3 Water hardness and Glyphosate with respect to CKDu

Stable complexes formed by Glyphosate with hard water were also considered as the causative factors for CKDu as Glyphosate was a commonly used herbicide in the CKDu endemic areas. However, the health issues from glyphosate complexes have not been investigated due its difficulty in identification using conventional methods. [1].

Further continuation of the study is needed to find out other agricultural areas where excessive use of glyphosate and drinking ground water with high hardness have overlapped in causing kidney damage.

3.4 Impacts of Agricultural activities on CKDu

In Medawachchiya, a high proportion of CKDu patients were young male farmworkers, and both young age and agricultural work were independently associated with CKDu. [4].

Several environmental contaminants have been studied by Sri Lanka's Ministry of Health in collaboration with WHO and Sri Lanka's National Science Foundation, searching for etiological agents. Findings showed a 15% prevalence of CKDu in the population aged 15–70 years in North Central and Uva provinces.

It was hypothesized that the population could be exposed to these contaminants through food and drinking water, and that water hardness could play a role it has been proposed that such routes of environmental exposure to combinations of nephrotoxic agents (rather than just a single substance), acting with predisposing factors, could lead to development of CKDu.

4. Materials and Methods

4.1 Selection of hypotheses for the study

Study hypotheses for the causative factors for CKDu were based on the past research outcomes such as high hardness and high fluoride content in drinking water, low water consumption due to high hardness causing taste issues, long working hours and exposure to sunlight causing severe dehydration resulting the development of heat stress.

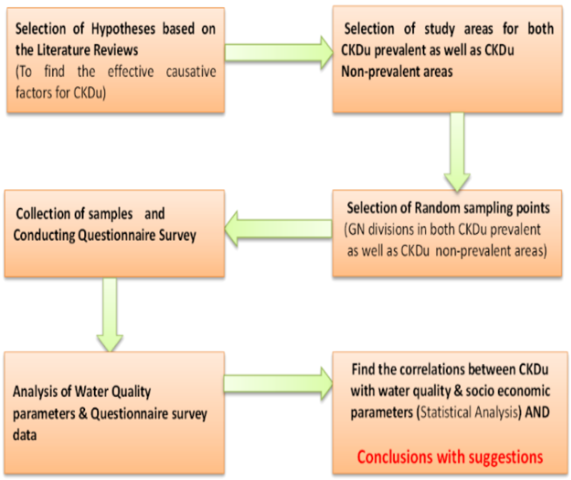

Figure 1 - Methodology of the study

4.2 Description of Methodology

The main study area was selected as Medawachchiya because high numbers of reported CKDu patients [4]. and for non-prevalence area Vavuniya was selected for the same socio economic background.

The sampling points were randomly selected. 82 water samples used for drinking purposes were collected for the analysis. Sources of sample collection in the sutdy area were dug wells, RO filters, Tanks, Rain water harvesting tanks, Springs and tube well.

Sample sizes were selected using Cochran's (1977) formulas. The alpha level used in determining sample size in most educational research studies is either **0.05** or 0.01. [9].

$$ss = (Z2 * (p) * (1-p))/ c2 \quad \text{....(1)}$$

Where, Z value is 1.96 for 95% confidence level, value of **p** is 0.5 which is the percentage picking for the worst case and the value of **c** is the confidence interval which is also expressed as decimal. [9].

Sample size corrected for finite Population is given below

$$ss_{corrected} = ss/ \{1 + (ss-1)/population\} \quad \text{.... (2)}$$

In-situ measurements of water quality parameters were temperature, pH and EC and Labouratory measurements taken for fluoride, hardness, and heavy metals (Cd and Pb)

Figure 2 – In-situ measurements of the drinking water samples at the study area

Water sampling points were predetermined and samples were collected from water supply areas, non-supply areas, farming and non-farming areas.

In the study areas, sources of sample collection were dug wells, RO filters, Tanks, Rain water harvesting tanks, Springs and tube wells.

54 Questionnaire surveys were done household wisely to identify the socio economic parameters of the people in the study area. Questionnaire survey was done carried out parallel with the sample collection process.

ArcGIS 10.3.1 software was used to generate the spatial distribution maps of selected drinking water sampling points.

For this study, water quality analysis was done to compare the samples with SLS drinking water standards especially hardness and fluoride

Statistical Analysis was done to find the significant difference of water quality parameters between the CKDu prevalent and CKDu non prevalent areas and also to find the correlation between the socio economic parameters with the occurrence of CKDu.

5. Results and Discussion

5.1 Mapping of sample collection points

In the CKDu prevalent areas, 1st water sample collection was done in Angunochchiya GN division, 2nd sample collection was done in Etaweeragollewa and Maha Divulwewa GN divisions and 3rd sample collection was done in Medawachchiya town areas.

Figure 3 – 1st Sample collection points in CKDu prevalent area

Table 1 – In-situ measurements in CKDu prevalent areas

CKDu prevalent area					
Source	No of samples	pH range	Exceedance	EC range µS/cm	Exceedance
Dug well	33	6.21-7.78	1	324-1502	17
RO filter	8	5.66-8.04	5	20-86	
Tube well	2	6.75-7.19		856-1224	1
RWH tank	3	7.31-9.28	2	26-120.34	
Canal water	1	7.7		379	
Tanks	17	6.65-9.17	1	680-890	2
Spring	1	5.39	1	128	

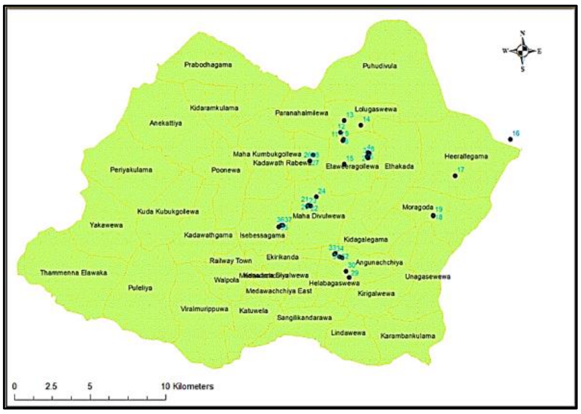

Figure 4 – 2nd Sample collection points in CKDu prevalent area

In the CKDu non- prevalent areas, 4th water sample collection was done in Cheddikulam, Kankankullam, Vavuniya Town, Nedunkulam & Katharsinnakulam GN divisions which are located in Vavuniya district.

5.1 Water quality analysis in CKDu prevalent areas

From the initial analysis of in-situ measurements 51.52% of Dug wells and 62.5% RO Filters exceeded SLS 614-highest desirable limit for EC and pH range respectively. Where, SLS Range for pH is 6.5-8.5 and highest desirable limit for EC: is 750 µS/cm [5].

77% of the samples exceeded the SLS limit for Hardness which is 250 mg/l. [5].

Sources and respective hardness ranges of samples collected in CKDu prevalent area shown in Table 2 given below.

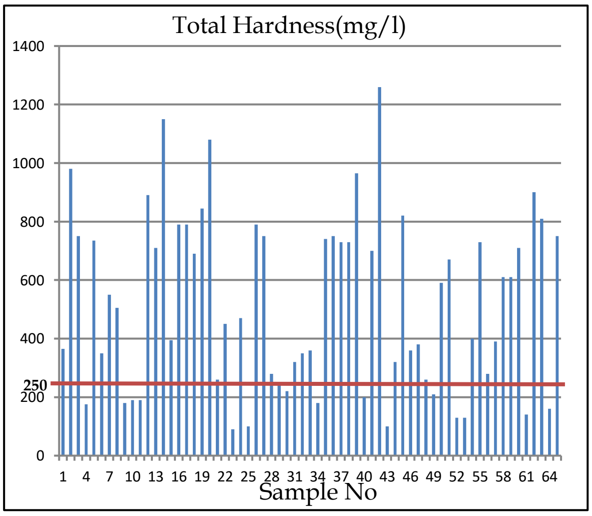

Figure 5 - Bar chart showing total hardness values of water samples

Table 2 – Source wise hardness range in CKDu prevalent areas

Source	No. of samples collected	Hardness (mg/l)	No. of samples exceeded the limit (250mg/l)
Dug Well	33	130-965	32
RO filter	8	90-395	2
Tank	17	100-1150	11
Rain Water harvesting Tank	3	175-260	1
Spring water	1	220-1260	1
Tube Well	2	550-710	2
Canal Water	1	590	1

97 % of dug wells used for drinking purposes exceeded the SLS limit for hardness. Where, it was revealed from the questionnaire survey that most of the people used dug wells as their drinking water sources.

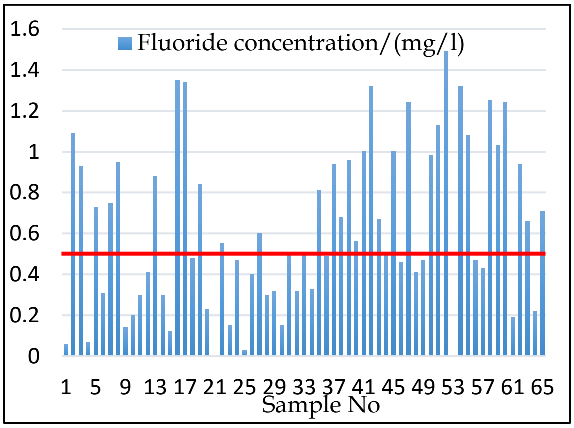

Figure 6 – Bar chart showing Fluoride Concentration of water samples

54 % of water samples used for drinking purposes, exceeded WHO's optimum fluoride level in drinking water for general good health which is 0.5 mg/l. [6].

5.2 Water quality analysis in CKDu non-prevalent areas

Table 3 – In-situ measurements in CKDu non-prevalent areas

Source	No. of samples	pH Range	Exceedance	EC Range µS/cm	Exceedance
Dug Well	8	6.36-8.04	1	240-1041	2
RO filter	1	6.63		74	
Tube Well	4	6.73-7.32		420-558	
RWH Tank	0	-			
Canal water	0	-			
Tank	3	8.02-8.8	2	210-472	
Spring	0	-			
Sand filter	1	8.22		381	

From the initial analysis of in-situ measurements most of the samples were within the SLS Standards for both pH & EC.

Sources and respective hardness ranges of samples collected in CKDu non-prevalent area shown in Table 4 given below.

Table 4 – Source wise Hardness range in CKDu non-prevalent areas

Source	No. of samples collected	Hardness (mg/l)	No. of samples exceeded the limits(250mg/l)
Dug Well	8	120-1190	7
RO filter	1	120	0
Tube Well	4	280-520	4
Tank	3	260-760	3
Sand Filter	1	170	0

82.4% of water samples exceeded SLS limit for hardness in CKDu non- prevalent regions which is 250 mg/l.

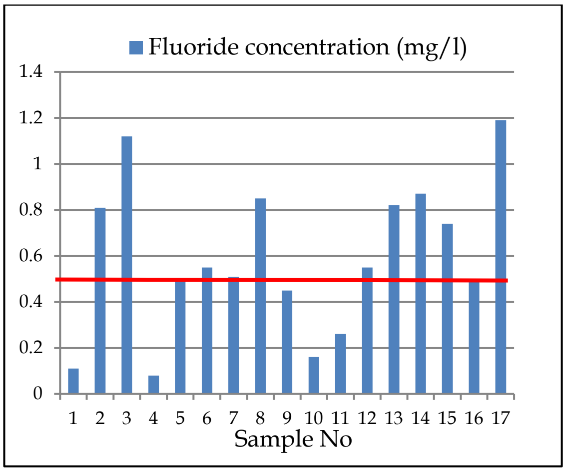

Figure 7 – Bar chart showing Fluoride concentration of water samples at CKDu non-prevalent Area.

58.8% of water samples exceeded WHO limit for fluoride content.

5.3 Statistical analysis on water quality parameters

2-Sample T-test was done to compare the hardness values in CKDu prevalent areas with CKDu non-prevalent areas to find the significant difference between them by using **Minitab 17 software.**

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Welcome to Minitab, press F1 for help.

Two-Sample T-Test and CI: Total Hardness(mg/l), Total Hardness(mg/l)_1

Two-sample T for Total Hardness(mg/l) vs Total Hardness(mg/l)_1

                                      SE
                     N  Mean  StDev  Mean
Total Hardness(mg/l)    65   519    297    37
Total Hardness(mg/l)_1  17   494    265    64

Difference = μ (Total Hardness(mg/l)) - μ (Total Hardness(mg/l)_1)
Estimate for difference:  24.6
95% CI for difference:  (-127.6, 176.7)
T-Test of difference = 0 (vs ≠): T-Value = 0.33  P-Value = 0.743  DF = 27
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Figure 8 - Two sample T-test for the significance difference in hardness

As p-value = 0.743 > 0.05, There was no significant difference between the hardness in CKDu prevalent areas with CKDu non-prevalent areas.

Ground water sources considered for the study were dug wells, deep wells & tube wells. When comparing ground water sources, P-value = 0.737 > 0.05. So, there was no significant difference between hardness in CKDu prevalent areas with CKDu non-prevalent areas.

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Welcome to Minitab, press F1 for help.

Two-Sample T-Test and CI: Fluoride concentration (mg/l), Fluoride concentra
tion (mg/l)_1

Two-sample T for Fluoride concentration (mg/l) vs Fluoride concentration (mg/l)
_1

                            N   Mean  StDev  SE Mean
Fluoride concentration (  65  0.627  0.401    0.050
Fluoride concentration (  17  0.592  0.330    0.080

Difference = μ (Fluoride concentration (mg/l)) - μ (Fluoride concentration (mg/
l)_1)
Estimate for difference:  0.0356
95% CI for difference:  (-0.1571, 0.2284)
T-Test of difference = 0 (vs ≠): T-Value = 0.38  P-Value = 0.708  DF = 29
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Figure 9 - Two sample T-test for the significance difference in fluoride content

When comparing fluoride content in CKDu prevalent with CKDu non-prevalent area, P-value = 0.708 > 0.05. So, there was no significant difference between fluoride content in CKDu prevalent areas with CKDu non-prevalent areas.

5.4 Questionnaire survey analysis

Factors considered for the questionnaire survey for statistical analysis were age (> 50 yrs, < 50 yrs), Engagement in agriculture (farming, non-farming), hours exposed to sunlight (> 6Hrs, < 6Hrs) and amount of water consumption for drinking (> 1.5l, < 1.5l). All the selected independent variables were analysed using cross tabulations to study the nature of their association with the occurrence of CKDu.

Table 5 - Cross tabulation for age and occurrence of CKDu

			CKDu Status		Total
			CKDu affected	CKDu free	
Age	Less than 50	Count	6	27	33
Age	Less than 50	% within Age	18.18	81.82	100.0
Age	Less than 50	% within CKDu status	26.09	87.01	61.11
Age	More than 50	Count	17	4	21
Age	More than 50	% within Age	80.95	19.05	100.0
Age	More than 50	% within CKDu status	73.91	12.90	38.89
Total		Count	23	31	54
Total		% within Age	42.59	57.41	100.0
Total		% within CKDu status	100.0	100.00	100.0

74% of the people within CKDu status in the CKDu endemic area are greater than 50 years.

Table 6 - Cross tabulation for engagement in agriculture and occurrence of CKDu

			Employment		Total
			Farmer	Other Employment	
CKDu	Affected	Count	21	2	23
		% among affected	91.30	8.70	100.0
		% Total	47.73	20.00	42.59
	Free	Count	23	8	31
		% among non-affected	74.19	25.81	100.0
		% Total	52.27	80.00	57.41
Total		Count	44	10	54
		% of Total	81.48	18.52	100.0

91% of the people within CKDu status in the CKDu endemic area are Farmers

Table 7 - Cross tabulation for hours exposed to sunlight and occurrence of CKDu

			CKDu affected	CKDu free	Total
Work hours exposed to sunlight	Less than 6 hours	Count	3	6	9
		% within Work hours	33.33	66.67	100.0
		% within CKDu status	13.04	19.35	16.67
	Greater than 6 hours	Count	20	25	45
		% within Work hours	44.44	55.56	100.0
		% within CKDu status	86.96	80.65	83.33
Total		Count	23	31	54
		% within Work hours	42.59	57.41	100.0

87% of the people within CKDu status in the CKDu endemic area expose to sunlight more than 6 hours.

Table 8 - Cross tabulation for amount of drinking water consumption and occurrence of CKDu

		Consumption		Total
		Greater than 1.5L	Less than 1.5L	
Affected	Count	4	19	23
	% among affected	17.39	82.61	100.0
	% within Consumption Group	26.67	48.72	42.59
Free	Count	11	20	31
	% within CKDu	35.48	64.52	100.0
	% within Consumption Group	73.33	51.28	57.41
Total	Count	15	39	54
	% within CKDu	86.70	13.30	100.0
	% within Consumption Group	100.0	100.0	100.0

83% of the people within CKDu status in the CKDu endemic area consume water less than 1.5 litres.

Bi-variate correlation analysis from Kendall's tau-b formula and spearman- rho formula via Statistical Package for Social Sciences (SPSS) showed significant correlations related to the occurrence of CKDu as follows:

1. Farming: p-value=0.04 (Within CKDu Status: 91.3 % of the people's occupation is Farming)
2. Consumption of water is less than 1.5 litres: p-value=0.022 (Within CKDu Status: 57.58% of people's water consumption < 1.5l)
3. Age > 50 years: p-value= 0.003 (Within CKDu Status: 73.91% of people > 50 years)

6. Conclusions

The following conclusions were derived from the results obtained from the analysis of water quality parameters.

1. When considering drinking water sources, both CKDu prevalent and non-prevalent areas have high hardness and fluoride concentration but, there was no significant difference between them.

2. Concentration of heavy metals (Cd, Pb) found in the samples were negligible in both CKDu-prevalent & CKDu non-prevalent areas.

Hence it can be identified that the occurrence of CKDu doesn't depend only on the factors such as hardness, fluoride content and heavy metals in drinking water.

From the analysis of the questionnaire survey, correlations between occurrence of CKDu and the factors such as occupation (farming), age limit and water consumption were identified.

Results showed that, high percentage of farmers who consume less than 1.5 l of drinking water were mostly affected by CKDu because dehydration is the consequence of insufficient water intake and farmers' exposure to nephrotoxic chemicals. It can be suggested that high hardness causing taste issues for the low water consumption.

Questionnaire survey analysis showed that Aluminium utensils used for cooking purposes can be also related to the occurrence of CKDu as Aluminium can be easily soluble in water with high fluoride content [7]. From the questionnaire survey, it was also found that people who used water from reservoirs and natural springs were less affected, but the number of people who used those sources were few.

7. Recommendations

It can be recommended that fluctuations in water quality parameters and socio economic patterns in the CKDu endemic areas should be identified through further studies.

Multi variable analysis is needed to identify the correlation between the drinking water quality parameters and socio economic factors related with the occurrence of CKDu.

The relation between the usage of Aluminium utensils for cooking purposes and the occurrence of CKDu should be analysed as Aluminium is soluble in water with high fluoride content.

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