Potential link between ground water hardness, arsenic content and prevalence of CKDu

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Highest prevalence of CKDu occurs in the largest rice farming areas in Sri Lanka and it is reported that approximately 99 % of CKDu patients are farmers[1]. It was reported that source of drinking water of CKDu patients are obtained from dug wells (92 %) and tube wells (08 %)[2]. Age of majority of the CKDu patients are between 30 – 40 years and they are heavily exposed to agrochemicals as very little attention is given to hazardous effects on human health[2]. Our preliminary investigations revealed that significantly higher percentage of CKDu patients ($p<0.05$) showed spotty pigmentations on their soles and palms. However it was also confirmed that it is different from characteristic pigmentations observed among people in Bangladesh due to chronic arsenic toxicity (fig. 1)[4]. This was the main reason to concentrate our work on investigation of arsenic content in urine and hair of CKDu cases[4-6]. Analysis of urine and hair of 348 subjects in the study area (CKDu, n=125; controls from endemic area, n = 180; controls from nonendemic area, n = 43) indicated that approximately 72.5 % of CKDu patients had urine arsenic levels > 21 μg/g creatinine and significantly high concentration of arsenic has been observed in high keratin containing tissues such as hair and nails among the CKDu cases ($p<0.05$)[5]. Analysis of organ samples of deceased CKDu patients from the study area also have shown about ten-fold increase of arsenic in comparison to that of kidneys of an unexposed individual[6].

In an attempt to investigate source of arsenic in population of the study area, arsenic content in water, most abundant trees, terrestrial and aquatic herbaceous plants and soil samples in the study area were analyzed. The results revealed that arsenic is present in noteworthy amounts in the flora of the study area and their capacity to retain arsenic differs largely from one species to another as well as from roots, bark, flowers and leaf, i.e. in the bark of *Azadirachta indica* (Kohomba) (753 ± 4.2 μg kg^{-1}), in roots of *Terminalia arjuna* (Kumbuk) (815 ± 2.4 μg kg^{-1}) and bark of of *Terminalia arjuna (*115 ± 2.4 μg kg^{-1}). The aquatic floating plant, *Eichhornia crassipes* (553.5 ± 2.4 μg kg^{-1}) as well as flowers and roots of *Nelumbo sp.*(Lotus) (1101 ± 10.2 μg kg^{-1}) were found to contain excessive amounts of arsenic. These data hence indicate their relative capacity of phytoremediation for arsenic[7-8]. Rice (*Oryza sativa* L.) is one of the major food crops in many countries and it is one of the dominant sources of arsenic and cadmium. Presence of arsenic in rice samples (n=75) collected from various parts of the country were evaluated and reported that the rice samples collected contain 3.6 - 183 μgkg^{-1} and over 60 % of the rice samples tested contained more than 50 μgkg^{-1}of arsenic. Further it was reported that from the survey of 12 countries across the world, cadmium levels in rice grain were the highest in Bangladesh and Sri Lanka, with both these countries also having high per capita rice intakes [9-10]. There is no significant difference in the cadmium levels in areas affected by the CKDu and others areas.

Fig. 1. Spotty pigmentation of chronic arsenic poisoning observed in Bangladesh (A) and in CKDu patients NCP (B)[1]

It is reported that analysis of arsenic content in Sri Lankan soils, particularly in the agricultural areas revealed that arsenic content in soil gradually decreases with depth, implying that it is not present naturally in soils nevertheless has been introduced from the surface, most probably due to anthropogenic activities. The analysis of soil samples collected from the study area revealed that surface layers of soil in paddy fields of Padaviya area were detected to have relatively high levels of arsenic (1.5 mg kg^{-1}) when compared to that of the deep layers (0.61 mg kg-1). No arsenic was detected below 7 feet depth in Padaviya reservoir [7,8].

Since, results of the above study suggested that the arsenic is not present naturally in the soils of the study area[7,8] investigations have been carried out to test the agrochemicals, namely, pesticides, herbicides and synthetic and natural fertilizer for arsenic in order to find the source of high concentration of arsenic in the soil samples collected from the surface layers. The highest total arsenic content was reported from imported Triple Super Phosphate (TSP), used for rice cultivation ranged from 25.49 mg kg $^{-1}$ to 37.86 mg kg^{-1}. Moderate amounts of arsenic, (6.02 - 7.61 mg kg^{-1}) were present in the dolomite samples that are also used in crop cultivation[11-12]. Analyses on pesticides widely used in CKDu endemic areas confirmed the presence of arsenic in the range of 180 μg kg^{-1} - 2586 μg kg^{-1}

and the amount of arsenic present varied depending on the type of active ingredient, brand and batch of pesticides as well as the location from which the samples were collected [13]. Hence, gradually decreasing arsenic content in soil indicated that it's presence is not from the bedrock but due to anthropogenic causes, most likely due to wide use of agrochemicals that contain arsenic[13].

Most of the inhabitants in CKDu prevailing areas complained that they observe a significant increase in the hardness of well water over the last two decades[15,16]. Most of the villagers who happen to drink water from wells with very hard water have got affected with CKDu[1]. It is known that water hardness is not caused due to a single substance and variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations, and other cations (e.g. aluminium, barium, iron, manganese, strontium and zinc) contribute to hardness of water[14]. Presence of high concentrations of Ca^{2+} and Mg^{2+} increase the hardness of water and based on the concentration of $CaCO_3$ in hard water, it is categorized into three groups, water containing $CaCO_3$ at concentrations below 60 mg $L^{-1}$is generally considered as soft; 60–120 mg L^{-1}, moderately hard; 120–180 mg L^{-1}, hard; more than 180 mg L^{-1}, very hard[16]. Information on groundwater hardness obtained from the Water Resources Board[11] presents extend of hardness in groundwater resources of Sri Lanka (Fig. 2a). Degree of hardness in groundwater resources of Sri Lanka appears to have a strong positive correlation with the distribution of prevalence of CKDu patients in Sri Lanka (Fig 2 a & b and fig 3)[16-20]. The results revealed that water hardness vary among areas, i.e. Padavi-Sripura (270 – 820 mg L^{-1}), Anuradhapura urban area (108 – 312 mg L^{-1}), Polpithigama (90 – 615 mgL^{-1}), Nikawewa (115 - 612 mg L^{-1}), Mahawa-Siyambangamuwa (60 - 410 mg L^{-1}), Medawachchiya (60– 685 mg L^{-1}), Matale (60 - 460 mg L^{-1}), Gonameriyawa water spring (6 - 9 mg L^{-1}) and Pasgoda (28- 54 mg L^{-1}) [17-20]. The hardness of water in the reservoirs of the study area was ranged from 100 – 175 mg L^{-1}. When compared the prevalence of CKDu and source of drinking water of people in the study area, it was evident that inhabitants who consume water from Gonamariyawa spring in Kebithigollawa area; hardness of water is below 9 mg L^{-1} and from Anuradhapura urban area; hardness of water is below 175 mg L^{-1} were not affected with CKDu. It was also revealed that the water samples contained iron (0.14 - 0.46 μg L^{-1}), phosphates (61.1 - 80.25 μg L^{-1}), nitrates (0.30 – 5.82 μg L^{-}) and sulphates (0.11 – 21.02 μg L^{-1}) in addition to very high content of calcium and magnesium. However, the water samples collected from dug wells, tube wells, reservoirs and paddy fields indicated that levels of arsenic in water used by CKDu ranged from 1.1 - 12.3 μg L^{-1} and highest levels of arsenic was detected in paddy fields[18-20].

Present study therefore able to produce data that support the hypothesis, agrochemicals contaminated with arsenicals is one of the most potential causative agents of CKDu, the foremost health crisis in Sri Lanka. This study was further strengthen by the research findings reported by Jayatilake et al. (2013) as their results revealed that presence of arsenic and cadmium in urine, hair and nail of subjects in the study area and contamination of food with arsenic and cadmium[21].

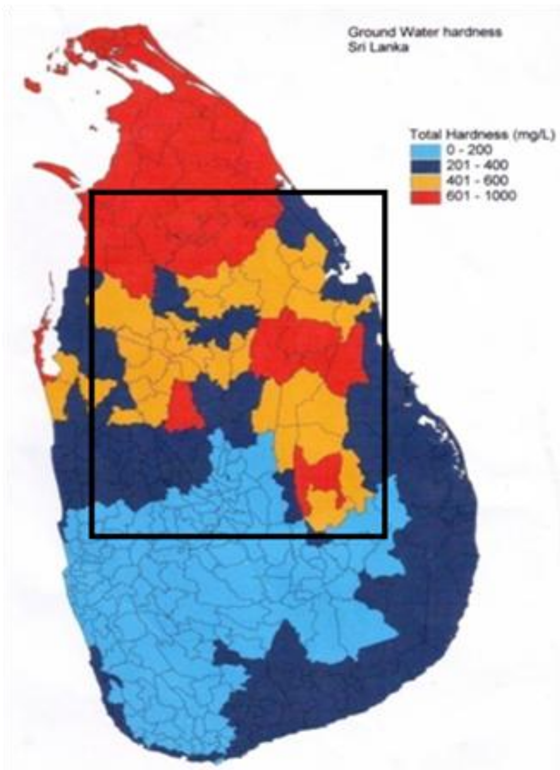

Fig. 2a: Distribution of hardwater in Sri Lanka[11]

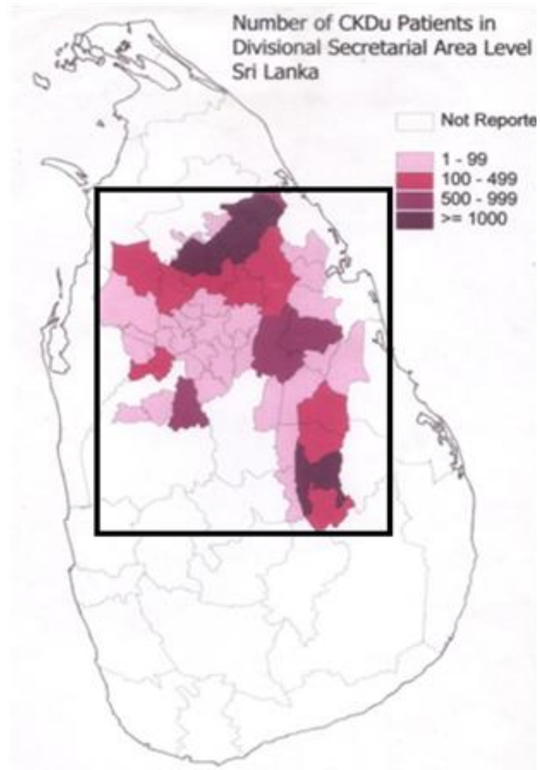

Fig. 2b: Distribution and prevalence of CKDu in Sri Lanka[1]

CKDu has gradually emerged as the major health problem in the dry zone of Sri Lanka for last two decades. Arsenic has already been identified as one of the major etiological factors for the disease[1,21]. Chemical fertilizer, especially TSP evidently is the major source of arsenic in disease endemic areas as no scientific evidence is available for its natural presence in the bedrocks. Findings of the present study also revealed that arsenic content in the biofertilizer / natural fertilizer is comparatively very low and hence the farmers should be encouraged to minimize the use of imported contaminated inorganic arsenic fertilizer and use fertilizer with natural origin in order to avoid further contamination of environment with arsenic.

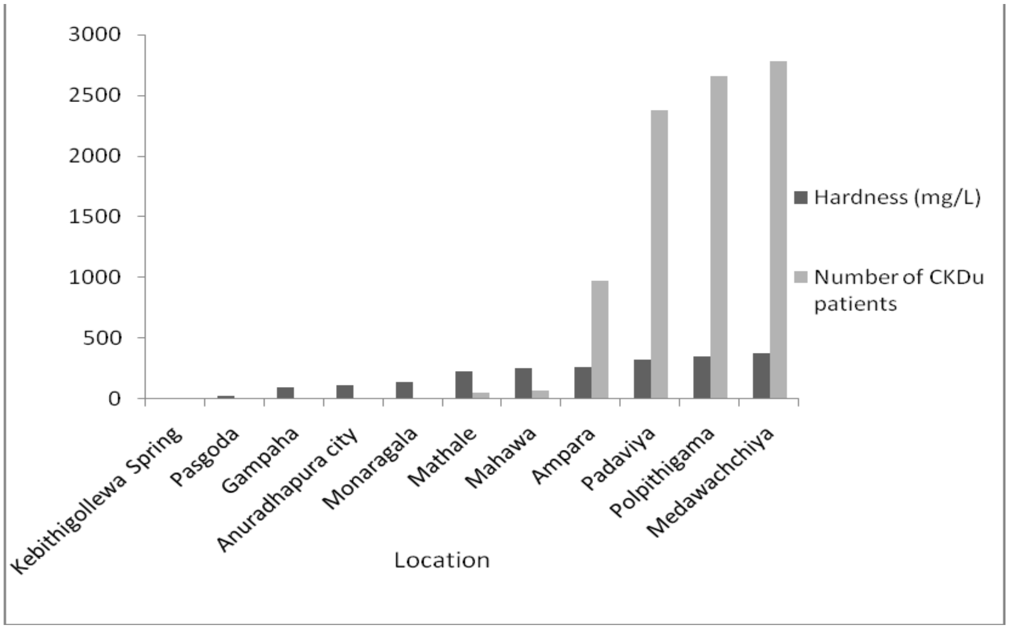

Figure 3. Relationship between water hardness and number of CKDu patients in sampling areas[16]

It is an urgent need to divert more resources to consolidate these findings and to plan and implement strategies to investigate pollution of the environment with arsenic and other contaminants (such as cadmium, mercury, cyanide and radioactive nuclei) derived from agrochemicals. Rainwater harvesting for drinking purposes, development of herbal remedies to minimize health deterioration with CKDu, public awareness over chronic toxicity of arsenic, introduce phytoremediation methods to remove toxic trace elements in soil and potential risk in agrochemical – based agriculture may be prudent immediate measures in addressing this issue. Moreover, since Sri Lankan law and regulations pertinent to use of hazardous material, particularly arsenic is outdated and thus they should be altered at least to meet the standards of UN that is based on recent knowledge on chronic toxicity of poisons like arsenic.

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