



Chemical Fertilizer Application in Paddy Farming; A Review Based on Kidney Disease of Unknown Etiology in North Central Province, Sri Lanka

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Abstract

Chronic Kidney Disease (CKD) has become a serious health issue in the North Central Province (NCP) of Sri Lanka where agriculture is the major livelihood of the community. However, the specific feature of CKD discovered in the NCP is that its etiology does not include traditional risk factors. Hence, this new form of the disease is named as Chronic Kidney Disease of Unknown Etiology (CKDu). A study conducted by World Health Organization revealed that nearly 15% of people in the NCP within age group 15 -70 years are affected by CKDu. The total affected number is approximately 40,000. Some researchers argue that Chronic Kidney Disease has multifactorial origin. One strong argument is continuous exposure to high ionicity in drinking water is a possible causative factor to weaken the kidney via a protein denaturing

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mechanism. High cadmium (Cd) and arsenic (As) levels in drinking water, fish and edible aquatic rhizomes in the endemic area have led to another hypothesis that Cd and As are the possible reasons for CKDu. Studies revealed that chemical fertilizers contribute immensely to elevate Cd, As levels and ionicity of water. This paper discusses the effect of chemical fertilizers use in paddy farming to elevate above causative factors of CKDu in the endemic area.

The NCP extends over 10,500km² in the dry zone of Sri Lanka where majority is involved in paddy farming. Government of Sri Lanka provides a subsidy for chemical fertilizers especially for paddy farming and hence over application of fertilizer is common in the region. Some analysis indicated that, Triple Super Phosphate (TSP), the principal source of P in paddy farming contain mean As and Cd levels of 31mg/kg and 2 mg/kg respectively. However, these results have been challenged by some other studies conducted in the same area. Government has taken some initiatives to reduce the amount of fertilizer distribution under subsidy scheme but soil test based fertilizer application would be the most appropriate remedial measure to overcome this problem.

Key words: *Kidney disease, Water quality, Fertilizer use, Ionicity of water*

Background

Structural or functional abnormality of the kidney with or without decreased Glomerular Filtration Rate (GFR) is generally called Chronic Kidney Disease (CKD) (Wanigasuriya, 2015). Traditional causes of CKD included diabetes, hypertension, mellitus and glomerular nephritis (Ramachandran, 1994). However, the specific feature of CKD discovered

in the North Central Province (NCP) of Sri Lanka is that its etiology does not include traditional risk factors. Hence, this new form of the disease is named as Chronic Kidney Disease of Unknown Etiology (CKDu) (Anonymous, 2009). This is a major health issue among rural community of NCP where majority do paddy and rainfed farming for their livelihood. This disease was initially recorded in mid 1990s in the NCP and rapidly spread over some other agricultural areas over next two decades. However, disease is confined to a certain geographical area of the country. A study conducted by World Health Organization revealed that nearly 15% of people in the NCP within age group 15 -70 years are affected by CKDu. The total affected number is approximately 100,000 (Wimalawansa, 2014). CKDu is a serious health issue in many other countries including China (Lin et al, 2004), United State (Coresh et al, 2007), Canada (Arora et al, 2003), El Salvador (Gracia-Tabanino et al, 2005) and South Asia (Jessani et al, 2014) since mid 20th century (Dharmawardana et al, 2015).

Some researchers argue that Chronic Kidney Disease has multifactorial origin. They believe that CKDu is a result of many causative factors such as malnutrition, frequent dehydration, effect of agrochemicals, ionicity of drinking water, food and water contaminated by heavy metals and behavioral issues. One strong argument is continuous exposure to high ionicity in drinking water is a possible causative factor to weaken the kidney via a protein denaturing mechanism (Dharmawardana et al, 2015). High cadmium levels in drinking water, fish and edible aquatic rhizomes in the endemic area have led to another hypothesis that Cd is the possible reason for CKDu (Jayathilaka et al, 2013). Arsenic the well known poison was identified as another possible etiological factor for CKDu in the NCP (Jayasumana et al, 2013). The chemical fertilizers

enhance ionicity of water because of high solubility in water. Fertilizers like TSP manufactured from raw- materials extracted from the ground is contaminate by Cd and As. Over application of these fertilizers may enhance the level of above etiological factors. Then the aim of this paper was to study the pattern of fertilizer application and residual nutrient contents of paddy soils which can directly contribute ionicity, Cd and As levels of surface and ground water in CKDU endemic areas.

Ionicity of water and CKDu

It is documented that some of the cations and the anions available in the water have the capacity to denature of the proteins in cell membranes. These ions control folding and unfolding of proteins. Continuous exposure of kidney membrane (which consist of proteins) to ions dissolved in water may be a possible causative factor to CKDU. These ions are ranked by their capacity to denaturing of proteins. This series is called Hofmeister series. It contains both cations and anions as follows (Baldwin, 1996):

Cations: $\text{NH}_4^+ > \text{K}^+ > \text{Na}^+ > \text{Mg}^{2+} > \text{Ca}^{+2}$

Anions: $\text{F}^- > \text{H}_2\text{PO}_4^- > \text{SO}_4^{2-} > \text{HCO}_3^- > \text{Cl}^- > \text{NO}_3^-$

Chronic exposure to water containing above ions even in low concentrations has increased capacity for denaturing proteins in kidney membrane (Dharmawardana et al, 2015). Some of these ions are found in water with fertilizer runoff. Common ions in the fertilizer runoff such as NH_4^+ , K^+ , H_2PO_4^- have a higher rank in the Hofmeister series.

Effect of Arsenic (As) and Cadmium (Cd) on CKDu

Cadmium is a heavy metal which is identified as potential environmental contaminant to cause renal failures. Chronic Cd exposure

via respiratory and gastrointestinal tracts leads to Cd accumulation in kidneys. Jayatilaka et al (2010) reported that 0.03 to 0.06 mg/L of dissolved Cd in reservoir water in affected areas which is significantly higher level compared to 0.005mg/L, the Maximum Contaminant Level recommended by US Environmental Protection Agency. In contrast to these findings Chandrajith et al (2011) found that Cd contents of reservoir water in endemic areas were lower compared to WHO recommended level (ie:0.005mg/L). However, approximately 88% of CKDu patients tested by WHO survey in 2013 had urine Cd level above 0.6µg/g. Findings of some studies have shown that excretion of this level of Cd may consider as an early symptom of CKDu.

Arsenic remains in both organic and inorganic forms in the soil. The inorganic fraction exists as arsenate (AsO_4^{3-}) and arsenite (AsO_3^{3-}). The prominent form under aerobic condition is arsenate and arsenite dominates under reducing condition. Submerged paddy soils contain arsenite the reduced form which is the more soluble species of As indicating high risk to contaminate surface and groundwater sources. It was found that As is the major causative factor of kidney disease of Bangladesh. The biopsy data of CKDu patients in Sri Lanka also showed elevated As levels. The WHO report (2013) revealed that about 63% of the CKDu patients had urine arsenic level above 21µg/g creatinine. It also reported that, As levels found in nails of CKDu patients in the NCP were greater than 0.03µg/g.

Fertilizer use in the NCP

The CKDU spreading areas in the NCP are under agricultural land uses specially paddy farming. Paddy farmers enjoy fertilizer subsidy introduced about 10 years back focusing towards the food security of

the country. Three fertilizer types viz. Urea (N source), Triple Super Phosphate (P source) and Murate of Potash (K source) are provided in nominal price in two times annually (ie.two cultivating seasons per year).All paddy farmers are entitle for fertilizer subsidy scheme and the amount of fertilizer issued by this scheme is decided only based on land extent irrespective of the existing nutrient contents in the soil.

Nitrogen fertilizers

Urea is the widely used nitrogen fertilizer in NCP, Sri Lanka. The use of urea in the NCP is higher compared to other provinces in the country. This may probably due to the higher cultivated land extent in the NCP. Urea is manufactured from base elements and hence heavy metal contamination is minimal. Figure 01 shows soil available N content of 57 paddy blocks in disease endemic area. The soil nitrogen content of fifty six out of 57 land allotments showed over 500 ppm at the land preparation stage (ie. before adding fertilizers).

Thirty three land allotments irrdicated soil nitrogen above 1000ppm and seven allotments had over 1500 ppm which is the optimum N level for lowland rice. This elevated N level could possibly due to over application of chemical fertilizer which is subsidized by the government. Urea $\text{CO} [\text{NH}_2]_2$ is the widely used N fertilizer for paddy farming in Sri Lanka. As rice plants quickly response to urea, farmers tend to apply high dosage without concerning required amount. When applied to the soil, urea transformed to NH_4^+ within few days. Some of the NH_4^+ is converted to NO_3^- in the soil with the presence of O_2 . The available N content in the analyzed soil samples illustrate that nearly 50% of urea fertilizer application can be reduced at least for coming season.

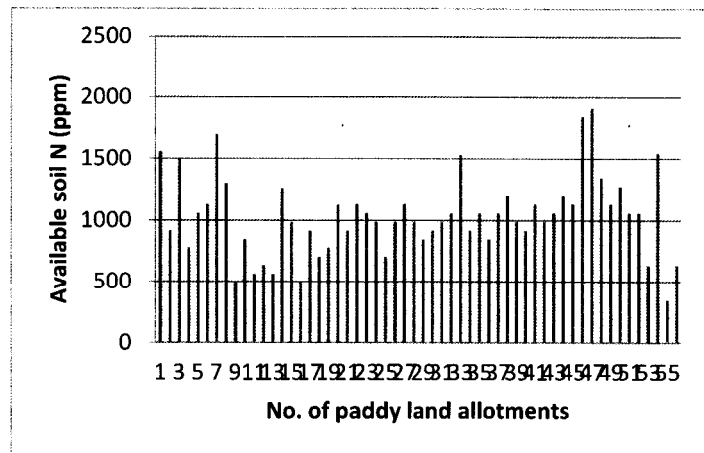


Figure 01. Available soil N content

Source: Weerathna and Amarasekara (2012)

Phosphorus fertilizers

The recommended optimum level of available soil P for paddy in NCP, Sri Lanka is 10 ppm. Soil samples collected from all 57 paddy allotments showed available P above 10 ppm (Figure 02). Approximately 30% of the allotments recorded 3 times higher P level compared to optimum level of 10 ppm. However, farmers tend to apply TSP continuously without considering existing P level in the soil. This may possibly be due to lack of knowledge and proper guidance to farming community. It was reported that TSP is a major source of Arsenic (As) which was identified as a possible etiological factor for the epidemic of CKDU. The mean value of As reported in TSP was 31 mg/kg. It was the highest recorded As level compared to that of all tested agricultural inputs including highly toxic pesticides (Jayasumana et al, 2015). About 1000

tons of TSP is imported to Sri Lanka annually containing significant amount of arsenic as trace element. Imported granular TSP is the source of P mainly used for paddy farming in Sri Lanka. Rice is a semi aquatic plant capable to accumulate As and Cd available in the anaerobic flooded soil. It is the staple food of the country and the widely growing crop in the NCP. Mean total As content of polished rice recorded in newly improved rice varieties grown in three locations of NCP was 164µg/kg. However, the maximum As content of polished rice detected in same varieties was about 427µg/kg. The Maximum Allowable Limit (MAL) for inorganic As recommended by Codex Alimentarius for polished rice is 200µg/kg. This corresponds to about 286 µg/kg of total As content based on the assumption of 70% of the total As exists in the inorganic form in the rice. As such 11.6% of tested rice samples in three locations of NCP exceeded the MAL (Jayasumana et al, 2015). Since NCP contribute approximately 25% of national paddy production, elevated As content recorded in rice may create a risk of causing many non-communicable diseases even in other parts of the country. Cadmium is another hazardous heavy metal found in TSP. Fertilizer analysis exhibits that about 2 mg/kg of Cd available in TSP.

The elevated soil P levels in paddy soils indicate that amount of TSP application can be reduced by 50% for next couple of seasons. It directly reduces the adding of As and Cd to paddy soils.

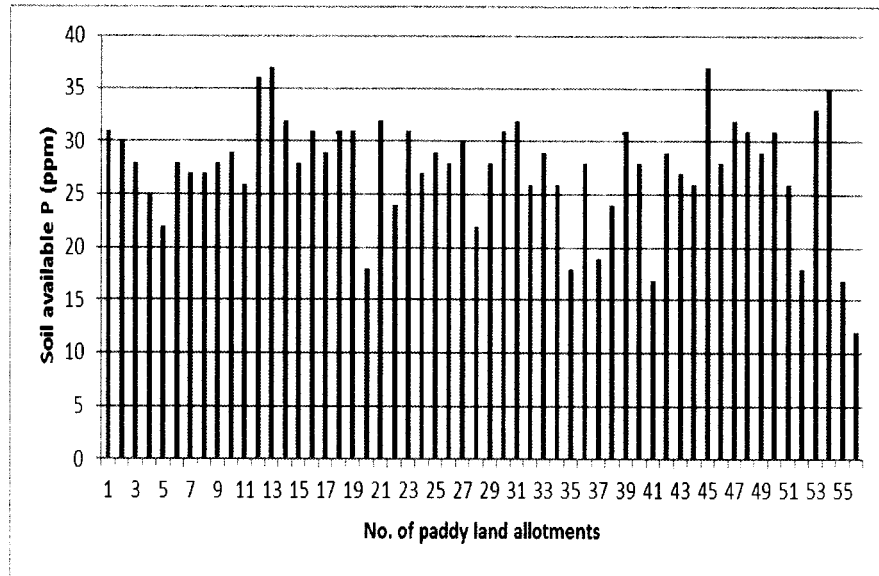


Figure 02. Available soil P content

Source: Weerathna and Amarasekara (2012)

Potassium Fertilizers

Murate of Pottash (MOP) is the main K containing fertilizer used in Sri Lanka. Most paddy farmers apply MOP only flowering stage of the crop. They believe that MOP is not much essential unlikely urea and TSP. Therefore,over application of MOP is not a common practice in paddy farming. This may be the possible reason forlow residual K content in the analyzed soil samples(Figure 03). The recommended optimum level of K for rice is 160 ppm.

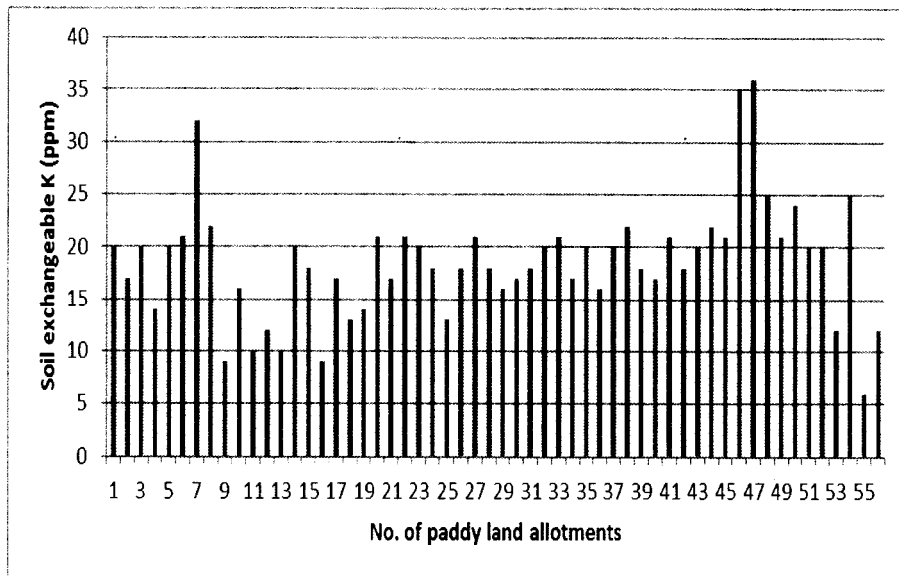


Figure 03 - Exchangeable soil K content

Source: Weerarathna and Amarasekara (2012)

Soil pH

Soil pH is a key factor which determines the solubility of plant nutrients. Plants take up ionic forms of nutrients dissolved in soil moisture. The optimum soil pH range for nutrient uptake by plants is 6.0 - 7.0. The analyzed soil samples indicated that soil pH of paddy soils ranges from 5.5 to 7.5 (Figure 04). In this range two phosphate ions (ie: H_2PO_4^- and HPO_4^{2-}) are prominent in the soil. Addition to that, NH_4^+ , K^+ and Mg^{2+} are also available in ionic forms in the same pH range. Most of these ions have higher rank in Hofmeister series.

The NCP belongs to Dry Zone of Sri Lanka where water is a scarce resource. This area has undulated topography and the surface runoff from highlands towards the lowlands has been harnessed by series of reservoirs (tanks) basically to irrigate paddy fields. The return flow from

a cluster of paddy fields is diverted to next tank located at the lower elevation to irrigate another cluster of paddy fields. This type of connected series of tanks is called tank cascade system, a well established ancient water management system functioning effectively even today.

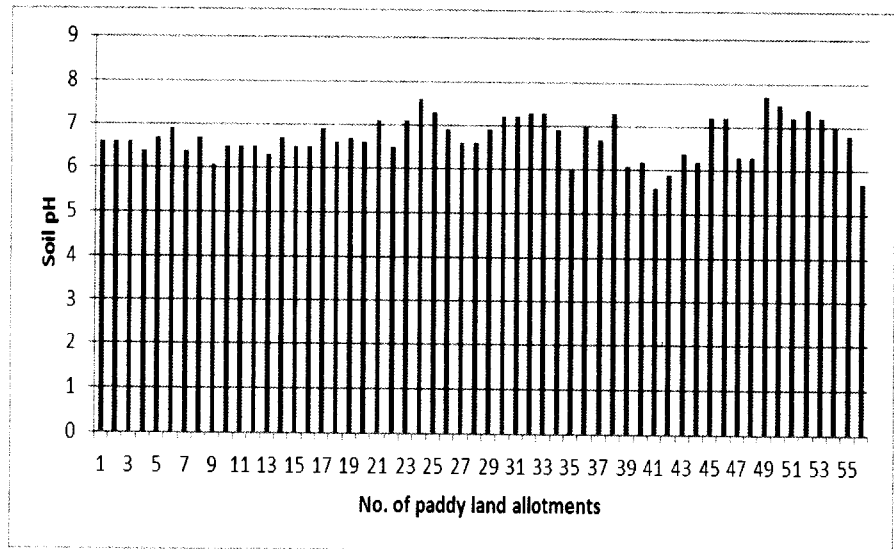


Figure 04 - Soil pH

Source: Weerathna and Amarasekara (2012)

People use tank water not only for irrigation but also several other purposes such as bathing, drinking and domestic uses. The N,P,K, As and Cd rich return flow coming through paddy fields get store in tanks in the cascade system threatening to the health of water users. The hydrology of highland soils in the region may also influence on increased acidity of water. Bimodal rainfall pattern exist in the NCP cause frequent fluctuations in the groundwater table creating reducing and oxidizing conditions in the soil profile. This promotes solubilizing of minerals containing heavy metals and arsenic. The fluctuation of

groundwater table also increases leaching of chemical fertilizers that may reach to shallow and deep aquifers. High growth rate of algae and other aquatic plants in surface water bodies in the area is a clear indication of fertilizer runoff. A study conducted by WHO (2013) reported that majority of patient suffering from CKDu excrete raised levels of As and Cd in the urine. This intake of As and Cd may possibly through food and drinking water.

Fertilizer distribution in the NCP

Distribution of fertilizers for paddy farming in NCP has gradually gone down from 2010 to 2014 (Table -05). It clearly reveals that fertilizer application has also drastically reduced during this period. However, it did not affect on paddy production yet because of the residuals of fertilizer in the soil. Distribution of TSP has decreased during last five years from 15,580 mt to 5128 mt. This may create long term effects such as declining soil fertility and ultimately low paddy production. It will also affect adversely on income of poor farmers. However, the most appropriate mechanism is fertilizer recommendation through nutrient analysis in the soil. Even though this is a costly operation, it reduces health and environmental hazardous without affecting on rice yield.

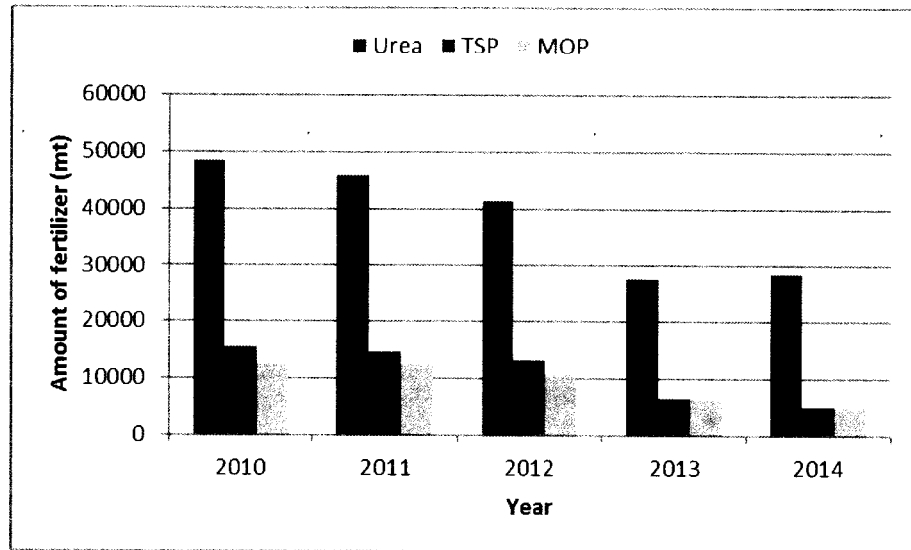


Figure -05-Distributions of chemical fertilizers in NCP from 2010 to 2014

Source: National Fertilizer Secretariat, Sri Lanka

Conclusion

Excess fertilizer use in paddy farming increases accumulation of soluble ions in the soil. It directly contributes to ionicity of water which plays a role in denaturing proteins in kidney membranes. Overuse of TSP is a principal source of inorganic arsenic and cadmium in CKDu endemic areas. Soil test based fertilizer recommendation would be a better option to reduce over application of chemical fertilizers in order to minimize environmental pollution and health hazard.

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