CKDu: Are We Shooting the Right Target?

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Abstract

The Government of Sri Lanka is spending billions of rupees to tackle the Chronic Kidney Disease of unknown etiology (CKDu). No doubt it is a major health issue, which needs serious attention. At present, the government efforts are mostly aimed at providing financial assistance to affected families, improving medical treatment facilities of the affected areas and to provide clean but expensive water. The quest for identifying the reasons behind the CKDu is high among scientists than finding a cure for it. Research conducted so far, has not produced any tangible results and some findings are in fact contradictory. The most commonly blamed cause is the use of agrochemicals. However, little action is taken and no efforts are being made to cap the misuse, abuse and overuse of agrochemicals. Interestingly, the use of agrochemicals in many areas affected by CKDu is lower than other areas with intensive agriculture that have no sign of the disease. Therefore, there is still an urgent and crucial need to identify the cause for this problem.

This paper describes a new hypothesis for etiology of this disease. The paper affiliates the cause to the hydrogeology of the landscape and the Hofmeister effect. The research conducted thus far has not addressed these aspects. The results obtained in this study as of now and other available evidence supports this hypothesis. However, it must be noted that the results reported here are partially complete. If the hypothesis discussed in this paper is affirmative, then it appear easy to control and eradicate this major health hazard from the country.

Background

The Government of Sri Lanka and the civil society are making a huge effort to manage the situation and help the victims (Nanayakkara et al., 2012; Wanigasuriya, 2012). This is because of the huge impact this disease has on the poor rural communities living in endemic areas (Jayatilake, et al., 2013).

Known risk factors, such as hypertension and diabetes, are not the cause of the disease (Nanayakkara et al., 2012). CKDu is asymptomatic in its early stages. Patients then experience kidney impairment in the proximal tubules and the interstitium as
the disease progresses slowly towards the final stage of renal failure (Wanigasuriya et al., 2009; Chandrajith et al., 2011; Nanayakkara et al., 2012).

The exact prevalence and geographic scope of the problem in Sri Lanka is not known as yet (de Silva, 2014). The disease mainly occurs in some areas of the Dry Zone, especially the North Central Province (NCP) of Sri Lanka. It disproportionately affects males from poor socio-economic backgrounds, who are mostly engaged in paddy (rice) farming (Senevirathna et al., 2012; Jayasekara et al., 2013).

Medical experts in Sri Lanka have estimated that the disease has affected approximately 400,000 people and a death toll of thus far stand at around 20,000 (Perera, 2012; Gunawardena, 2012). Some estimates suggest a 2 to 3% prevalence rate among those older than 18 years of age (Chandrajith et al., 2011), while other recent work suggests a prevalence rate closer to 15% (Jayatilake et al., 2013).

Number of studies have presented a multitude of factors that are thought to be the cause for CKDu. However, there is no conclusive evidence to prove that the factors identified are the cause(s) for this disease (Noble, A. et al., 2014). Therefore, it is very important to identify cause(s) of the disease, in order to control and eradicate this menace. Commonly proposed thesis is that prolonged environmental exposures to high concentrations of nephrotoxicants such as Arsenic (As), Cadmium (Cd), Lead (Pb), and Uranium (U), which may accumulate and cause functional and structural damage in the proximal tubule cells of the kidney (Sabolic, 2006). Previous studies using case – control methodologies have reported that CKDu is related to biomarkers for As (Jayasumana et al., 2013) and Cd (Bandara, 2003; Wanigasuriya et al. 2011), and have identified farming and the use of agrochemicals (fertilizer, weedicides, pesticides or other) as risk factors (Chandrajith et al., 2011; Jayatilake et al., 2013). Jayasumana et al. (2013) also report that high levels of As exposure in CKDu patients coincide with observable skin lesions. More recently Jayasumana et al. (2014) have surmised that the ‘use of Glyphosate’ as the cause for CKDu. Several other reports point at external sources of contaminant of water and food like cooking utensils made of poor quality aluminum, Ayurveda preparations, illicit liquor, snake bites, including chewing betel leaves with tobacco, eating lotus tubers may be the causes of this disease, while some identify genetics, algae in lakes, climate change, malnutrition, dehydration as possible causes. However, the greatest irony is that all these causal factors are perhaps more severely prevalent in other areas where no cases of this disease have thus far been reported.
However, there is no study that views this issue through the lens of hydrogeology of the landscape. Dr. C. R. Panabokke, a well-known scientist, with his long years of experiences and good understanding of the soils and groundwater conditions in the dry zone has formulated this thesis. Accordingly, the incidence of CKDu is linked to the regolith nature of the aquifer in the region. Thus in the following chapters we try to verify this thesis. If this hypothesis is proven, disease could be contained easily and a new set of guidelines on shallow well management would be framed.

**Hypothesis**

In the CKDu affected areas the landscape of the regolith aquifer provides a conducive environment for concentration of salt ions. Certain ratios of concentrations attained by such ions activate the *Hofmeister series effect*, which leads to toxicity and damages the kidneys of humans.

This hypothesis is based on the information already known about the geography, geology and groundwater behavior in the Dry Zone (Sirimanne, 1952; Panabokke, 1959; Herbert, et al., 1988; Cooray, 1988; Wright, et al., 1992; Sakthivadivel, and Panabokke, 1996; Senaratne, 1996). These studies characterized the nature of the topography, regolith aquifer and its behavior during the dry and wet seasons. This knowledge combined, one can visualize the groundwater dynamics (flow patterns and accumulations) in this shallow regolith aquifer.

The *Hofmeister series* is a classification of ions in the order of their ability to *salt out* or *salt in* proteins. The order of cations is usually given as \( \text{NH}_4^+ > K^+ > Na^+ > Li^+ > Mg^{2+} > Ca^{2+} > \text{Guanidinium} \). Anions appear to have a larger effect than cations, and are usually ordered \( F^- \approx SO_4^{2-} > HPO_4^{2-} > \text{acetate} > Cl^- > NO_3^- > Br^- > CI^- > CIO_4^- > SCN^- \). The mechanism of the *Hofmeister series* is not entirely clear, but does not seem to result from changes in general water structure, instead more specific interactions between ions and proteins, and ions and the water molecules directly contacting the proteins may be more important (from Wikipedia).

**Methodology**

*Data collection:* A field survey was carried out in areas identified as endemic areas (*Map 1*) by Jayasekara et al., (2013) to locate the wells used by CKDu affected families. Most of these areas are in the North Central Province, and surrounded by small tank cascade systems. A total of 614 wells were surveyed and 754 families were interviewed. Among those, 54 wells used by households had no reported cases of the disease. This survey collected data on location of the wells, its age, Electrical conductivity (Ec) values of water, number of users and user demography. Seventy water samples were collected and analyzed at *Industrial Technology Institute* (ITI) laboratories, Colombo for Na, Mg, Ca and F contents.
Furthermore, isotope technique was used to verify whether the water in these wells has any connection with rest of water flowing in the area. Dehiatthakandiya (Map 2), which comes under a major irrigation system was the first site selected for isotope testing. Further isotope studies is being carried out in Padawiya- Kahatagasgilliya area (small tank systems) and Laggala- Pallegama area – on the eastern slopes of the Matale district. Isotope testing was entrusted to Sri Lanka Atomic Energy Board (formerly Authority).

Analysis

The research team established (via interviews) that there were cases displaying symptoms similar to the CKDu even prior to the current outbreak. At the time, such cases were thought to be the result of ‘Bad Karma’ or due to ‘evil sprites attacks’. However, those were few in numbers and not known widely. Furthermore, during those days shallow wells were not popular as of now.
The number of wells have increased since mid-1980s, just before widespread appearance of the disease in mid 90s. Data on the age of these shallow wells clearly indicate that most of the wells are of recent origin (Fig. 1).

![Chart showing well proliferation and identification of CKDu patients over time.](chart.png)

**Fig. 1.** Well proliferation and identification of CKDu patients over the time in Medawachchiya Division

A shallow well has become a household asset, with subsidies given since mid-80s by various government organizations and projects, including the NGOs. Currently, almost all village households have access to a well and most shallow wells are equipped with pumps. Only a handful could be seen with a rope and a bucket. However, not all well water users are affected, but only a few in a village (Map 3).

![Map showing location of troublesome wells in a village.](map.png)

**Map 3 –** Location of troublesome wells in a village
A large number of wells in a village are located close to paddy lands. However, the Map 3 clearly indicates that 'problem causing wells' are located at a distance from paddy lands and are few in numbers. This is true even in the Dehiatthakandiya, - major irrigation area – (Map 2), where the settlements were established on the highlands. All most all wells identified as being used by CKDu affected families are in this category.

The topography in these areas is described as etched plain (Diagram 1), because of the rolling ridges and valley bottoms. Upper part of the highlands consist of porous Reddish Brown Earth (RBE) and valley bottoms consist of less porous Low Humic Gley (LHG) - clays and alluvial (Diagram 2). The famous tank cascades and paddy lands are located along valley bottoms. Such valleys are numerous in this area. The soils here are shallow and around 10m or less deep depending on the place (Diagram 3).

Beneath the soil layer starts a layer of highly weathered rock and soil mix, and weathered bedrock. Below that is the fresh bed rock with joints, fissures and deep fractures (Coo-ray, P. G. 1988; Sirimanne, C. H. L., 1952). Obviously, the underground hard rock surface is not smooth, have some fractures, cavities and depressions.

Panabokke, C. (1959) established the behavior of groundwater during dry and wet seasons on slopes of either side of valley bottoms (Diagram 4). With about 10-15% of annual rains the groundwater level starts rising rapidly on both sides of the valley and lowers when rains reseeds. Further, (Senaratne, A. 1996) established the perennial occurrence of groundwater in the valley bottoms (Diagram 5; Source: Panabokke, 1996).
5. Groundwater in valley bottom

Accordingly, during the rainy season, groundwater levels rise over the underground hard rock, filling all fractures, cavities and depressions. During the dry period this water moves towards valley bottom and groundwater therein is perennial, and in constant move towards subsequently towards downstream of the watershed. While draining back to valley bottom, some water is held up in depressions and cavities, as of receding floods over the land surface (Diagram 6). Such small pockets of water left behind, is then get isolated for the rest of the year, until next rainy season. And there is no guarantee, that next rainy season will have enough rains to bring back the groundwater levels to such heights that these isolated pockets get connected again to the rest of groundwater around. This connectivity is important, because it will freshen-up such underground pockets with new water. If there is no sufficient rains during the season to raise the groundwater levels to required heights, then the only source of replenishment is percolation of rain water from upper parts of the catena. Therefore, the ‘performance’ (appearance and disappearance) of such isolated pools are subject to the amount of rainfall over the season.
The isotope studies conducted in Dehiatthakandiya area clearly indicate this disconnect. Samples were collected during pre and post monsoon periods representing dry and wet seasons in the area. The stable isotopes ($^{18}$O & $^2$H) compositions in suspected wells are not the same as in water from canals. These clearly indicate the differences of origin or the disconnect (Fig 2). This was true for both Yala and Maha seasons last year (2014), where there was less rains in the area. The isotope testing is continuing in Padaviya in Anuradhapura district and Laggala- Pallegama area of Matale district.

![Isotope plot of natural waters in Dehiaththakandiya](image)

**Fig. 2.** Isotope plot of natural waters in Dehiaththakandiya.

Generally, water in these areas are rich in fluoride and also indicate high levels of hardness. Extraction and replenishment process of water from such isolated pockets would trigger some changes in the chemical contents concentration. Water extraction from wells or the ‘pumping’ is done just for about 10-15 minutes and the rest of day is left undisturbed. The sudden draw-down during the pumping shall trigger rapid influx of salts through leaching of minerals from the surrounding areas into the well water and then stagnate for the rest of the day. This stagnation of water inside the well promote those minerals to stratify into different concentrations. Normally, the foot-valve of the pump is placed at the bottom of the well and extracts the chemically and thermally stratified water undisturbed, from the lowest layer. There is a notable differences in Electrical conductivity (Ec) values of water from these “suspected wells” and the normal wells. Although all values are within the prescribed limits, the Ec values of suspected well water is several times higher than in water from normal wells, spouts and in flowing canals in the vicinity (Fig 3).
Fig. 3: Variation of Electrical Conductivity in pre and post monsoon periods

The water at the bottom of the wells are rich in fluoride (F), chlorides (Cl), bicarbonates (HCO$_3^-$), etc., anions and with concentrations of cations such as Sodium (Na$^+$), Calcium (Ca$^{2+}$), Magnesium (Mg$^{2+}$), etc. It is suspected that these ionic concentrations of salts appearing in particular ratios activate the Hofmeister effect. This effect is known to cause dissolving of proteins and could be leading to kidney damage. This aspect needs further investigation.

Conclusions

Groundwater levels in the dry zone area are intrinsically linked with rainfall pattern. Groundwater level in the area increases with rainfall. During times of no rainfall, the groundwater level starts to recede. While receding, certain pockets of water (pools) are left behind due to the regolith nature of the aquifer. When the water is intermittently pumped out from such places, the processes of salt leaching and stagnation takes places over a period of time, in particular during the dry season. This leads to concentration of anions and cations (fluoride (F), chlorides (Cl), bicarbonates (HCO$_3^-$), etc., and Sodium (Na$^+$), Calcium (Ca$^{2+}$), Magnesium (Mg$^{2+}$), etc.) in such ratios, which probably triggers the Hofmeister phenomenon. The resultant ionocity is toxic and damages the kidneys. The appearance and disappearance of isolated water pockets and the resulting anion and cation concentrations are dependent on rainfall. Therefore, damage to kidney progresses slowly depending on rainfall conditions until the tipping point arrives.

Further research is being conducted to identify the ratios of these elements in water that is harmful to the kidneys.


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Geographical Society of London.