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Environmental contamination and its association with Chronic Kidney Disease of Unknown Etiology in North Central Region of Sri Lanka

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1. About the CSE Laboratory

The Centre for Science and Environment (CSE), one of India's leading non-governmental organization based in New Delhi, has set up the Pollution Monitoring Laboratory (PML) to monitor environmental pollution and food contamination. PML is an ISO 9001:2008 certified laboratory accredited by SWISO, CH-5610, Wohlen, Switzerland, conducting Pollution Monitoring and Scientific Studies on Environmental and food Samples. The Lab has qualified and experienced staff that exercise Analytical Quality Control (AQC) and follow Good Laboratory Practices (GLP). It is equipped with state-of-art equipment for monitoring and analysis of air, water and food contamination, including Gas Chromatograph with Mass Spectrometer (GC-MS), Gas Chromatograph (GC) with ECD, NPD, FID and other detectors, High Performance Liquid Chromatograph (HPLC), Atomic Absorption Spectrometer, UV-VIS Spectrophotometer, Mercury Analyzer, Respirable Dust Sampler etc. Its main aim is to undertake scientific studies to generate public awareness about food contamination and environmental pollution. It provides scientific services at nominal cost to communities that cannot obtain scientific evidence against polluters in their area. The lab and its work is directed to use science to achieve environmentally sound and socially relevant public policy.

2. Introduction

Over the last decade, anew form of kidney disease of unknown etiology has emerged in the dry zone of Sri Lanka. The occurrence is mainly amongst males of age group 30–60 years engaged in agriculture. Almost 80% of these patients eventually die from kidney failure within the first two years after diagnosis. High prevalence of Chronic Kidney Disease(CKD) has become an environmental health issue of national concern in Sri Lanka. Hypertension and Diabetes is known to be the main causes for renal failure, but in areas with high prevalence of CKD, the majority of patients do not show any identifiable cause. Thus, it has been named CKD of unknown etiology (CKDue).

High prevalence (2-3% of the population) of CKDue is observed in the north central region of Sri Lanka[1]. High incidence is mainly in the divisions of Medawachchiya (approx. 2500 casespresently),Girandurukotte (approx. 1500 cases presently), Mahiyanaganaya (approx. 800 casespresently), Padaviya (approx. 1000 cases presently), Medirigiriya (approx. 800 casespresently),Dehiattakandiya (approx. 400 cases presently), Nikawewa (approx. 400 cases presently) and Kabithigollawa[2].

The disease process appears to mainly affect the proximal tubules and the interstitium giving rise to characteristic, recognizable histopathological and clinical features. Clinically, the disease is characterized by tubular proteinuria, usually b2-microglobulinuria, and the absence of hypertension and edema. Thehistological appearance of the disease is 'tubulointerstitial' that can commonly be observed in toxic nephropathies[3].

The presence of high levels of fluoride, widespread use of agrochemicals, presence of heavy metals like cadmium, lead and arsenic and uranium in soil and water are postulated as contributory factors. In some

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[1] Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekara T, Harada K, Watanabe T, Koizumi A. Chronic kidney disease of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications. Environ Geochem Health, 2010

[2] http://www.elaw.org/system/files/Arsenic+in+Pesticides.pdf; Data presented by Dr Chana Jayasumana, Faculty of Medicine at Rajarata University

[3] Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekara T, Harada K, Watanabe T, Koizumi A. Chronic kidney disease of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications. Environ Geochem Health, 2010

studies, mycotoxins, use of herbal/ayurvedic medicines, smoking and snakebite are some other factors that have been considered[4]. Up to now, there is no unequivocal evidence to recognize the possible environmental causative factors that could lead to a nephrotoxins responsible for the disease.

The prevalence of the disease is mostly among paddy farmers and agriculture laborers. Many of these poor farmers die simply because they cannot afford the cost of treatment. Apart from the cost, it's the lack of availability of dialysis facilities in nearby hospitals that makes it extremely difficult for the poor to avail treatment. This grave situation calls for mobilization of public support for fund raising activities as the morbidity and mortality of these patients are often related to their state of poverty.

3. Chronic Kidney Disease (CKD)

Chronic Kidney Disease occurs when one suffers from gradual and usually permanent loss of kidney function over time. This happens gradually, usually months to years. CKD is divided into five stages of increasing severity. The term 'renal' refers to the kidney so another name for kidney failure is 'renal failure'. Mild kidney disease is often called renal insufficiency. With loss of kidney function there is accumulation of water, waste and toxic substances in the body that are normally excreted by the kidney. Loss of kidney function also causes other problems such as anemia, high blood pressure, acidosis (excessive acidity of body fluids), high cholesterol and fatty acids, and bone disease. Stage five CKD is also referred to as kidney failure, end-stage kidney disease, or end-stage renal disease (ESRD), wherein there is total or near-total loss of kidney function. There is dangerous accumulation of water, waste and toxic substances and most individuals in this stage of kidney disease need dialysis or transplantation to stay alive[5].

CKD is a key component of Non Communicable Diseases (NCD). In developing countries such as India, non-communicable diseases (example cardio vascular disease, chronic kidney disease) are the major cause of mortality compared with communicable diseases (example infections in the form of diarrhea, respiratory tract infections, tuberculosis).There is no concrete data on the true incidence and prevalence of chronic renal failure in the developing world[6].

Data from community-based studies in India show an alarmingly high burden for CKD. In a study by Agarwal *et al*the prevalence of CKD in the adult population in India was 0.785% or 7852 per million; the prevalence data on ESRD or stage five of CKD between 2000 and 2004 rose from 151 to 232 persons per million[7].

According to a hospital based CKD registry in Sri Lanka, by World Health Organisation (WHO)in 2009, in the four hospitals in North Central Province—Anuradhapura, Polonnaruwa, Medirigiriya and Medawachchiya— there were 1997 patients of which 39% (775 cases) were of CKDue cases. CKDue cases as a percentage of total CKD cases in different hospitals were as follows: Anuradhapura- 48%, Polonnaruwa- 14%, Medawachchiya- 13% and Medirigiriya- 25%. According to the WHO registry, of those suffering from CKDue, 72% were males and 28% were females[8].

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[4] Wanigasuriya KP, Peiris-John RJ, Wickremasinghe R, Hittarage A. Chronic renal failure in North Central Province of Sri Lanka: an environmentally induced disease. Trans Royal Soc Trop Med Hyg 2007;101(10):1013-7

[5] http://www.nlm.nih.gov/medlineplus/ency/article/000471.htm

[6] Chronic kidney disease in India: from a resident physician's perspective, N Udayakumar; Postgrad Med J. 2006 November; 82(973): 697–698.

[7] Agarwal S K, Dash S C, Irshad M. *et al* Prevalence of chronic renal failure in adults in Delhi, India. Nephrol Dial Transplant 2005. 201638–1642.1642. [PubMed]

[8] WHO Sri Lanka home page CKD leaflet Feb 2010.pdf

An on going study by WHO, which is yet to be published, states that 15% of the people in North Central Region are affected by CKDue[9]. The Ministry of Health with technical support from WHO had launched a comprehensive National Research Initiative in 2009 to investigate the magnitude and etiology of CKDue with a view to developing preventive strategies. The detailed report is yet to be released.

4. Chronic Kidney Disease of unknown etiology (CKDue)

The symptoms of the CKD, in North Central Province of Sri Lanka, were found to be very different from the known risk factors of diabetes, hypertension or glomerulonephritis and hence it was termed as CKDue. In the case of CKDue, the kidney shrinks to a very small size— from the normal size of 12-15 cm to 7-8 cm— and this is beyond repair[10].

According to a circular issued by the Sri Lanka Ministry of Health, in 2009,CKDue is defined as follows:

- No past history or current treatment for diabetes mellitus or chronic/ severe hypertension, snake bite, urological disease of known etiology or glomerulonephritis
- A three month average blood glucose level of less than 6.5%
- BP <160/100 mm Hg untreated or <140/90 mm Hg on up to two antihypertensive agents

5. Geographical Distribution of CKDue

Endemic occurrence of the kidney disease was recognized in the 1990s in the North Central Province, situated in the dry zone of Sri Lanka, and this has been increasing over a period of 10–15 years. High prevalence of CKDue is observed in two main districts of the North Central Province —Anuradhapura and Polonnaruwa.The prevalence is now spreading to the adjoining districts of North Western province, Uva province, Eastern province, Central province and the Northern province. The affected area covers approximately 17000 square km and with a population about 2.5 million in which more than 95% live in rural areas[11].

The worst affected areas areMedirigiriya (identified 8 years ago) in Polonnaruwa district, and Medawachchiya (identified 20 years ago), Kabithigollawa, Padaviya (identified 18 years ago) in the Anuradhapura district in North Central Province, Nikawewa(identified 5 years ago) in Kurunegalla district in North West province, Girandurukotte (identified 12 years ago) in Badulla district in Uva province and Dehiattakandiya in Ampara districtin the Eastern province[12].

The CKDue in Sri Lanka has been compared to the Balkan Endemic Nephropathy (BEN), which in 1950's was described as a chronic tubulointerstitial kidney disease. The most remarkable characteristic of BEN was that it affected only certain endemic rural foci along tributaries of the Danube River in the Balkan nations of Bosnia, Bulgaria, Croatia, Romania and Serbia. BEN stands out from Sri Lanka's CKDue in that the geographical distribution is so stable that 50 years after the original description, no new endemic areas have been reported and no endemic areas became free from BEN. It is strictly restricted in 142 settlements in former Yugoslavia, 40 in Bulgaria, 40 in Southwest Romania; total area not exceeding 500

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[9] Joint press statement of Ministry of Health, Sri Lanka and WHO

[10] CSE interview with Dr Thilak Abeysekhara

[11] Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekara T, Harada K, Watanabe T, Koizumi A. Chronic kidney disease of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications. Environ Geochem Health, 2010

[12] Dhamika M Dissanayake, 2011, The Cyanobacterial Toxins: A Hidden Health Hazard

miles in length or 20,000 square km[13]. On the other hand, incidence of CKDue in Sri Lanka has spread from the North Central Province to adjoining districts; now known as the North Central Region. They are however restricted to the dry zone in the country. The glaring similarity is that both in BEN and CKDue in Sri Lanka, those affected are the rural farming population and never inhabitants of the big cities.

6. Statistics of CKDue

CKD is a growing problem in Sri Lanka. Hospital admissions due to diseases of the genitourinary system have doubled during the period between 1990 and 2007. During the same period, hospital deaths due to diseases of the genitourinary system rose from 2.6 to 9.1 per 100,000 populations[14]. CKD has been thepredominant contributor to this rise in in hospital morbidity and mortality.Diabetes and hypertension are considered to be the chief causes of CKD in areas outside the CKDue provinces[15].

The medical statistics of the Anuradhapura General Hospital, which is the main hospital in the North Central Province, in 2010, shows a 227% increase in live discharge patients with end-stage CKDue, whereas the death rate increased by 354% during the last few years.According to 2005-2006 data, the Nephrology unit of the Teaching Hospital in Kandy treated 3000-3500 patients annually, out of which 50-69% of those treated do not have identifiable cause and belong to the North Central Province[16]. The current number of patients suffering from CKDue in these regions is estimated at 15,000[17].

The disease mostly affects males in the age group of 30-60 years. Most of those affected are paddy farmers or agricultural laborers.This trend is now being observed in women and children as well.Impact is beginning to show on cattle—a study showed that 40 % of the cattle tested were affected with interstitial nephritis[18].

Epidemiological data indicates that all the high prevalent areas are clustered around reservoirs of the irrigation system. Low prevalence of the disease was noted in communities who consume water from natural springs for drinking[19].

7. Theories of CKDue

Even though several studies have been conducted in Sri Lanka, the main reason for CKDue is not yet confirmed. These studies involve a diverse group of scientists and researchers and there is no consensus on any one school of thought.

Cadmium:The study carried out by JMR Sarath Bandara of the University of Peradeniya in 2007 emphasized that CKDue in the dry zone is due to high cadmium content in the environment such as

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13 *'Balkan Nephropathy: Evolution of Our Knowledge'; Giorgos Bamias,MD, and John Boletis, MD; World Kidney Forum; American Journal of Kidney Diseases, Vol 52, No 3 (September, 2008):pp 606-616*

14 Annual Health Statistics of Sri Lanka, 2007

15 Katulanda P, Sheriff MH, Mathews DR. The diabetic epidemic in Sri Lanka: a growing problem. Ceylon Med J 2006;51:26-8.

16 Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekara T, Harada K, Watanabe T, Koizumi A. Chronic kidney disease of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications. Environ Geochem Health, 2010

17 CSE interview with Dr T Abeysekara in February 2012

18 Dhamika M Dissanayake, 2011, The Cyanobacterial Toxins: A Hidden Health Hazard

19 Dhamika M Dissanayake, 2011, The Cyanobacterial Toxins: A Hidden Health Hazard

water, fish and lotus rhizome[20]. Exposure to cadmium was through the food chain. They attributed high cadmium in the environment to the heavy use of cadmiumcontaminated phosphate fertilizer.
Trace metals in the environment are considered as a major geo-environmental factor that could contribute to the etiology of renal damage. Several international studies done in the past have shown significantly high content of metals such as cadmium, mercury, lead, vanadium, uranium and chromium in phosphate fertilizer[21].

These findings were refuted in a 2010 study. The study showed that cadmium levels in water were higher in the non-endemic regions compared to the endemic regions. Also the cadmium content in the rice samples wasmuch lower than what was reported by Bandara*et al*[22]. The clinical evidence too did not show any symptoms in CKDue patients that were commonly associated with cadmium exposures such as bone disease (itai-itai), renal calculi and respiratory effects that manifest before renal effects, among others.

Fluoride in drinking water: The link between fluoride geochemistry in water in an area and the incidence of dental and skeletal fluorosis is well established. As in the case of some essential trace elements, the optimum range of fluoride varies within a narrow range and this causes fluoride imbalances, very often in large populations, mostly in developing countries of the tropical belt[23].

In several regions of the dry zone of Sri Lanka, excessive quantities of fluoride in groundwater have affected the water quality significantly. According to a 2010 study, high fluoride levels were found in the endemic region as well as the non-endemic regions.This does not explain the geographical distribution of the CKDue cases.

In all the studies the incidence of dental and skeletal fluorosis was widespread. Studies show 89.8% prevalence of mild to severe dental fluorosis in Anuradhapura[24]. Other studies have cited a prevalence of 55-77% in 7 to 20 year old school children in North Central Province and high levels of fluoride in drinking water in Anuradhapura[25]. The incidence of dental fluorosis in the dry zone at Anuradhapura (groundwater fluoride levels 0.10- 4.70 ppm) and Polonnaruwa (0.50- 13.10 ppm) are at about 77.5% and 56.2% respectively while in Kandy (0.02-3.7 ppm), which falls in the Wet Zone, the incidence is at 13%[26]. Though there are not enough studies on the exposure to natural fluorides and its nephrotoxic effects, animal experiments have shown kidney damage even at lower levels of fluoride exposure for a long period of time[27].

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[20] Bandara JMRS, Senevirathna DMA, Dasanayake DMRSV,Herath V, Bandara JMRP, Abeysekara T, Rajapaksha KH. Chronic renal failure in cascade irrigation systems in Sri Lanka associated with elevated dietary cadmium levels, rice and fresh water fish (Thilapia)

[21] Doul, J., Klassen, C.D and Amdour, M.O. 1980 Casaret and Doul's Toxicology (2nd ed., pp. 239-245) NY: Macmillan

[22] Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekara T, Harada K, Watanabe T, Koizumi A. Chronic kidney disease of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications, Environ Geochem Health, 2010

[23] Dissanayake and Chandrajith 2007

[24] *4th International Workshop on Fluorosis Prevention and Defluoridation of Water;* Dental Fluorosis in Anuradhapura District, Sri Lanka
T M M H Tennakoon; Sri Lanka

[25] *4th International Workshop on Fluorosis Prevention and Defluoridation of Water;* Dental Fluorosis in Anuradhapura District, Sri Lanka
T M M H Tennakoon; Sri Lanka

[26] Fluoride in groundwater, surface water, rocks and soils of an area of endemic fluorosis: in the dry zone of Sri Lanka.
H.A. Dharmagunawardhane, Department of Geology, University of Peradeniya, Sri Lanka

[27] Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekara T, Harada K, Watanabe T, Koizumi A. Chronic kidney disease of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications, Environ Geochem Health, 2010

High temperatures in Sri Lanka and long working hours in the paddy field (most of those affected are farmers or agriculture laborers) means that there is a high consumption of water, which is readily filtered by the kidney but not readily secreted by the renal tubules[28].

Although drinking water is traditionally considered to be the main source of fluoride, regular consumption of tea can also increase the fluoride intake. Farmers in the dry zone region drink 4-6 cups of tea per day—the fluoride intake gets accentuated due to the narrow range of fluoride tolerance and toxicity. According to studies, the traditional Sri Lankan black tea contains up to 1.7 ppm of fluoride, the fluoride content may further get enhanced, if the tea was prepared by fluoride containing water[29].

Combination of fluoride in drinking water and aluminum pots: According to 2009 study by OA Illeperuma, people affected by CKDue, consumed fluoride rich water and almost exclusively used sub-standard aluminum pots for cooking and storing water[30]. Leaching of aluminum under different fluoride stress and under the acidic conditions used in cooking was studied. In the absence of acidic spices, the amount of aluminum leached was quite small with a maximum of 1.20 ppm (after 10 minutes of boiling in 6 ppm fluoride solution). Under acidic conditions, with use of tamarind (with a pH of 3.02), the aluminum leached was around 18 ppm even in the absence of fluoride, with a regular enhancement of leaching at higher fluoride levels. 29 ppm of aluminum leached after 10 minutes of boiling in a 6 ppm fluoride solution. So while aluminum plays a positive role in enhancing fluoride intake to the body, the fluoride enhances the leaching of aluminum in cooking utensils. The Aluminofluoride complexes may play a significant role in causing chronic renal failure.

According to the hypothesis, people inthe areas affected by CKDue generally use inferior quality aluminum pots and pans made from re-melted scrap aluminum and used aluminum containing alloys, and hence are likely to be contaminated with other heavy metals such as lead which is a potent poison to kidneys. Such impurities present in the utensils could accelerate the dissolution of metal, when subjected to especially acidic conditions obtained during cooking.

However, the use of aluminum pots and pans does not explain the geographical distribution of CKDue patients since it is used in other parts of the country as well.

Arsenic:MACS Jayasumana of the Faculty of Medicine at Rajarata University and PA Paranagama of the Department of Chemistry at the University of Kelaniya have proposed the theory of arsenic as the main causative factor of CKDue. Jayasumana has drawn the link between the impact of arsenic, hard water and reddish brown earth and low humic gley soil. According to Jayasumana, the calcium content in the hard water combines with the arsenic found in fertilizers and pesticides, forms calcium arsenate crystals and the crystals are bound to arsenic transporters in the liver and transport to kidneys. Their studies have shown that post-mortem test of the diseased kidney had deposition of calcium arsenate crystals.

[28] Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekara T, Harada K, Watanabe T, Koizumi A. Chronic kidney disease of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications, Environ Geochem Health, 2010

[29] Chandrajith et al, 2007

[30] Illeperuma, O. A., Dharmagunawardhane, H. A., & Herath, K. P. R. P. (2009). Dissolution of aluminum from sub- standard utensils under high fluoride stress: A possible risk factors for chronic renal failures in the North-Central Province. Journal of the National Science Foundation of Sri Lanka, 37, 219–222.

Calcium arsenate crystals are bound to arsenic transporters at the liver and transported to kidneys and it disturbs the antioxidant defense system in the renal tissues[31].

The clinical assessment conducted by this team found high levels of arsenic in hair (mean of 460 ppb), high arsenic was detected in all drinking water (0.02-0.1 ppm as against the WHO recommended standard of 0.01 ppm). They have cited earlier studies to show how high arsenic levels were found in rice up to 0.26 ppm[32]. Rice is known to be particularly more susceptible to arsenic than other cereals.
They suspect agrochemicals to be a major source for arsenic. The Sri Lanka government had banned arsenic in pesticide, as an active ingredient way back in 2001— but the proponents of the arsenic theory believe that arsenic is still being used in pesticides illegally. Astudy presented by Dr Jayasumana, at the Water professionals' day symposium in October 2011, found a range of 0.18–2.58 ppm levels of arsenic in pesticides and fertilizers used by the Sri Lankan farmers[33]. However this doesn't explain the geographical extent of the CKDue patients as fertilizers and pesticides are used across the country and in other parts of the dry zone.

The arsenic theory has been subject of some skepticism after Nalin de Silva, dean of the faculty of science of University of Kelaniya, who backed the arsenic theory, in 2011 said that, he received the arsenic theory from god 'Natha' himself.

Hard water:Drinking water is at the base of all theories. The quality of drinking water is a concern. Most of the scientists agree that hard water could be a causative factor. Dr Jayasumana and his teams, with the technical support of the Water Resources Board, have brought to light that the total hardness of drinking water of CKDue patients is very high as the geographical distribution of patients overlapped with distribution pattern of high ground water hardness[34].

In a study published by Fonseka *et al* a strong positive correlation was revealed between the arsenic content and groundwater hardness in CKDue prevalent areas when compared to the other areas that showed a weak correlation between the two variables. The study also indicated that arsenic associated with elevated levels of hardness could reasonably be one of the potential causes of CKDue[35].
Janita A Liyanage of the University of Kelaniya too suggested hard water as one of the probable causes of the renal failure. Liyanage conducted a preliminary study in three divisions of North Central Province (Padaviya, Medawachchiya, Kabithigollawa) and Ampara division in Western Province. According to her preliminary findings, high levels of calcium, magnesium and zinc were found in the drinking water but lead, mercury and arsenic was not detectable. These samples were taken from the areas, which had high numbers of patients. There were no physical symptoms of arsenic poisoning but they did come across cases of brittle bones, a symptom of hard water[36].

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[31] http://www.elaw.org/system/files/Arsenic+in+Pesticides.pdf;Presentation by Dr Chana Jayasumana, Faculty of Medicine at Rajarata University

[32] Lin et al, 2004, Yamily et al,2008

[33] Jayasumana et al, Symposium Proceedings of The Water Professionals' Day, October 01, 2011

[34] CSE interview with Dr Chana Jayasumana, University of Rajarata

[35] Hardness and presence of arsenic in aquifers of selected CKDU prevalent and other areas in Sri Lanka;Fonseka Sl, Jayalath K, Amarasinghe M, Mahamithawa AMP, Senanayake VK,Paranagama PA-Faculty of Science, University of Kelaniya; Department of Pharmacology, Faculty of Medicine, Rajarata University

[36] CSE interview with Dr Janita Liyanage, University of Kelaniya

Though hard water is a problem, it is the high calcium content in the hard water in the dry zone as compared to the wet zone that has adverse effect[37]. Water is mainly calcium type in the north Central region. The groundwater of Sri Lanka is divided into 4 categories- calcium, magnesium, sodium /potassium and non-dominant action type. Calcium type of water is distributed in the northern and north central region[38].

According to a study by DM Dissanayake, low prevalence of the disease was noted in communities that consumed water from natural springs for drinking. In the five high prevalent areas—Medawachchiya, Padaviya, Girandurukotte, Medirigiriya and Nikawewa— the distribution of CKDue cases were related to stagnant irrigated water. GPS mapping showed most of the cases are located below the level ofsome reservoirs and some were related to the irrigation canals[39].

Cyanobacterial toxins:Dhammika M Dissanayake of the University of Peradeniya, in a paper in 2011, has proposed the theory of cyanobacterial toxins[40]. All the high prevalent areas are clustered around reservoirs/tanks of the irrigation system. Low prevalence of the disease was noted in communities who consumed water from natural springs. The analysis of water from natural springs revealed absence of algae and cyanobacteria and contained very low levels of fluoride, nitrogen, potassium and phosphate while the analysis of water samples from reservoirs showed the presence of blooms of cyanobacteria capable of producing hepatotoxic and carcinogenic effects. The presence of large numbers of water reservoirs within a given area in the North Central Region of Sri Lanka could explain the incidence of high prevalence of CKDue.

Bioaccumulation:Bioaccumulation of pesticide residues, heavy metals and toxins in the plants and aquatic animals especially in the big tanks is postulated as another cause for high prevalence of CKDue. The dry zone especially the North Central Province is the hub of the Mahaweli irrigation system and the Minneriya irrigation system. Through the cascade irrigation system, the water from the hills, through the tanks and eventually the fields carry not just hardness but also pesticide residues,heavy metals and toxins. The region has over 11000 tanks. These then accumulate in fishes and plants especially paddy, that is grown in these tanks. The bioaccumulation affects not just the surface water but will further percolate into the groundwater and contaminate the wells[41].

Liquor:Illicit liquor is another probable cause. Consumption of poor quality illicit liquor for prolonged periods could also lead to destruction of vital organs such as the liver and kidneys.Locally brewed liquor is made from the same water that is used for drinking, which could be hard water and have high fluoride content. According to the villagers, in order to make the liquor potent,apart from fruits and coconut toddy, barbed wire, cement and zinc was added[42].

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[37] Chandrajith et al (2009)

[38] Dissanayake.C.B. Water Quality in the Dry Zone of Sri Lanka- Some Interesting Health Aspects J.Natn.Sci.Foundation Sri Lanka 2005 33 (3:161-168)

[39] A study of geographical distribution of chronic kidney disease of unknown origin in Sri Lanka; Dissanayake DM, Jayasekera JMKB, Adhikari SB, Bandara P

[40] Dhamika M Dissanayake, 2011, The Cyanobacterial Toxins: A Hidden Health Hazard

[41] CSE interview with environmentalist and author Ranil Senanayake

[42] CSE interview with villagers at Padaviya, Anuradhapura

Alcohol is readily available in Sri Lanka. According to WHO data, the per capita consumption of alcohol in Sri Lanka for the period 2003-05 is 0.8 litres (of pure alcohol). During the same period the per capita consumption of alcohol in South East Asia region is 2.2 litres (of pure alcohol)[43].

A paper cites a community survey conducted in Sri Lanka. The survey of seven districts found 20 – 32 %of population consuming alcohol. In the rural area those who drink, do so heavily. A survey in eight villages showed 71 % of respondents drinking daily. Use was higher among poor families. 93 % of respondents used locally produced alcohol, which was not reflected in the per capita consumption[44].
In a period of 16 years (1991-2007), the alcohol production increased 158 %. The consumption of hard liquor and beer and their local production have increased since 2000 despite the government's campaign against alcohol— 'Mathata Thitha' campaign. Consumption of beer increased from 50.6 million litres in 2000 to 53.4 million litres in 2008 and 52.4 million litres in 2009. Hard liquor consumption increased from 52.4 million litres in 2000 to 75.1 million litres in 2009. As per official records, there are 200,000 illicit brew retailers as against 3200 licenced retails stores. Of the illicit liquor dens nearly 20,000 were in Colombo, Gampaha (Western Province) and Kurunegalla (North Western Province) district— these are areas adjoining the North Central Province, the CKDue affected region[45]. However, no correlation between CKDue and alcohol consumption has been established.

Pesticides:The villagers believe that it is bioaccumulation and the use of pesticides in these regions that have affected not just their drinking water but also the food that is grown using these pesticides. They have lost the local fish varieties and also have noticed effects on their cattle. Most of the people here were brought in from the wet zone in the 1950's after the Minneriya Irrigation System was put in place. They were mostly settlers so the parents of some of the affected people who are nearly in their 80's and above are not affected as much as their children are who began farming here. It was after the latter part of 1960, around 1967, when the condition became worse with the introduction of the green revolution[46]. Though there are no provincial data available, the pesticide usage is high in the paddy cultivation and vegetable growing regions—Ampara, Polonnaruwa, Anuradhapura, Humbantota, Badulla, Nuwara Eliya and Kandy.Some of these are badly hit by CKDue[47].

Ayurvedic medicines:Like in the case of BEN, there have been no definitive answers for the cause of CKDue, but a converging line of evidence supports the theory that long-term consumption of food contaminated with Aristolochic Acid underlies the pathogenesis of BEN[48]. In the Balkan regions, the exposure to Aristolochic Acid found in flour obtained from wheat contaminated with seeds of *Aristolochia clematis* could be responsible for the so-called Balkan-endemic nephropathy[49].

In Sri Lanka too herbal/ ayurvedic medicines was suspected as one of the causes. Considerable attention was put on the usage of herbal medicines, which contained Aristolochic Acid and the incidence of chronic renal failure. Many researchers have observed that the use of such herbal medicines have

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[43] http://www.who.int/substance_abuse/publications/global_alcohol_report/profiles/lka.pdf

[44] '*Impact of alcohol consumption on Asia'By Mary Assunta Consumers Association of Penang, Malaysia*

[45] '*Alcohol policy in Sri Lanka needs a rethink' by GD Dayaratne, Manager, Health Economic Policy Unit-IPS (published in The Island (online) on July 26,2012)*

[46] CSE interview with villagers in Anuradhapura and Polonnaruwa

[47] CSE interview with research officer at the Pesticide Registrar office at Kandy

[48] '*Balkan Nephropathy: Evolution of Our Knowledge'; Giorgos Bamias,MD, and John Boletis, MD; World Kidney Forum; American Journal of Kidney Diseases, Vol 52, No 3 (September, 2008):pp 606-616*

[49] Kidney Int. 2008 Jul;74(2):158-69. Epub 2008 Apr 16; Aristolochic acid nephropathy: a worldwide problem; Debelle FD, Vanherweghem JL, Nortier JL; Department of Nephrology, Dialysis and Renal Transplantation, Erasme Hospital, Brussels, Belgium.

resulted in nephrotoxic effects being found in patients and experimental animals[50]. Studies revealed that nearly 66 prescriptions contained *Aristolochia indica* (*Sapsanda*) as an ingredient. It was also found that only 10% of the selected ayurvedic practitioners studied were using *Aristolochia indica* as an ingredient in their recipes prescribed in CKDue prevalence areas. Leaf, root, fruit or vine with leaves of *Aristolochia indica* were used as ingredients of their remedies against a few diseases and poison bites. The common method of use was external application. Further, the balance of 90% of the sample uses alternative ayurvedic medical remedies. Therefore, it was concluded that the use of Nephrotoxic herbal medicines were not causal factor for the current CKDue situation found in the North-Central areas of Sri Lanka[51].

Multifactorial:A combination of two or more of above factors and its synergistic effect could be responsible for CKDue. Chemical substances formed by combining agrochemical derivatives and naturally found fluoride could also be responsible.

Box: 1Other studies in the pipeline

- ***World Health Organization (WHO)*** in association with the epidemiology unit of the Ministry of Health, in May 2009, appointed about ten study groups to conduct research in to diverse aspects of the CKDue. The report has been submitted to the government but not yet released.A joint press release by the Ministry of Health and WHO, states that one of the causative factors of CKDue is co exposure of susceptible individuals to a combination of nephrotoxic heavy metals (cadmium and arsenic) at low concentration[52].
- ***University of Peradeniya*** is also doing a research on genetic predisposition of the people affected with the disease to understand if there are any genetic predispositions that are responsible for the prevalence of CKDue in the North Central region[53].

8. State of Medical Care and Research

In 2005, about 350 million rupees (4.6% of the Annual Health Budget of Sri Lanka) were spent on the management of patients with Renal Diseases[54]. Latest data is not available.

There is lack of sufficient medical facilities in the country to deal with the rising number of CKDue. There is a district hospital each at Anuradhapura (also the biggest district in the country), Polonnaruwa and Badulla—these are known as general hospitals. These hospitals are under equipped to handle the large number of dialysis patients. They have to then go to either the Kandy hospital (which is nearest to the affected regions) or to Colombo. Ten mobile clinics and renal satellite centers have been set up with the initiatives of doctors at the Kandy hospital. The mobile clinics and satellite renal centers helps to identify renal failures in its initial stages and proceed with treatment[55].

[50] Nephrology (Carlton). 2010 Jun 15; Suppl 2:10-7; Herbal medicines and chronic kidney disease- Jha V, Department of Nephrology, Postgraduate Institute of Medical Education and Research, Chandigarh, India

[51] *Usage of Nephrotoxic Herbal Medicines and Their Impacts on the Prevailing CKDue Increase in Sri Lanka;* Hewagamage P, Hemachandra P, Ethugala DN, and Ranathungamage K

[52] Joint press statement of Ministry of Health and WHO

[53] CSE interview with Prof Rohan Chandrajith, University of Peradeniya

[54] http://www.searo.who.int/LinkFiles/News_Letters_CKDu.pdf

[55] CSE interview with CEJ, doctors and villagers in the North Central region

9. Objective of the study

The Hon'ble minister for Water Supply and Drainage Mr Dinesh Gunawardana, in December 2011 had approached CSE to assist in water quality testing to understand the renal/kidney failure problem in the north central region of Sri Lanka.

The Centre for Environmental Justice (CEJ) also approached CSE in 2011 to do the same study. CEJ is an environmental organization based in Colombo in Sri Lanka and works on issues related to environmental and human health. CSE decided to do the study in association with CEJ.

In Sri Lanka, the quality of drinking water is at the base of all theories linked with CKDue. In many studies, trace metals (especially arsenic) in the environment have been identified as a major geo-environmental factor contributing to the etiology of renal damage. The focus of the study, therefore, was to analyze drinking water quality for physico-chemical parameters and heavy metals in affected and unaffected regions. Samples of soil, food commodities (rice grain and plant), pesticides and fertilizers were also tested for arsenic to understand the linkage of arsenic with CKDue.

10. Sampling

Study Area

In the North Central Province of Sri Lanka, high numbers of CKDue cases have been observed in the two districts:Anuradhapura and Polonnaruwa. The prevalence is now spreading to the adjoining districts ofUva Province, Eastern Province andNorth Western Province.

To understand the probable causes of renal failure, an analysis of water samples was done.Thirty-five water samples werecollected from CKDueaffected areas of Hingurukgoda and Medirigiriya in the Polonnaruwa district; Padaviya, Medawachchiya and Kabithigollawain the Anuradhapura district; Dehiattakandiya in the Ampara district; and, Girandurukotte and Mahiyanganaya in the Badulla district. Five water samples were also collected from the non-affected areas of Kandy district(see Table 1-4).

Jayasumana *et al* (2011) reported the presence of arsenic compounds in drinking water, in rice grown in the area, and in hair and urine of CKDue patients[56]. This led to the hypothesis that presence of arsenic compounds in drinking water and food could be a potential cause of CKDue and the arsenic in pesticides and fertilizers may be the potential source of the contamination. Therefore, in addition to water samples, sixteen soil samples, six rice plant and grain samples, five pesticide samples and three fertilizer samples were also collectedfrom endemic areas and were analyzed for their arsenic content.

Water

During the study,water samples (n=35) from ground water (dug well and tube well), municipal supply, tank, river and springswere collected from the affected areas. Inorder to compare the results of water quality in the endemic regions, five water samples were taken from Kandy area (n=5). Kandy in Central Province, which falls in the wet zone, was used as reference area as there were no reports of CKDue from here.

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[56] Jayasumana et al 2011. Presence of Arsenic in Pesticides used in Sri Lanka: A preliminary Analysis.Abstract published in the Symposium Proceedings of The Water Professionals' Day

The 40 water samples collected from both endemic (n=35) and reference areas (n=5) have the following source-wise categorization: well water (n=28; 23 dug well and 5 tube well), tank water (n=4; Ampara, Padaviya, Minneriya and Konduwatwana Tank), municipal supply(n=4),river(n=1) and spring (n=3).

The well water samples were collected from the centre of the well and at about a depth of three feet from water surface in clean plastic bottles.During sample collection, CKDuepositive patients and their family members were interviewed and data on age, occupation, and source of drinking water and family history were recorded(see Table 1).All the water samples were analyzed for physico-chemical parameters and heavy metals.

Soil

Of the total soil samples (n=16) collected, 14 were from the affected endemic region, while 2 were from the control. From the endemic region, samples were collected from Ampara district (n=4), Badulla district (n=2), Polonnaruwa (n=4) and Anuradhapura (n=4).For comparisonof soil quality, samples were also collected from Kandy (n=2). The samples were collected in polythene bagsand were stored under refrigerated conditions until analyzed for arsenic content (see Table 2).

Rice

Rice samples (n=6)—riceplant(n=4)and grain (n=2)—were collected from the fields and from households in the affected areas in polythene bagsand were stored under refrigerated conditions untilanalyzed for arsenic content (see Table 3).

Fertilizer

Three samples of commonly used fertilizer—Urea, Triple Super Phosphate (TSP),Muriate of Potash (MOP)— were purchased fromretail outlets in Udawalawe in Uva Province and analyzed for arsenic content(see Table 4).

Pesticide

Sealed samples of 5 pesticides—insecticide, weedicide and fungicide—were purchased from retail outlets in Medawachchiya in Anuradhapura districtand analyzed for the arsenic content. Information provided by the manufacturers did not mention about the presence of arsenic as active ingredient(seeTable 4).

District-wise samples

- Ampara (Eastern Province): 10 water samples (6 well, 1 tube well, 2 tank, 1 municipal supply), 4 soil samples and 1 rice plant sample
- Badulla (Uva Province): 5 water samples (4 well, 1 municipal supply), 2 soil samples and 1 rice plant sample
- Polonnaruwa (North Central Province): 10 water samples (8 well, 2 tube well, 1 tank), 4 soil samples, 1 rice plant sample and 2 rice grain sample
- Anuradhapura (North Central Province): 10 water samples (6 well, 1 tube well, 1 tank, 2 spring), 4 soil samples and 1 rice plant sample
- Kandy (Central Province): 5 water samples (1 tube well, 2 Municipal supply, 1 spring, 1 river) and 2 soil samples

11. Methodology

Water

- The**physico-chemical parametersin water samples**—*pH, hardness, TDS, conductivity, alkalinity, calcium, magnesium,sulfate, chloride andfluoride*—were analyzed using standard methodology provided by American Public Health Association (APHA 1985)[57].

- For **heavy metals in water samples**—*lead, cadmium and chromium*—samples were prepared by EPA method 3010 for aqueous and extracted samples analyzed by Flame Atomic Absorption Spectrophotometry(FLAA).Detection limit for lead was 0.01 ppm, cadmium 0.01ppm, and chromium 0.02ppm.*Arsenic*in water samples wasanalyzed using standard methodology prescribed by Environment Protection Agency, EPA method 7060A –Graphite Furnace Atomic Absorption Spectrometry (GFAA).Detection limit for arsenic was 0.002ppm.

Soil

Soil samples (n=16) collected from the endemic and non endemic areas were analyzed for arsenic using standard methodology prescribed by Environment Protection Agency, EPA method 7062–Vapour Hydride Generation(VGA) by Borohydride generationmethod. Detection limit for arsenic in soil was 0.004ppm.

Rice

The rice (grain and plant) samples after acid digestion was analyzed by Vapour Hydride Generation(VGA) using Borohydride generation method given by Lin *et al* 2004[58].Detection limit for arsenic in rice grain and plant was 0.06 ppm.

Pesticide and Fertilizer

Pesticides and fertilizer sampleswere analyzed for arsenic using standard methodology prescribed by Environment Protection Agency, EPA method7060–Graphite Furnace Atomic Absorption Spectrophotometry (GFAA).Detection limit for arsenic in pesticides and fertilizers was 0.004ppm.

12. Results and Discussion

a). Water Samples

The results of the physico-chemical parameters and heavy metalsanalyzed in the water samples (n=40)—groundwater (n=28), tank water (n=4), municipal supply(n=4), spring (n=3) and river water(n=1)—collected from the endemic and non endemic areas is given in Table 5 and Table 6.

In the present study theSri Lanka standards for potable water prescribed inSLS 614: 1983were used for the comparison of the water quality parameters in the CKDue affected and unaffected areas. The standard provides the **maximum desirable levels** and the **maximum permissible levels** for drinking water.

[57] APHA 1985 Standard Methods for the examination of waterand waste water 16th Edition. Washington DC.

[58] Haw- Tarn Lin et al (2004) Heavy Metal content of Rice and Shellfish in Taiwan. Journal of Food and Drug Analysis, Vol 12, No. 2 Pg 167-174.

Total Dissolved Solids

Under SLS 614: 1983 the ***maximum desirable level for TDS is 500 ppm*** and the ***maximum permissible level is 2000 ppm***. The results of the Total Dissolved Solids (TDS)in the water samples collected from CKDue affected areas (n=35) and reference areaof Kandy(n=5) are as follows:

Affected areas

- In the Ampara district (n=10),TDSwere detected at a mean level of 211.1ppm. The TDS levels in 9 samples were within the maximum desirable level of 500 ppm and 1 sample was above the maximum desirable level but well within the maximum permissible level of 2000 ppm. Highest concentration of 599 ppm was detected in one tube well sample (40-50 feet deep) collected from the house of K Jayanti of Mahaoya division. Lowest concentration of 49.3 ppm was detected in the municipal water supply collected from tap water in Ampara town (see Table 6).

- In Badulla district(n= 5), TDS were detected at a mean level of 217.7 ppm, in the range of 65.7-399 ppm. All the samples were within the maximum desirable levels of 500 ppm.The highest concentration of 399 ppm was detected in one well-water sample (15 feet deep) collected from the house of BB Ukubanda of Mahiyanganaya area. Lowest concentration of 65.7 ppm was detected in the municipal water supply collected from Mahiyanganayaarea (see Table 6).

- In Polonnaruwa district (n=10), TDS were detected at a mean level of 341.3 ppm, in the range of 112 to 539 ppm. The TDS levels in 9 samples were within the maximum desirable level of 500 ppm and 1 sample was above the maximum desirable level but well within the maximum permissible level of 2000 ppm. Highest concentration of 539 ppm was detected in one well-water sample (15-20 feet deep) collected from the house of Jaya Singhu in Medirigiriya area. Lowest concentration of 112 ppm was detected in the well water (15 feet deep) collected fromnear MK Heratha's house in Medirigiriya (see Table 6).

- In Anuradhapura district (n=10), TDS were detected at a mean level of 399.3 ppm, in the range of 56.4 to 792 ppm. The TDS levels in 5 samples were within the maximum desirable level of 500 ppm and 5 samplesexceeded the maximum desirable level but well within the maximum permissible level of 2000 ppm. The 5 samples that exceeded the maximum desirable level were in the range of 563 to 792 ppm and were collected from the Medawachchiya (n=4) and Kebithigollewa (n=1) areas in Anuradhapura. Highest concentration of 792 ppm was detected in a well-water sample (15 feet deep) collected from near a shop in Medawachchiya. Lowest concentration of 56.4 ppm was detected in spring water collected fromKebithigollewa (see Table 6).

Unaffected areas

- In the reference area of Kandy (n=5),TDS were detected at a mean level of 113.2 ppm, in the range of 34 to 237 ppm. None of the samples exceeded the maximum desirable level of 500 ppm. Highest concentration of 237 ppm was detected in municipal supply collected from a shop in Ambatenna town. Lowest concentration of 34 ppm was detected in river water collected from Mahaweli River at Kandy (see Table 6).

Source-wise results

- In 40 water samples collected, TDS was detected at a mean level 363 ppm in dug wells; 306 ppm in tube wells; tank water was 192.3 ppm followed by municipal water 97.5 ppm, spring water 57.2 ppm and river water 34 ppm(see Table 7-8).
- The mean TDS level in all water samples (n=35) of the affected area was 271.3 ppm as compared to 113.2 ppm in the reference area (n=5).

<u>Hardness</u>

Under SLS 614: 1983 the ***maximum desirable level for hardness is 250 ppm*** and the ***maximum permissible level is 600 ppm***. The results of hardnessin the water samples collected from CKDue affected areas (n=35) and reference areaof Kandy(n=5) are as follows:

Affected Areas

- In Ampara district (n=10), hardness was detected at mean level of 210 ppm in the range of 120 to 350 ppm. The hardness levels in 1 sample exceeded the maximum desirable level of 250 ppm but were well within the maximum permissible level of 600 ppm. Highest hardness levels of 350 ppm was detected in well water sample collected from DM Senaviratha's house in Dehiattakandiya area. Lowest hardness level of 120 ppm was collected from well water sample 15-20 feet (see Table 6).

- In Badulla district (n=5), hardness was detected at a mean level of 154 ppm in the rangeof 120 to 220 ppm. All the samples were within the maximum desirable level of 250 ppm. Lowest hardness was detected in well water (14 feet deep) sample collected from the house of HM Muthubanda in Girandurukotte area and the highest levels of hardness was detected in well water sample collected from house of M Tilakratna in Girandurukotte(see Table 6).

- In Polonnaruwa district (n=10), hardness was detected at a mean level of 256.7 ppm in the range of 160 to 350 ppm. Hardness levels in 5water samples exceeded the maximum desirable level but were well within the maximum permissible level. Hardness levels were beyond the maximum desirable level in 4dug well samples collected from Hingurukgoda (n=2) and Medirigiriya (n=2) area and one tube well sample collected from Medirigiriya. Five samples were within the maximum desirable level—one water sample taken from Minneriya tank and 3 samples each of well water (Hingurukgoda (n=1) and Medirigiriya (n=1)) and tube well water from Medirigiriya. Highest level of hardness of 350 ppm was detected in the well water sample from Medirigiriya from the house of MK Sisipal and the lowest levels of hardness was detected in the Minneriya tank(see Table 6).

- In Anuradhapura district (n=10), hardness was detected at a mean level of 274.1 ppm in the range of 80 to 470 ppm. Hardness levels in 7 water samples exceeded the maximum desirable level but were within the maximum permissible level. Hardness levels were beyond the maximum desirable level in 6 dug well samples collected from Padaviya (n=2) and Medawachchiya (n=3) and Kebithigollewa (n=1) area and one tube well sample collected from Medawachchiya. Highest level of hardness of 470 ppm was detected in the well water (15 feet deep) sample from opposite the hospital at Medawachchiya and the lowest levels of hardness of 80 ppm was detected in the sample collected from spring water (Lion spring) at Kebithigollewa (see Table 6).

Unaffected Area

- In Kandy district (n=5), hardness was detected at a mean level of 136 ppm in the range of 50 to 270 ppm. Hardness levels in 1 tube well water (80-90 feet deep) collected from a house in Kandy area exceeded the maximum desirable level but were within the maximum permissible level. Lowest level of hardness of 50 ppm was detected in a spring water sample collected from Kandy (see Table 6).

Source-wise results

- In 40 water samples collected, hardness was detected at a mean level of 291.5 ppm in tank water, 258 ppm in dug wells; 246 ppm in tube wells; followed by municipal water 155 ppm, spring water 93 ppm and river water 59.7 ppm(see Table 7-8).
- The mean hardness level in all water samples (n=35) of the affected area was 225.8 ppm as compared to 136 ppm in the reference area (n=5).

Calcium

Under SLS 614: 1983 the ***maximum desirable level for calcium is 100 ppm*** and the ***maximum permissible level is 240 ppm***. The results of calciumin the water samples collected from CKDue affected areas (n=35) and reference areaof Kandy(n=5) are as follows:

Affected Areas

- In Ampara (n= 10), calcium was detected at a mean level of 64.4 ppm, in the range of 8 to 120 ppm.One well-water sample, collected from DM Senaviratha's house in Dehiattakandiya, exceeded the maximum desirable level. The lowest level of 8 ppm was found in a well water (15-20 feet deep) sample collected from the house of KM Chandravati at Ampara area(see Table 6).

- In Badulla district (n= 5), calcium was detected at a mean level of 69.6 ppm,in the range of 52 to 80 ppm. All the samples were within the maximum desirable level for calcium. The lowest levels of calcium was detected in 1 well water (15 feet deep) sample collected from the house of M Tilakratna atGirandurukotte. The highest levels of calcium were found in two samples—1 municipal supply sample collected from Mahiyanganaya and the other is well water sample collected from the house of Uppalapananayaka at Girandurukotte(see Table 6).

- In Polonnaruwa district (n=10), calcium was detected at a mean level of 73.6 ppmin the range of 40 to 140 ppm.Four well water samples (Hingurukgoda (n=3) and Medirigiriya (n=1)) exceeded the maximum desirable level. Highest calcium levels of 140 ppmwas detected in well water sample collected from Hingurukgoda area from the house of SWC Werasinghe and the lowest calcium levels were detected from well water taken from the house of MK Heratha in Medirigiriya (see Table 6).

- In Anuradhapura district (n**=**10), Calcium was detected at a mean level of 84.4ppmin the range of 8.0 to 172 ppm**.** Three well water samples— 2 dug well (Medawachchiya (n=1) and Kebithigollewa (n=1)) and 1 tube well (Medawachchiya)— exceeded the maximum desirable levels but were within the maximum permissible level. Seven samples were within the desirable levels. The highest calcium levels were detected in dug well (15 feet deep) sample collected from a shop in Medawachchiya area and lowest calcium levels were detected in the spring water sample collected from Kebithigollewa area (see Table 6).

Unaffected Area

- In Kandy district (n=5), calcium was detected at a mean level of 43.2 ppm in the range of 12 to 100 ppm. None of the water samples exceeded the maximum desirable levels. The highest level of 100 ppm was detected in a municipal supply sample collected from a shop in Kandy town. The lowest level of calcium was detected in a municipal supply sample collected from a shop close to the Mahaweli River (see Table 6).

Source-wise results

- In 40 water samples collected, calcium was detected at a mean level 86 ppm in dug wells, 62 ppm in tube wells, 66 ppm in tank water followed by municipal water 52 ppm, spring water 16 ppm and river water 20 ppm(see Table 7).
- The mean calcium level in all water samples (n=35) of the affected area was 70.7 ppm as compared to 43.2 ppm in the reference area (n=5).

Alkalinity

Under SLS 614: 1983 the ***maximum desirable level for alkalinity is 200 ppm*** and the ***maximum permissible level is 400 ppm***. The results of alkalinityin the water samples collected from CKDue affected areas (n=35) and reference areaof Kandy(n=5) are as follows:

Affected Areas

- In Ampara (n= 10), alkalinity was detected at a mean level of 61 ppm, in the range of 10 to 130 ppm. All water samples were within the maximum desirable levels. Highest level was detected in a tube well (40-50 feet deep) sample collected from the house of K Jayanti Mahaoya area in Ampara. Lowest levels were detected in tank water and municipal supply from Ampara (see Table 6).

- In Badulla (n= 5), alkalinity was detected at a mean level of 66ppm, in the range of 20 to 110 ppm. All water samples were within the maximum desirable limits. Highest alkalinity level was detected in a dug well (15 feet deep) sample collected from the house of BB Ukubanda in Mahiyanganaya area. The lowest levels were detected from the municipal supply from Mahiyanganaya area (see Table 6).

- In Polonnaruwa (n=10) the mean alkalinity level was 121.7 ppm in the range of 30 to 200 ppm. All the samples were within the maximum desirable levels. Highest alkalinity was detected in two dug well water samples from Medirigiriya area. The lowest was detected in a dug well water sample collected from the house of Premasone in Medirigiriya (see Table 6).

- In Anuradhapura (n=10) the mean alkalinity level was 147.7 ppm in the range of 10 to 250 ppm. Five well water samples (1 tube well and dug well each from Medawachchiya, 1 dug well from Padaviya and Kebithigollewa each) exceeded the maximum desirable levels but were within the maximum permissible levels. Highest levels were detected in samples collected from 2 places- 1 tube well (35-40 feet deep) sample collected from the house of K Senaviratta in Medawachchiya area and 1 dug well (15-20 feet deep) sample from the house of Somavati in Kebithigollewa area (see Table 6).

Unaffected Area

- In Kandy (n=5), the mean level of alkalinity was 26 ppm, in the range of 10 to 50 ppm. All the samples were well within the maximum desirable levels. The lowest levels were detected in municipal supply (from near the Mahaweli River) and river water samples in Kandy area. The highest levels were detected in municipal supply sample collected from near a shop in Ambatenna town in Kandy area (see Table 6).

Source-wise results

- In 40 water samples collected, alkalinity was detected at a mean level 131 ppm in dug wells, 96 ppm in tube wells, 72.5 ppm in tank water followed by municipal water 22.5 ppm, spring water 16.7ppm and river water 10 ppm(see Table 7-8).
- The mean alkalinity level in all water samples (n=35) of the affected area was 95 ppm as compared to 26ppm in the reference area (n=5).

Fluoride

Under SLS 614: 1983 the ***maximum desirable level for fluoride is 0.6 ppm*** and the ***maximum permissible level is 1.5 ppm***.The results of fluoridein the water samples collected from CKDue affected areas (n=35) and reference areaof Kandy(n=5) are as follows:

Affected area

- In Ampara (n= 10), fluoride was detected at a mean level of 0.6 ppm, in the range of 0.4 to 1.2 ppm. Two samples exceeded the maximum desirable levels of 0.6 ppm. Highest level was detected in a tube well (40-50 feet deep) sample collected from the house of K Jayanti, Mahaoya area in Ampara. Lowest levels were detected in dug well water (22 feet deep) sample collected from the house of AM Selavathi in Dehiattakandiya area (see Table 6).

- In Badulla (n=5), fluoride was detected at a mean level of 0.9 ppm, in the range of 0.6 to 1.2 ppm. Four samples exceeded the maximum desirable levels of 0.6 ppm set by Sri Lanka. Of those that exceeded the Sri Lanka standards, 4 were dug well samples and 1 was from municipal supply. The highest level was detected in a dug well (15 feet deep) sample collected from the house of BB Ukubanda in Mahiyanganaya area. The lowest levels were detected from a dug well water sample collected from the house of Uppalapananayaka inGirandurukotte area(see Table 6).

- In Polonnaruwa (n=10), fluoride was detected at a mean level of 0.9 ppm, in the range of 0.5 to 1.7 ppm.Eight well water samples exceeded the maximum desirable levels of 0.6 ppm set by Sri Lanka. Of the well water samples, 6 were dug well samples (Medirigiriya (n=3) and Hingurukgoda (n=3)) and 2 tube wells from Medirigiriya. One sample exceeded the maximum permissible levels set by Sri Lanka.Maximum levels were detected from a sample in tube well (200 feet deep) from the Bisobandara village in Medirigiriya. The lowest fluoride level was detected in a well water sample from the house of MK Heratha in Medirigiriya (see Table 6).

- In Anuradhapura (n=10) the mean fluoride level was 0.9 ppm in the range of 0.4 to 1.5 ppm. Seven samples exceeded the maximum desirable levels-Five well water (Padaviya (n=2), Medawachchiya (n=2), Kebithigollewa (n=1)), 1 tube well (Medawachchiya)and 1 tank (Padaviya)- but were within the maximum permissible level. The highest level of fluoride was detected in a dug well (20 feet deep) sample collected from the house of KA Vijaypal in the Padaviya area. Lowest levels were detected in spring water collected from Kebithigollewa area (see Table 6).

Unaffected area

- In Kandy (n=5), the mean level of fluoride was 0.5 ppm, in the range of 0.3 to 0.9 ppm. One tube well water sample collected from a house in Kandy area exceeded the maximum desirable level but was within the maximum permissible level. The highest levels were detected in tube well sample close to Kandy town. The lowest levels were detected in municipal supply sample collected from near a shop in Ambatenna town in Kandy area (see Table 6).

Source-wise results

- In 40 water samples collected, fluoride was detected at a mean level1 ppm in dug wells, 1 ppm in tube wells, 0.7 ppm in tank water followed by municipal water 0.5 ppm, spring water 0.4ppm and river water 0.5 ppm(see Table 7-8).
- The mean fluoridelevel in all water samples (n=35) of the affected area was 0.8 ppm as compared to 0.5ppm in the reference area (n=5).

Other parameters

The other parameters tested were for **pH, chloride, sulfate and magnesium**. In all the 40 water samples, these parameters were found to be within the maximum desirable levels prescribed for drinking water under SLS 614: 1983.The results of pH, chloride, sulfate and magnesium are given in Table 6-8.

Heavy metals in drinking water

Cadmium, arsenic, chromium and lead were not detected in drinking water samples collected either from the affected area or reference area, indicating that these heavy metals in drinking waterisnot a contributing factor for CKDue in Sri Lanka, as also reported earlier[59]. If heavy metal is a causative factor of CKDue, then its source is different than drinking water (see Table 6-7).

b). Soil

Soil samples (n=16) collected from the affected and unaffected areas were analyzed for arsenic. There are no standards for arsenic levels in soil in Sri Lanka.

Arsenic was detected in 16 soil samples in the range of ND-0.28 ppm.The mean arsenic level in the soil sample from the affected region was 0.06 ppm.Mean level of arsenic in the soil samples from Ampara district (n=4) was 0.105 ppm; from Polonnaruwa (n=4) was 0.128 ppm and Anuradhapura (n=4) was 0.050 ppm. Arsenic was not detected in soil samples from Badulla district (n=2). Arsenic content in the soil (n=2) samples collected from the unaffected reference area of Kandy was 0.035 ppm (see Table 9).

According to Agency for Toxic Substances and Disease Registry (ATSDR) of the US, the mean level of arsenic permissible in soil is 7.2 ppm and the maximum acceptable level of arsenic recommended by the European Community for agricultural soil is 20.0 ppm. The levels of arsenic found in the soil samples of the affected and unaffected areas of Sri Lanka are well within the above-mentioned standards. Also, the difference in the arsenic levels in the soil samples of the affected and the unaffected areas are not significant.

[59]Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekara T, Harada K, Watanabe T, Koizumi A. Chronic kidney disease of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications, Environ Geochem Health, 2010

c). Rice

Rice is susceptible to arsenic accumulation compared to other cereals and presence in locally grown rice has been reported from Sri Lanka[60]. However in the present study arsenic was not detected in rice grain (n=2) and plant samples (n=4) samples collected from the affected region—Ampara (rice plant n=1), Badulla (rice plant n=1), Polonnaruwa (rice plant n=1, grain n=2), Anuradhapura (rice plant n=1) (see Table 10).

d). Pesticides

Samples of 5most commonly used pesticides—insecticide, weedicide and fungicide—were tested for arsenic in the present study. Sealed packets of pesticides were purchased from the retail outlet. Arsenic was detected in the range of 0.009 to 0.254 ppm(see Table 11).The levels detected in the present study suggest that arsenic is likely to be present as an impurity from other ingredients rather than adulteration of these products.

A recent study from Sri Lanka detected arsenic in 29 out of 31 pesticide brands in the range of 0.180 to 2.586 ppm. The arsenic content varied depending on the type of active ingredient, brand, batch of pesticides, importer and the area that it was used in[61].

Fertilizers

Samples of three most commonly used fertilizers—Urea, Triple Super Phosphate(TSP) and Muriate of Potash(MOP)— were analyzed for arsenic. These samples were purchased from retail outlets in Udawalawe in Uva Province. Arsenic was detected in the range of 0.09 to 0.406 ppm– Urea 0.203 ppm,TSP 0.406 ppm and MOP 0.090 ppm (see Table 11).

However, a study conducted in Sri Lanka showed that among the chemical fertilizers TSP had 31 ppm arsenic while Urea and MOP were not contaminated with arsenic[62].

13. Conclusion

40 water samples—groundwater (n=28), tank water (n=4), municipal supply(n=4), spring (n=3) and river water (n=1)—were analyzed (see Table 5).The results are as follows: -

- Total Dissolved Solids exceeded the maximum desirable levels of 500 ppm in 6 out of 40 samples—5 dug well water and 1 tube well water, all in the affected areas.
- Hardness exceeded the maximum desirable levels of 250 ppm in 14 out of 40 samples—11dug well water and 3 tube well water. 1 tube well water sample, which exceeded the maximum desirable levels, was from the reference area.
- Calcium exceeded the maximum desirable levels of 100 ppm in 9 out of 40 samples—7 dug well water and 2 tube well water, all from the affected areas.
- Alkalinity exceeded the maximum desirable levels of 200 ppm in the 5 out of 40 samples—4 dug well water and 1 tube well water, all from the affected areas.

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[60] Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekara T, Harada K, Watanabe T, Koizumi A. Chronic kidney disease of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications, Environ Geochem Health, 2010

[61] Jayasumana *et a*l 2011. Presence of Arsenic in Pesticides used in Sri Lanka: A preliminary analysis.*Abstract* published in the Symposium Proceedings of The Water Professionals' Day

[62] Jayasumana *et al* 2011. Determination of arsenic content in synthetic and organic manure basedfertilizers available in Sri Lanka.

- Fluoride levels exceeded the maximum desirable levels of 0.6ppm in 22 out of 40 samples—15 dug well water, 5 tube well water, 1 municipal supply and 1 tank water sample. 1 tube well water sample, which exceeded the maximum desirable levels, was from the reference area. One tube well water sample from Polonnaruwa exceeded the maximum permissible levels of 1.5 ppm.

The physico-chemical parameters --TDS, alkalinity, hardness and calcium were higher in groundwater (dug well and tube well) samples than the water samples collected from tanks, municipal supply, springs and river. People in the affected areas of Ampara, Badulla, Polonnaruwa and Anuradhapura district were consuming water directly from these dug wells and tube wells (see Table 8).Not all households have access to water filters[63].

The results also indicate that maximum number of groundwater samples exceeded the maximum desirable level of fluoride.The study shows that fluoride levels of groundwater in the dry zone are higher, in the range of 0.4 to 1.7 ppm as compared to those of the wet zone that is in the range of 0.3 to 0.9 ppm. Though the fluoride levels, in all but one sample, is within the maximum permissible levels prescribed in SLS 614: 1983, studies have shown that fluoride at these low levels over a long period of time is a possible risk factor responsible for kidney diseases[64].

Heavy metals—lead, cadmium, chromium and arsenic—were not detected in drinking water samples collected from the affected areas. Arsenic was not detected in rice gain and plant. Arsenic was detected at very low levels in soil, pesticides and fertilizers collected from the affected areas. The samples of pesticides and fertilizer were randomly selected and the sample size was small. A larger study on the agrochemicals needs to be done conclusively to establish the levels of arsenic in them.

It can be safely concluded that:

- **People in the affected areas are drinking relatively poor quality water than those in the unaffected areas.**
- **The spring, river water and municipal water are of comparatively better quality (based on the parameters tested)than dug well and tube well water.**
- **Heavy metals in drinking water are not related to CKDue in Sri Lanka. If heavy metal is responsible, then there is a different source for it than drinking water and that should be explored.**

14. Recommendations

The affected area covers approximately 17000 square km and with a population about 2.5 million in which more than 95% live in rural areas[65]. The results show that groundwater, available for the villages in the affected regions, is not of desirable quality. Thus the chemistry of the groundwater has an important bearing on the health of the population.

Inthe survey by CSE and CEJ in the affected regions, it became evident that there was a need to enhance the medical facilities in the north central region of Sri Lanka. Doctors have set up mobile clinicsbut they

[63] CSE interview with villagers

[64] Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekara T, Harada K, Watanabe T, Koizumi A. Chronic kidney disease of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications, Environ Geochem Health, 2010

[65] Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekara T, Harada K, Watanabe T, Koizumi A. Chronic kidney disease of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications. Environ Geochem Health, 2010

are unable to meet the demands. Early diagnosis saves lives. Enough dialysis facilities are not available in the hospitals and patients have to go to as far as Kandy and Colombo for treatments[66].

Thus, it is recommended that: -

- Efforts should be made to supply clean drinking water to villages so that their dependence on unfiltered groundwater is eliminated.
- Medical facilities in the affected area should be upgraded.
- Government should increase the number of mobile clinics so that patients can be diagnosed at an early stage and treatment can begin.
- Dialysis is critical. Enough dialysis sets should be made available in the district hospitals to ensure that patients do not have to travel far for their treatment.
- Government of Sri Lanka should support further research on CKDue and its linkages with environmental and life style patterns. It should also organize an annual symposium/ meeting and bring all the experts working on the issue of CKDue together to forge a way ahead.

[66] CSE – CEJ interview with villagers

Table 1.Details of the water samples collected from the affected and reference areas in Sri Lanka

Sample No.	Source	Depth	Province	Place	District	CKD affected /unaffected	Remarks
Reference area (n=5)							
1	Municipal water		Central Province	Ambatenna	Kandy	CKD unaffected	Kalena enterprises shop
2	Spring water	20-30 feet	Central Province		Kandy	CKD unaffected	Used for drinking purpose
3	River water		Central Province	Mahaweli River	Kandy	CKD unaffected	Used for drinking purpose
4	Municipal water		Central Province	Mahaweli	Kandy	CKD unaffected	TMD, Sirisena, Ajanta tailors
5	Tube well	80-90 feet	Central Province	Minmeya Rd, Kandy	Kandy	CKD unaffected	W-O5House, Minmeya Rd
Affected Area (n=35)							
6	Well water	15 feet	Eastern Province	Near Ampara Rd	Ampara	CKD unaffected	From the well in the house of Kemchandrawati, 54 years
7	Tube Well	40-50 feet	Eastern Province	Mahaoya	Ampara	CKD affected	K Jayanti's house,father died of CKDue
8	Well water	15-20 feet	Eastern Province	Ampara town	Ampara	CKD unaffected	From the road side, used for drinking purpose
9	Ampara Tank		Eastern Province	Ampara town	Ampara	CKD unaffected	Used for drinking purpose
10	Municipal water		Eastern Province	Ampara town	Ampara	CKD unaffected	Fromthe hotel used for drinking purpose
11	Konduwatuwana Tank	3.0 mm above MSL	Eastern Province	Ampara town	Ampara	CKD unaffected	Irrigation and drinking purpose
12	Well water	22 feet	Eastern Province	Dehiattakandiya	Ampara	CKD affected	A. M Selawathi, 53 years, high blood pressure
13	Well water	20-30 feet	Eastern Province	Dehiattakandiya	Ampara	CKD affected	DM Senaviratha, 53 years kidney problem diagnosed 4 years ago, no alcohol consumption, protein level high in urine
14	Well water	23 feet	Eastern Province	Dehiattakandiya	Ampara	CKD affected	D.M.Ukkubanda, Village Bakmenewawa, diagnosed with CKD 2 years back
15	Well Water	20 feet	Eastern Province	Dehiattakandiya	Ampara	CKD affected	RMPRathnayaka, using water before diagnosis of CKDue
16	Well water	17 feet	Uva Province	Girandurukotte	Badulla	CKD affected	Uppaldapanayaka,446/57, Village Belaganwewa.
17	Well water	14 feet	Uva Province	Girandurukotte	Badulla	CKD affected	From the house of HM Muthubanda, Village Belanganwewa
18	Well water	15 feet	Uva Province	Girandurukotte	Badulla	CKD affected	From the house of MTilakratana
19	Well water	15 feet	Uva Province	Mahiyanganaya	Badulla	CKD affected	From the house of BB Ukkubanda, Dibulpalarisa
20	Municipal water		Uva Province	Mahiyanganaya	Badulla	CKD unaffected	Drinking purpose
21	Well water	25 feet	North Central Province	Hingurukgoda	Polonnaruwa	CKD affected	From the house of SWC Werasinghe

S. NO.	Source	Depth	Province	Place	District	CKDaffected /unaffected	Remarks
22	Minneriya tank		North Central Province	Hingurukgoda	Polonnaruwa	CKD unaffected	Drinking purpose, no cases of renal failure
23	Well water	15 feet	North Central Province	Hingurukgoda	Polonnaruwa	CKD unaffected	Sanasuma shop used for drinking purpose
24	Well water	20 feet	North Central Province	Hingurukgoda	Polonnaruwa	CKD affected	From Rodrigo's house,Kumargram,Gypsum filter (sand, stones) used to filter water before use
25	Tube well	30 feet	North Central Province	Medirigiriya	Polonnaruwa	CKD affected	From Bisobandara Vidyalaya -400-500 students. 4 villages. 75 families use the tube well water for drinking
26	Well water	22 feet	North Central Province	Medirigiriya	Polonnaruwa	CKD affected	Premasone, Village Bisobandara, 10-12 families take waterfrom well water
27	Well water	15 feet deep	North Central Province	Medirigiriya	Polonnaruwa	CKD affected	MK Herath, Village Bisobandara about 20 families take from thewell built byUNESCO
28	Tube well	200 feet deep	North Central Province	Medirigiriya	Polonnaruwa	CKD affected	Bisobandara Village, 18 families take water, built in 1982
29	Well water	30 feet	North Central Province	Medirigiriya	Polonnaruwa	CKD affected	MK Sisipal, 3 months back diagnosed with kidney problem
30	Well water	15-20 feet	North Central Province	Medirigiriya	Polonnaruwa	CKD affected	From the house of Jayasinghus 's place
31.	Spring water		North Central Province	Padaviya	Anuradhapura	CKD unaffected	Used for drinking purpose; people using this not affected by CKDue
32	Well water	20 feet	North Central Province	Padaviya	Anuradhapura	CKD affected	K A Vijaypal, CKD affected abdominal pain, undergoing dialysis
33	Well water	30 feet	North Central Province	Padaviya	Anuradhapura	CKD affected	VMA Jemes Signha, 68 years, drinking habit, low GFR
34	Padaviya tank		North Central Province	Padaviya	Anuradhapura	CKD unaffected	People using tank water, not affected with CKD
35	Tube Well	35-40feet	North Central Province	Medawachchiya	Anuradhapura	CKD affected	From the house of K Seneveratta, 57 yrs. age
36	Well water	20 feet	North Central Province	Medawachchiya	Anuradhapura	CKD affected	Deepika Priyangana, 42 years, swollen feet
37	Well water	20 feet	North Central Province	Medawachchiya	Anuradhapura	CKD affected	S Jayasekara and wife Jayanti using well for drinking purpose, both suffering from kidney disease,Husbands parents also had kidney problem
38	Wellwater	15 feet	North Central Province	Medawachchiya	Anuradhapura	CKD unaffected	From Ajith shop infront of the hospital
39	Well water	15-20feet	North Central Province	Kebithigollewa	Anuradhapura	CKD affected	Somawati, 60 years diagnosed with kidney problem
40	Spring water		North Central Province	Kebithigollewa	Anuradhapura	CKD unaffected	Lion Spring people using this water

Table2. Details of the soil samples collected from the affected and reference areas

Sample No.	Source	Province	Place	District	CKD affected /unaffected	Remarks
1	Soil around the well	Central province	Kandy	Kandy	CKD unaffected	W-O5 house, Matale Road
2	Soil near the well	Central province	Kandy	Kandy	CKD unaffected	TMD, Sirisena, Ajanta tailors,no kidney relatedproblem
3	Soil from Rice field	Eastern Province	Mahaoya	Ampara	CKD affected	From the house of K Jayanti's house,Father died of CKD
4	Soil from Rice field	Eastern Province	Near Ampara Rd	Ampara	CKD unaffected	Kemchandrawati, CKD unaffected,
5	Soil from Rice field	Eastern Province	Ampara city area	Ampara	CKD affected	Udhagiriyaudhana
6	Soil from Rice field	Eastern Province	Ampara	Ampara	CKD affected	DMUkkubanda, VillageBakmenewawa, diagnosed with CKD 2 years back.
7	Soil from Rice field	Uva Province	Girandurukotte	Badulla	CKD affected	HMMuthubanda,Village Belanganwewa
8	Soil from Rice Field	Uva Province	Girandurukotte	Badulla	CKD affected	Uppaldapanayaka, 446/57, Village Belaganwewa.
9	Soil near the well	North Central province	Medirigiriya	Polonnaruwa	CKD affected	MK Sisipal, 3 months back diagnosed with kidney problem
10	Soil from rice field	North Central province	Medirigiriya	Polonnaruwa	CKD affected	From the house of Jayasinghus 's place
11	Soil from House	North Central province	Hingurukgoda	Polonnaruwa	CKD affected	From Rodrigo's house, CKD affected
12	Soil from Rice field	North Central province	Hingurukgoda	Polonnaruwa	CKD affected	S.W.C Werasinghe House
13	Soil from Rice Field	North Central province	Medawachchiya	Anuradhapura	CKD affected	S. Jayasekara and wife Jayanti using well for drinking purpose, both suffering from kidney disease;Husbands parents also had kidney problem
14	Sandy soil (Temple)	North Central province	Padaviya	Anuradhapura	CKD unaffected	From the Padaviya Temple
15	Soil from garden near well	North Central province	Padaviya	Anuradhapura	CKD affected	VMA Jemes Signha, 68 years, drinking habit, Glomerulation filtration rate low
16	Soil from house	North Central province	Kebithigollewa	Anuradhapura	CKD affected	House of Somawati, 60 years CKD affected

Table 3. Rice samples collected from the CKDue affected areas in the North Central Province

S.No.	Source	Province	Place	District	Remarks
1	Rice plant	Eastern Province	Ampara	Ampara	From field of K.Jayanti, Father died of CKD
2	Rice plant	Uva Province	Girandurukotte	Badulla	HM Muthubanda, Village: Belanganwewa, from the field.
3	Rice plant	North Central province	Hingurukgoda	Polonnaruwa	From the field of S.W.C Werasinghe Kothalawala
4	Ricegrain	North Central province	Medirigiriya	Polonnaruwa	Village Bisobandara, 379-2 Paddy after boiling rice mill near school sold @ SL 48-49 per kg. CKD cases reported from this area.
5	Rice grain	North Central province	Medirigiriya	Polonnaruwa	Village Bisobandara,AT-58 Paddy without boiling from rice-mill near school sold @SL 45 per kg. CKD cases reported from this area.
6	Rice plant	North Central province	Medawachchiya	Anuradhapura	From the field of S. Jayasekara and wife Jayanti both suffering from kidney disease; Husbands parents also had kidney problem

Table 4. Details of the fertilizer and pesticide samples collected from North Central Province

S.No.	Active Ingredient	Trade Name	Type	Province	Place of Purchase	Physical nature
Fertilizers						
1	Urea		Fertilizers	Uva	Udawalawe	Solid
2	Triple super phosphate		Fertilizers	Uva	Udawalawe	Solid
3	Muriate of Potash		Fertilizers	Uva	Udawalawe	Solid
Pesticides						
4	Captan 50% (W/W)	Captaf	Fungicide	Medawachchiya	Anuradhapura	Solid
5	Fenobucarb	Bassa 50EC	Insecticide	Medawachchiya	Anuradhapura	Liquid
6	MCPA0 400 g/L SL	Lankem M50	Weedicide	Medawachchiya	Anuradhapura	Liquid
7	Carbosulfan 200gm/L	Marshal 20SC	Insecticide	Medawachchiya	Anuradhapura	Liquid
8	Glyphosate	Destroy	Weedicide	Medawachchiya	Anuradhapura	Liquid

Table 5.Physico-chemical characteristics of the water samples

Sample no.	Source (n=40)	Depth	District	PH	TDS (ppm)	Hardness as CaCO3 (ppm)	Ca as Ca (ppm)	Mg as Mg(ppm)	Conductivity (µs)	Alkalinity as CaCO3 (ppm)	Chloride as Cl(ppm)	Sulphate (ppm)	Fluoride (ppm)	Cd (ppm)	Total Cr (ppm)	Pb (ppm)	As (ppm)
			SLS 614:1983 [1]	**7.0 - 8.5**	**500.0**	**250**	**100**	**30.0**	**750**	**200.0**	**200.0**	**200.0**	**0.6**	**0.005**	**0.05**	**0.05**	**0.05**
1	Municipal water		Kandy	8.4	237.0	200.0	100.0	0.0	367.0	50.0	30.0	126.0	0.3	0.0	0.0	0.0	0.0
2	Spring water	20-30 feet	Kandy	5.8	55.1	50.0	20.0	0.0	85.7	20.0	20.0	63.0	0.4	0.0	0.0	0.0	0.0
3	River water		Kandy	6.9	34.0	60.0	20.0	2.4	50.1	10.0	30.0	63.0	0.5	0.0	0.0	0.0	0.0
4	Municipal water		Kandy	6.9	37.8	100.0	12.0	17.1	56.2	10.0	20.0	48.0	0.5	0.0	0.0	0.0	0.0
5	Tube well	80-90 feet	Kandy	7.3	202.0	270.0	64.0	26.8	300.0	40.0	20.0	72.0	0.9	0.0	0.0	0.0	0.0
		Mean		**7.1**	**113.2**	**136.0**	**43.2**	**9.3**	**171.8**	**26.0**	**24.0**	**74.4**	**0.5**	**0.0**	**0.0**	**0.0**	**0.0**
6	Well water	15 feet	Ampara	6.6	49.6	210.0	8.0	46.4	71.5	30.0	30.0	96.0	0.5	0.0	0.0	0.0	0.0
7	Tube Well	40-50 feet	Ampara	7.8	599.0	210.0	104.0	0.0	895.0	130.0	70.0	65.0	1.2	0.0	0.0	0.0	0.0
8	Well water	2-5 feet	Ampara	7.5	66.5	120.0	60.0	0.0	99.1	20.0	30.0	59.0	0.6	0.0	0.0	0.0	0.0
9	Ampara tank		Ampara	7.4	32.5	200.0	8.0	43.9	47.3	10.0	40.0	60.0	0.6	0.0	0.0	0.0	0.0
10	Municipal water		Ampara	7.6	49.3	190.0	16.0	36.6	73.5	10.0	30.0	131.0	0.5	0.0	0.0	0.0	0.0
11	Konduwatwa naTank	3.0 mm above MSL	Ampara	7.9	36.3	210.0	12.0	43.9	55.6	20.0	20.0	99.0	0.5	0.0	0.0	0.0	0.0
12	Well water	22 feet	Ampara	7.1	324.0	250.0	116.0	0.0	475.0	120.0	50.0	94.0	0.4	0.0	0.0	0.0	0.0
13	Well water	Unknown	Ampara	7.0	388.0	350.0	120.0	12.2	544.0	100.0	50.0	87.0	0.6	0.0	0.0	0.0	0.0
14	Well water	23 feet	Ampara	7.9	241.0	200.0	48.0	19.5	358.0	80.0	20.0	202.0	0.6	0.0	0.0	0.0	0.0
15	Well water	15 feet	Ampara	8.2	84.0	160.0	44.0	12.2	128.0	30.0	20.0	60.0	0.7	0.0	0.0	0.0	0.0
		Mean		**7.5**	**187.0**	**210.0**	**53.6**	**21.5**	**274.7**	**55.0**	**36.0**	**95.3**	**0.6**	**0.0**	**0.0**	**0.0**	**0.0**
16	Well water	17 feet	Badulla	7.3	227.0	140.0	80.0	0.0	340.0	70.0	30.0	60.0	0.6	0.0	0.0	0.0	0.0
17	Well water	14 feet	Badulla	6.9	85.0	120.0	76.0	0.0	128.2	30.0	30.0	63.0	0.8	0.0	0.0	0.0	0.0
18	Well water	15 feet	Badulla	7.1	312.0	220.0	52.0	22.0	498.0	100.0	40.0	75.0	1.1	0.0	0.0	0.0	0.0
19	Well water	15 feet	Badulla	7.2	399.0	160.0	60.0	2.4	590.0	110.0	30.0	79.0	1.2	0.0	0.0	0.0	0.0
20	Municipal water		Badulla	6.3	65.7	130.0	80.0	0.0	105.5	20.0	20.0	83.0	0.7	0.0	0.0	0.0	0.0
		Mean		**7.0**	**217.7**	**154.0**	**69.6**	**4.9**	**332.3**	**66.0**	**30.0**	**72.0**	**0.9**	**0.0**	**0.0**	**0.0**	**0.0**

Sample No.	Source	Depth	District	PH	TDS (ppm)	Hardness as CaCO3 (ppm)	Ca as Ca (ppm)	Mg as Mg (ppm)	Conductivity (µs)	Alkalinity as CaCO3 (ppm)	Chloride as Cl(ppm)	Sulphate (ppm)	Fluoride (ppm)	Cd (ppm)	Total Cr (ppm)	Pb (ppm)	As (ppm)
			SLS 614:1983 [1]	**7.0 - 8.5**	**500.0**	**250**	**100**	**30.0**	**750**	**200.0**	**200.0**	**200.0**	**0.6**	**0.005**	**0.05**	**0.05**	**0.05**
21	Well water	25 feet	Polonnaruwa	7.8	426.0	270.0	140.0	0.0	638.0	180.0	20.0	67.0	1.2	0.0	0.0	0.0	0.0
22	Minneriya Tank		Polonnaruwa	7.8	115.0	160.0	56.0	4.9	168.7	50.0	20.0	66.0	0.6	0.0	0.0	0.0	0.0
23	Well water	15 feet	Polonnaruwa	8.0	405.0	310.0	116.0	4.9	598.0	170.0	20.0	69.0	1.0	0.0	0.0	0.0	0.0
24	Well Water	20 feet	Polonnaruwa	7.9	339.0	250.0	80.0	12.2	506.0	120.0	30.0	67.0	0.7	0.0	0.0	0.0	0.0
25	Tube Well	80 feet	Polonnaruwa	7.1	227.0	190.0	48.0	17.1	345.0	50.0	30.0	71.0	0.8	0.0	0.0	0.0	0.0
26	Well water	22 feet	Polonnaruwa	6.9	317.0	200.0	60.0	12.2	463.0	30.0	40.0	70.0	0.8	0.0	0.0	0.0	0.0
27	Well water	15 feet	Polonnaruwa	7.1	112.0	210.0	40.0	26.8	169.3	120.0	20.0	68.0	0.5	0.0	0.0	0.0	0.0
28	Tube Well	200 feet	Polonnaruwa	6.8	367.0	260.0	48.0	34.2	553.0	130.0	30.0	71.0	1.7	0.0	0.0	0.0	0.0
29	Well water	30 feet	Polonnaruwa	7.6	486.0	350.0	96.0	26.8	745.0	200.0	40.0	60.0	0.8	0.0	0.0	0.0	0.0
30	Well water	15-20 feet	Polonnaruwa	7.4	539.0	330.0	124.0	4.9	801.0	200.0	50.0	77.0	0.8	0.0	0.0	0.0	0.0
		Mean		**7.2**	**364.2**	**270.0**	**73.6**	**21.0**	**546.3**	**136.0**	**36.0**	**69.2**	**0.9**	**0.0**	**0.0**	**0.0**	**0.0**
31	Spring water		Anuradhapura	8.0	60.2	150.0	20.0	24.4	120.2	20.0	20.0	61.0	0.5	0.0	0.0	0.0	0.0
32	Well water	20 feet	Anuradhapura	7.5	458.0	320.0	84.0	26.8	713.0	200.0	20.0	61.0	0.8	0.0	0.0	0.0	0.0
33	Well Water	30feet	Anuradhapura	7.8	483.0	290.0	84.0	19.5	723.0	240.0	30.0	59.0	1.5	0.0	0.0	0.0	0.0
34	Padaviya Tank		Anuradhapura	7.3	344.0	200.0	80.0	0.0	518.0	150.0	30.0	54.0	1.0	0.0	0.0	0.0	0.0
35	Tube Well	35-40 feet	Anuradhapura	7.5	700.0	450.0	128.0	31.7	1061.0	250.0	100.0	78.0	1.2	0.0	0.0	0.0	0.0
36	Well water	20 feet	Anuradhapura	7.8	563.0	340.0	96.0	24.4	825.0	220.0	60.0	73.0	1.1	0.0	0.0	0.0	0.0
37	Well water	20 feet	Anuradhapura	8.2	519.0	300.0	100.0	12.2	756.0	230.0	40.0	69.0	1.3	0.0	0.0	0.0	0.0
38	Wellwater	15 feet	Anuradhapura	7.5	792.0	470.0	172.0	9.8	1182.0	160.0	200.0	75.0	0.6	0.0	0.0	0.0	0.0
39	Well water	15-20feet	Anuradhapura	7.9	736.0	370.0	124.0	14.6	1087.0	250.0	130.0	99.0	1.1	0.0	0.0	0.0	0.0
40	Spring water		Anuradhapura	8.4	56.4	80.0	8.0	14.6	107.9	10.0	20.0	82.0	0.4	0.0	0.0	0.0	0.0
		Mean		**7.6**	**400.4**	**274.8**	**84.6**	**16.3**	**601.3**	**148.4**	**47.0**	**69.8**	**0.9**	**0.0**	**0.0**	**0.0**	**0.0**

Note

1. SLS 614:1983Sri LankaStandards for Potable Water Physical and Chemical Requirements According to SLS 614: 1983
2. ND:Not detected

Table 6.Mean and Range of physico-chemical characteristics of the water samples

					Non endemic area		Endemic areas											
S.N.	Parameters	Sri Lanka Standards for Potable water		Districts	Kandy(Control)		Ampara			Badulla			Polonnaruwa			Anuradhapura		
		SLS 614:1983 [1]		No of samples	n=5		n=10			n=5			n=10			n=10		
		Maximum desirable level	Maximum permissible level	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
1	pH	7.0-8.5	6.5-9	7.1	5.8	8.4	7.5	6.6	8.2	7	6.9	7.3	7.2	6.8	8	7.6	7.3	8.4
2	TDS (ppm)	500	2000	113.2	34	237	211.1	49.3	599	217.7	65.7	399	341.3	112	539	399.3	56.4	792
3	Conductivity (µs/cm)	750	3500	171.8	50.1	367	312.3	71.5	895	332.3	128.2	590	512.7	168.7	801	599.7	107.9	1182
4	Hardness as $CaCO_3$ (ppm)	250	600	136	50	270	210	120	350	154	120	220	256.7	160	350	274.1	80	470
5	Ca as Ca (ppm)	100	240	43.2	12	100	64.4	8	120	69.6	52	80	69.3	40	140	84.4	8	172
6	Alkalinity as $CaCO_3$ (ppm)	200	400	26	10	50	61	10	130	66	30	110	121.7	30	200	147.7	10	250
7	Chloride as Cl(ppm)	200	1200	24	20	30	37	20	70	30	30	40	35	20	50	46.9	20	200
8	Mg as Mg(ppm)	30	150	15.5	ND	26.84	14.6	ND	46.4	12.2	ND	22	20.3	ND	34.16	18	ND	31.72
9	Sulphate (ppm)	200	400	74.4	48	126	95.3	59	202	72	60	79	69.5	60	77	69.8	54	99
10	Fluoride (ppm)	0.6	1.5	0.5	0.3	0.9	0.6	0.4	1.2	0.9	0.6	1.2	0.9	0.5	1.7	0.9	0.4	1.5
11	Cd (ppm)	0.005		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
12	Cr (ppm)	0.05		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13	Pb (ppm)	0.05		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14	As (ppm)	0.05		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note

1. Sri LankaStandards for Potable Water Physical and Chemical Requirements According to SLS 614: 1983
2. ND - Not Detected

Table 7.Water quality of the municipal supply, spring, tank water, river water and well water samples

Sample No.	Standards for drinking Water		pH	TDS (ppm))	Conductivity (µs/cm)	Hardness as CaCO3 (ppm)	Ca as Ca (mg/)	Mg as Mg (ppm)	Alkalinity as $CaCO_3$ (ppm)	Chloride as Cl(ppm)	Sulphate (ppm)	Fluoride (ppm)	Cd (ppm)	Cr (ppm)	Pb (ppm)	As (ppm)
	SLS 614:1983 [1]	Maximum desirable level	7.0-8.5	500	750	250	100	30	200	200	200	0.6	0.005	0.05	0.05	0.05
		Maximum permissible level	6.5-9.0	2000	3500	600	240	150	400	1200	400	1.5				
	IS:10500:2004 [2]	Maximum desirable level	6.5-8.5	500	-	300	75	30	200	250	200	1.0	0.003	0.05	0.01	0.01
		Maximum permissible level	6.5-8.5	2000	-	600	200	100	600	1000	400	1.5				0.05
	WHO [3]	Guideline Values		*	*	*	*	*	*	*	*	1.5**	0.003	0.05	0.01	0.1
	Category	*n=40*														
1.	Spring water	n=3	7.4	57.2	104.6	93.3	16.0	13.0	16.7	20.0	68.7	0.4	ND	ND	ND	ND
2.	Municipal Water	n=4	7.3	97.5	150.6	155.0	52.0	13.4	22.5	25.0	93.8	0.5	ND	ND	ND	ND
3.	Tank water	n=4	7.6	132.0	197.4	192.5	39.0	23.2	57.5	27.5	69.8	0.7	ND	ND	ND	ND
4.	River water	n=1	6.9	34.0	50.1	60.0	20.0	2.4	10.0	30.0	63.0	0.5	ND	ND	ND	ND
5.	Tube well	n=4	7.1	306.0	461.8	246.0	61.6	22.4	96.0	42.0	71.0	1.0	ND	ND	ND	ND
6.	Well water	n=24	7.5	363.1	540.8	258.3	86.1	13.5	130.9	44.8	77.8	0.8				

Note
1. Sri Lanka Standards for Potable Water Physical and Chemical Requirements According to SLS 614: 1983
2. Indian Standards Specifications for Drinking Water IS: 10500:2004
3. Guidelines for drinking-water quality, fourth edition, World Health Organization 2011
4. *No health based guideline. Not of health concern at levels found in drinking water.
5. ** Volume of water consumed and intake from other sources should be considered when setting national standards
ND- Not Detected

Table 8. Physico-Chemical Characteristics of the water samples consumed by people in affected and unaffected areas

Area	CKD affected /Unaffected	Source of Drinking Water	No. of samples	pH	TDS (ppm)	Conductivity (µs)	Hardness as $CaCO_3$ (ppm)	Ca as Ca (ppm)	Alkalinity as $CaCO_3$ (ppm)	Chloride as Cl(ppm)	Mg as Mg(ppm)	Sulphate (ppm)	Fluoride (ppm)
SLS 614:1983		**Maximum desirable levels**		**7-8.5**	**500**	**750**	**250**	**100**	**200**	**200**	**30**	**200**	**0.6**
		Maximum permissible levels		**6.5-9.0**	**2000**	**3500**	**600**	**240**	**400**	**1200**	**150**	**400**	**1.5**
Study Area (Ampara, Badulla, Polonnaruwa, Anuradhapura)	Unaffected	Spring water	n=2	8.2	58.3	114.1	115.0	14.0	15.0	20.0	19.5	71.5	0.5
	Unaffected	Municipal Water	n=2	7.0	57.5	89.5	160.0	48.0	15.0	25.0	18.3	107.0	0.6
	Unaffected	Tank water	n=4	7.6	192.3	291.5	192.5	66.0	72.5	30.0	6.1	69.8	0.7
	Unaffected	Well water	n=4	7.8	510.3	765.7	277.5	128.0	200.0	46.7	12.2	71.3	1.1
	Affected	Well water	n=18	7	363	541	253	86	131	45	13	78	1
	Affected	Tube well	n= 4	7	313	475	278	69	98	44	17	82	1
		Mean (Affected Area)		8	249	379	213	68	89	35	14	80	1
Reference area (Kandy)		Mean (Unaffected Area)	n=5	7.1	113.2	171.8	136.0	43.2	26.0	24.0	9.3	74.4	0.5

Table 9.Arsenic content of Soil Samples collected from household and fields in the affected and not affected area in Sri Lanka (ppm or mg/Kg)

Province	District	CKDue Affected /Unaffected	No. of samples	Arsenic content (ppm or mg/Kg)
Eastern Province	Ampara	Affected	n=4	0.105
Uva Province	Badulla	Affected	n=2	ND
North Central province	Polonnaruwa	Affected	n=4	0.128
	Anuradhapura	Affected	n=4	0.050
	Mean affected area			**0.06**
Central Province	Kandy (Reference area)	Unaffected	n=2	0.035

Note

According to ATSDR range of arsenic in soil in the U.S. is 7.2ppm (mg/kg)

As recommended by the European Community the maximum acceptable limit of As for agricultural soil is 20.0 ppm (mg/kg)

ND not detected

Table 10.Arsenic content in rice samples collected from household and fields

Sample	Province	District	CKD affected / Unaffected	No of samples	Arsenic content (mg/Kg or ppm)
Rice plant	Eastern Province	Ampara	Affected	n=1	ND
Rice plant	Uva Province	Badulla	Affected	n=1	ND
Rice plant	North Central province	Polonnaruwa	Affected	n=1	ND
Rice grain	North Central province	Polonnaruwa	Affected	n=1	ND
Rice grain	North Central province	Polonnaruwa	Affected	n=1	ND
Rice plant	North Central province	Anuradhapura	Affected	n=1	ND

Note:

ND- Not Detected

Table 11. Arsenic content in Fertilizers and Pesticides in ppm (or mg/kg)

S.No.	Active Ingredient	As inppm (or mg/kg)
Fertilizers		
1	Urea	0.203
2	Triple super phosphate	0.406
3	Potash	0.09
Pesticides		
4	Captan 50% (W/W)	0.254
5	Fenobucarb	0.009
6	MCPA0 400g/L SL	0.112
7	Carbosulfan 200gm /l	0.143
8	Glyphosate	0.150