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# Will Restoration of Ecological Functions of Tank Cascade System Contribute to Reduce CKDu in Sri Lanka? A review

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**Abstract**

People in the dry zone of Sri Lanka where hydraulic civilization once thrived, suffer from occurrence of a chronic kidney disease of unknown etiology (CKDu). The etiology for CKDu is now shown to be multi factorials and but related to water. Ancient people in the dry zone used surface water of tank cascades system and this system was interlinked with the ecosystem and social system of the area. It is hypothesized that the adverse changes that took place to the ecosystem of the tank cascade system and new commercial practices of agriculture in the CKDu prevalent area have also become reasons for the spreading of CKDu.

This review assesses the effect of different components of the tank cascade systems in improving the water quality. A number of studies have reported positive effects of improving the surface water quality of the tank by the *Wew Ismaththa* (closer catchment), *Thaulla* (upper peripheral gentle sloping land), *Kattakaduwa* (Interceptor) *Iswetiya* or *Potawetiya* (upstream soil ridges), *Godawala* (small silt trapping pond). The review also identified functions of *Thaulla* area approximately similar to a constructed wetland. This review highlights the issues and gaps in our understanding the ecological functioning of Globally Important Agricultural Heritage System. It is suggested that reconstruction of ecofriendly structural components of tanks and reestablishment of tank cascade system in the area would help to combat the spreading of CKDu in dry and intermediate zone of the country.

**Keywords**: Chronic kidney disease, Heavy metals, Tank cascade system, Ecology, Water Quality

## 1. Introduction

History of Sri Lanka is directly associated with the hydraulic civilization. Many civilizations such as Indus, Mexican, Maya and Inca had a long history and flourished with power and knowledge and faded away with passing the time. The causes behind the extinction cannot always be attributed to the attacks of other human nations and to the changes of the natural ecology, but it could be the consequence of the man made changes of the environment, outcome of the adverse agricultural environment etc. Sri Lankan hydraulic civilization has been an exception in this context though it had rise and falls during the past (Awsadahami, 2010). However, at present, an appreciable percentage of people in dry zone of Sri Lanka earlier *Rajarata* and *Ruhunu rata* where hydraulic civilization thrived suffer from the occurrence of chronic kidney disease of unknown etiology (CKDu). Due to its widespread geographical distribution and histopathological evidence, CKDu is considered a problem related to the environment. Hydro-geochemistry of the drinking water is believed to adversely effects the disease as it is highly endemic (Chandrajith et al., 2011). We observed that many hypotheses have been proposed as causative factors for CKDu and established at present as a multifactorial origin. However, these associated factors are related to water. We believe that this occurrence is due to the drastic changes happened to the hydraulic system of the dry and intermediate zone of the country. There is a growing concern over the high incidence of CKDu in dry and intermediate zone of Sri Lanka, and the ancient tank cascade system with its ecological functions has a potential for controlling this disease. Hence the present review was undertaken to find out the potential role of components of the tank cascade system in improving the water quality of the area and also the possibility of reestablishment of tank cascade system as aremedial measures for the spreading of this diseases in dry and intermediate zone in Sri Lanka.

### *1.1 What is CKDu and its Spatial Distribution?*

Unlike Chronic Kidney Disease (CKD) which is considered to be caused by a number of factors such as diabetes, hypertension, and the various forms of glomerulonephritis. Chronic Kidney Disease (CKDu) reported in some parts of Sri Lanka are not directly related to the above-mentioned factors and causal factors are not exactly known or well defined, hence, it is referred to as CKD of uncertain origin. CKDu was first reported in the early 90s from North Central Province in Sri Lanka. Similar disease conditions are also recorded in India (e.g. Uddanam), Nicaragua, Costa Rica, Central American states, China, Serbia, Bulgaria, Romania, Croatia, and Bosnia (Gifford, 2017). In Sri Lanka, there are approximately 20,000 admissions/ re-admissions of patients with CKDu to government hospitals with around 2,000 deaths annually (http://www.presidentialtaskforce.gov.lk/en/kidney.html#).

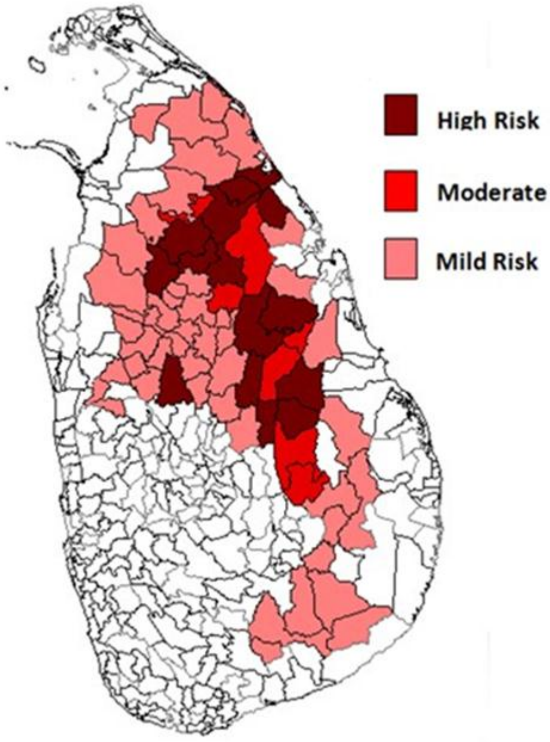


Figure 1. Registered CKDu patients upto December 2014 (adopted from http://www.presidentialtaskforce.gov.lk/en/kidney.html#)

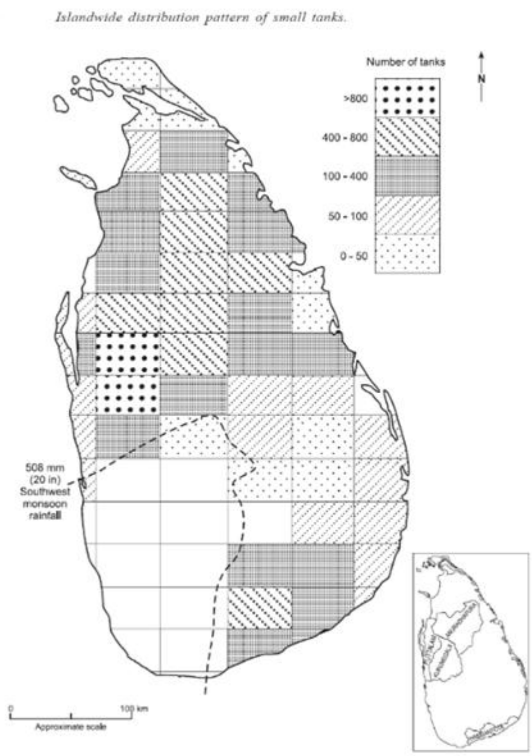


Figure 2. Island wide distribution of small tanks in Sri Lanka (adopted from Panabokke *et al*., 2002)

Figure 1 shows the divisional secretariat level distribution of CKDu patients in Sri Lanka while figure 2 exhibits the distribution of small tanks in Sri Lanka. We noted that the CKDu patient spatial distribution is approximately similar to those of tank spatial distribution. There are no reports indicating that the CKDu prevailed and significant death tall occurred during history in these regions. Instead, there are reports for the malaria infestation in recent past. That is also partially attributed to abundance of small tanks in the area. Therefore, we believe that the adverse changes that took place to the ecosystem of the tank cascade system or *ellangawa* (Sinhala folkloristic term) and new commercial practices of agriculture of dry and intermediate zone of the country have also become reasons for the spreading of CKDu.

*1.2 Relationship of Causes of CKDu to Water*

Various studies exploring the etiology of CKDu suggested that heavy metals cadmium (Bandara et al., 2010; Jayathilake et al., 2013), arsenic (Jayasumana et al., 2013), elevated levels of fluoride in groundwater, the specific composition of groundwater (Chandrajith et al., 2011), aluminum (Illeperuma et al., 2009), weedicide (Jayasumana et al., 2014) and cyanobacterial toxins ( Dissanayake et al., 2011) excessive ground water iconicity ( Dharma-wardena et al., 2015), excessive $PO_4$ ions present in water (Dharma-wardana,2017) etc. as causative agents. However, no particular agent is conclusively established and this paper doesn't attempt to review the causative factors. Reviews of etiological factors for the CKDus are found in Rajapakse et al., 2016; Lunyera et al., 2015; Wanigasuriya 2012,2014; etc. We along with other authors Soderland et al., 2010; Wimalawansa 2014; Wanigasuriya 2012, etc. believed that CKDu is a multifactorial and environmentally acquired disease.

Jayasekara et al., 2013 showed that the communities who live closer to irrigation system obtaining well water sourced by natural springs are affected less than those communities using well water source by the seepage of irrigation water. Moreover, according to Dharma-wardena et al. (2015), prolonged use of excessively ionic water from fertilizer runoff through Mahaweli water diversion is considered to be a cause of CKDu by a Hofmeister-type protein denaturing mechanism in the kidney.

These findings clearly indicate that the use of groundwater and polluted surface water have been the cause for the occurrence of CKDu. Ancient Sinhalese community used surface water from small tanks as potable water, the use of groundwater was never practiced even for agriculture (Wijesekara, 2016). However, at present, the use of surface waters in the tank cascade system is questionable.

## 2. What is Tank Cascade System?

The dry zone, which covers the lowlands of the northern, north-central and eastern areas of the country, is subjected to several months of dry period extending from May to September. In order to overcome the limited water availability during this period, the ancient Sinhalese developed their own water management system now known as the Tank Cascade System. According to Madduma Bandara, 1985, "A 'tank cascade' is a connected series of tanks organized within a meso catchment of the dry zone landscape, storing, conveying and utilizing water from an ephemeral rivulet". However the Sinhala folkloristic term for this water management system is *ellangava*. This system has been recognized as a Globally Important Agricultural Heritage Systems" (GIAHS) by the FAO (FAO, 2018) as this system is adapted agricultural system managed with time tested indigenous techniques. As indicated in figure 3, watershed boundary of the meso-catchment, the individual micro-catchment boundaries of the small tanks, the main central valley, side valleys, and axis of the main valley, component small tanks, and the irrigated rice lands (Sakthivadivel et al., 1997) are the main elements of a cascade.

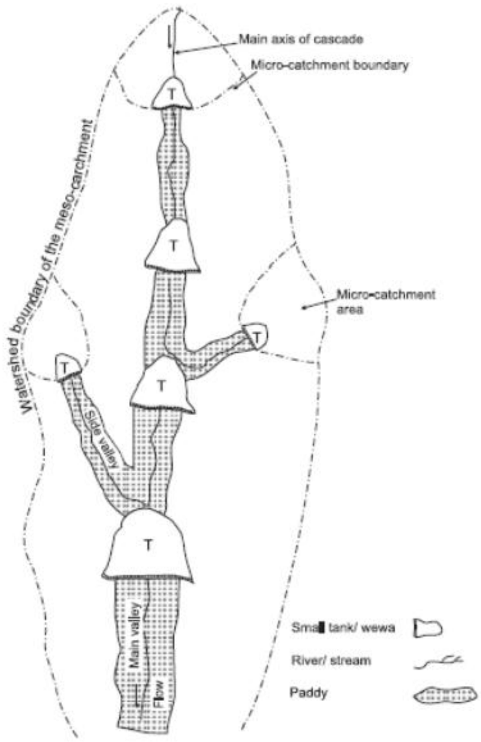


Figure 3. Schematic representation of small tank cascade system of Sri Lanka (adopted from Panabokke *et al*., 2002)

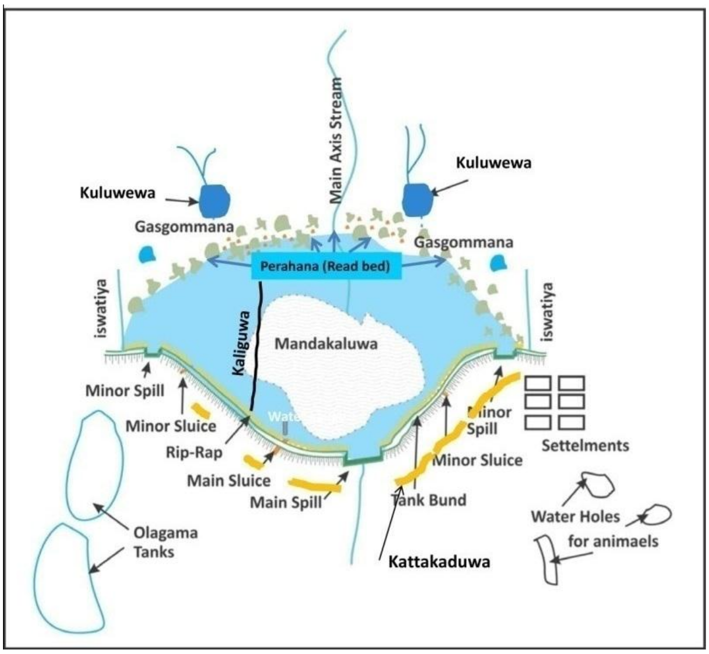


Figure 4. Components of a village tank and their relative positions in the small tank village in Sri Lanka (adapted from Tennakoon, 2015a)

*Wewa*/ small tank / small reservoir is the main element of tank cascade system and *Wewa* refers to an artificial lake or a pond for storing water on the surface of the ground, which has been constructed by local people at a geographically suitable location using their indigenous skills mostly during ancient times (Nawaratne and Gunawardena, 1999). Gilliland et al., 2013 showed that the majority of these tanks were constructed during the period of the Anuradhapura kingdom (377 BCE to 1017 CE). In fact, the tanks in dry and intermediate zone in Sri Lanka is not just water collecting vessels but can be considered as a special ecosystem considering its diverse functions. Ancient people used to get drinking water from a separate place called *'Diyamankada'* of tank where they have planted *Kumbuk* trees (*Terminalia arjuna*) and this place is open to wind and as a result, there are many ripples in the water. *Terminalia Arjuna* is believed to purify and cool the water, and it has an ability to reclaim saline and alkali soils and reduce soil erosion on banks (Agroforestry database). Ripples generating in the water has also capacity to purify the water. Moreover, this place (*'Diyamankada'*) is far away from bathing places (*Nana Mankada*), drinking places for cattle (*Boradiyamankada*) and cloth washing places (*Radamankada*) (Dalupota 2005). Even when the water quantity is less in the tank, villagers were used to get the water to a clay pot, filtered using piece of cloth and add *Ingini* (*Strychnos potatorum*) seeds to purify the water. According to the villagers (personal communication with *Uttimaduwa* villages in Anuradhapura), *Ingini (strychnos potatorum*) seeds have the capability to settle down the clay and other suspended matter in the water and soften it. In a study done by Muthuraman et al. (2013) showed the ability of *strychnos potatorum* to reduce the turbidity by greater than 87% as it contains anionic polyelectrolyte. Therefore, we can argue that the early people lived in dry and intermediate zone used soft good quality water for drinking. However after introduction of groundwater wells to the dry zone in 1950s, people used groundwater as a source of drinking water.

### *2.1 Components of Wewa/ Tank and Their Roles in Managing the Water Pollutants*

Tanks/ *Wewa* consists of some remarkable bio-engineering structures in order to conserve the soil, control water flow and purifying water. Schematic representation of components of small tank (Tennakoon, 2015) is shown in figure 4 while we try to show the tank profile and its components using figure 5. Proper functioning of these components, the earthen dam (*We-kanda*), sluice gates (*Sorrowwa*), spillways (*Pita Wana*), valve pit *(BissoKotuwa*), *iswetiya* (upstream conservation land), *gasgommana* (upstream wind barrier made of tree plantations), *kattakaduwa* (downstream wind barrier, located in between the sluice and paddy), *tisbamme* (land strip around the hamlet for protection), *Thaulla* (upper peripheral gentle sloping land) and *wew ismaththa* (closer catchment) ensure the better quality, quantity and sustainability of the water for the tank/*wewa*. Table 1 summarizes the functions of different components of the tank in relation to water quality improvements while figure 6 shows the successions of water quality improvements in a small tank system as a whole.

Table 1. Functions of different components of the tank in relation to water quality

| Tank components | Functions |
|---|---|
| Wew Ismaththa (closer catchment) | Increase the groundwater table through infiltration and gradual release of water to the tank.<br>Filter sediments and adsorption of pollutants |
| Thaulla (upper peripheral gentle sloping land) | Consist of Perahana and Gasgommana<br>Reduce the velocity of flow of water reaching to the tank.<br>Silt trapping action.<br>Pollutants retaining action and adsorption of pollutants.<br>Wind barrier.<br>Cooling the water. |
| Iswetiya or Potawetiya | Prevent sediments (eroded soil) entering from upper land slopes to the tank |
| Godawala and Kuluwewa | Trap sediments reaching through the ephemeral streams<br>Supply water to wild animals |
| Kattakaduwa (Interceptor) | Salt trapping action<br>Minimize seepage of the bund (dam)<br>Wind barrier |
| Kata sorrowwa/ Kumba sorrowwa | Release of low saline water to the paddy fields |
| Natural spillway opening to rock outcrop area | Control soil erosion |
| Flora along the *Kiul ela* | Trapping excess nutrients and salts |

### *2.2 Components of the Tank in Relation to Water Quality Improvement*

#### 2.2.1 Wew Ismaththa (Closer Catchment)

There was essentially an upstream land area dedicated to the tank from which water drains to the tank (closer catchment). The extent of this area depends on the water spread area of the tank and this area is maintained as a forest in the past. At present, the closer catchment is very rarely observed in small tanks. *Kuluwawa* and ephemeral streams are generally located in *Wew Ismaththa* (Figure 3). *Wew Ismaththa* is protected and cutting trees and *chena* cultivation (slash and burn cultivation) is prohibited. The purpose of the area was to increase the groundwater table through infiltration and thereby gradual release of water to the tank during the dry season is expected (Hitinayake et al., 2008, Geekiyanage and Pushpakumara, 2013). Farmers under the headmen of the village were used to grow trees in these areas such as *Weera (Drypetes sepiaria), Kumbuk (Terminalia arjuna)), Palu (Manilkara hexandra), Mee (Madhuca longifolia), Ahala (Cassia fistula), Thibiri (Diospyros malabarica),* etc. and establish vines such as *Kobbawel* (*Allophylus zeylanicus*)*, Eraminiya (Ziziphus oenoplia)* and *Thiththawel* (*Anamirta cocculus*) thinking that these will absorb more water during the rainy season and drain those absorbed water to the tank slowly. The resulting biotic environment is an ideal place for diverse macro and micro fauna. These organisms along with trees can purify water from upstream tank command areas in this system. Plants in the biotic-environment can absorb herbicide molecules sorbed onto organic matter. Soil microorganisms can degrade the herbicide molecules. According to Michael and Neary (1993) some herbicides like glyphosate showed not to leach at all and remain tightly sorbed onto organic complexes. Tree roots and enhanced level of soil organic matter from tree litter improve the soil structure, aggregate stability and promote faunal activity leading to higher macro porosity so that infiltrated water pass through the soil matrix (Bargués Tobella et al., 2014; Ellisona et al., 2017). This environment filter sediments and pollutant adsorbed to the sediment particle may not then reach to the tank water. Thus *closer catchment* had a higher potential to clean the drainage water and if this area is re-established and conserved as in the early days, there is still a potential to improve the tank water quality even though upstream area is heavily cultivated with recommended doses of agro chemicals following integrated nutrient and pest management techniques.

2.2.2 Thaulla (Upper Peripheral Gentle Sloping Land)

Waters discharged from the upper tank and drainage excess from upper stream paddy fields are received by the tank at downstream through an area termed as '*Thaulla'* (Mahatantila et al., 2007). This micro-catchment region is partly covered with water but completely flooded only during rainy seasons. As shown in the figure 4, 5, and 7, areas where *Gasgommana* and *Perahana* are located can be considered as *Thaulla*. *Thaulla* does not allow water flow from the upstream area/ upper catchment directly reaching it as fast flowing stormwater into the tank. This area consists of arrays of bushes such as *Boolpana (Glycosmis angustifolia), kooratiya (Phyllanthus polyphyllus), Tharana (Tarenna asiatica), Maila (Bauhinia racemosa*), *Pila (Tephrosia purpurea), Ankenda (Acronychia pedunculata), Ulkenda (Polyalthia korinti) Korakaha (Memecylon umbellatum)*, etc, and the trees such as *Nabada (Vitex leucoxylon), Dunuke (Pandanus foetidus), Mee(Madhuca longifolia), Damba (Syzygium gardneri), Kumbuk (Terminalia arjuna)* etc. In addition, sedges such as *Hambupan (Typha angustifolia), Thunhiriya (Schoenoplectus grossus), Gal ehi* (*Cyperus corymbosus), Borupan (Eleocharis dulcis)* and *Vatakeyya (Pandanus species)* and also different kind of climbers such as *Kaila (Phyllanthus reticulatus) Katukeliya (Caesalpinia bonduc), Kalawel* (*Derris parviflora) Bokalawel (Derris scandens)* (IUCN 2015) and grasses are abounded in these land mass. These florae have an ability to trap sediments and absorb pollutants and negate their toxicity reaching to the tank. Moreover, these strip of trees (*Gasgommana*) act as a wind barrier and also lower the temperature of the water in the tank. Mahatantila et al., 2007, using *Malagane* tank as an example in *Deduru Oya* river basin showed that pollutants draining into the tank can be effectively controlled by the *Thaulla*. Most water quality parameters except phosphorus showed a decreasing trend when water passes through *Thaulla* area. It has also been shown that Mg, Na, and Ca in a decreasing concentration in soils of *Thaulla* area towards the water spread area in *Ulankulama* tank at *Maradankadawala* in *Anurahdapura* and their concentration is higher in *Thaulla* area when compared to the normal values of the surrounding soils (Abeysingha et al. 2016*)*. These results suggest that *Thaulla*, can act approximately as an active 'constructed wetland' which efficiently removes pollutants in order to sustain the system. Role of constructed wetland and functions of wetland have been shown by many authors (Mazumdar and Das 2015, Jia et al., 2016 etc.). Wetlands can be referred to as the interface of aquatic and terrestrial ecosystems, forming specialized ecosystems where complex ecological processes occur due to the interactions between water, vegetation and soils (Naiman and Henri, 1997). Since *Thaulla* is submerged with water for about 3 to 5 months during rainy season ( November to Febrary), and then drying steadily during the other months, the *Thaulla* and tank water spread area its ecosystem can also be considered as a special wetland.

Mahatantila et al. (2007) and Abeysingha et al. (2016) showed the chemical precipitation function of *Thaulla* area and other wetland functions need to be tested by doing experiments to understand the degree of occurrence of those functions. It has been shown ecosystem services such as water storage and flood protection, biodiversity support, carbon (C) storage and sequestration, and water quality improvement benefits provided by the wetland and riparian buffers (Fennessy and Craft, 2011; Marton et al. (2014). However, not all wetlands equally provide the same functions. Marton et al. 2014 showed the lower water quality improvement functions and C pools in restored wetlands than in natural wetlands by taking 10 restored and five natural depressional wetlands in northern Indiana and four restored and four natural riparian buffers in central Indiana. *Thaulla* in most of the small tanks are just like the natural meadow with trees at the peripary, though it is submerged with water for about 3 to 4 months. It has been shown that many species of plants/ trees absorb contaminants such as lead, cadmium, chromium, arsenic, and various radionuclides from soils (Tangahu et al. 2011). Contaminants in water are reduced or removed by wetland systems by mechanisms including sedimentation, filtration, chemical precipitation and adsorption, microbial interactions and uptake by vegetation (Kivaisi, 2001). Similar function may perform by the trees and other aquatic plants naturally growing at the periphery of *Thaulla* area of the tank. Ancient people used to maintain the *Thaulla* area and used the water of these small tanks for all the purposes.

Ancient people knew that the life span of the tank depends on the functions of *Thaulla*. Therefore, entering into this area is customarily prohibited to anybody except the Ayurveda doctor in the village to collect medicinal plants. Protection of this areas is a duty of the headmen of the farmers or the village headmen (Dalupota, 2005). However at present, it is rather difficult to find out the good extent of *Thaulla* in most of the tanks and also conservation of this area is neglected due to overexploitation of the resources and ignorance. This degradation of *Thaulla* area results in lowering the water holding capacity of the tank and impair the water quality. If there was a possibility to drink surface water of the tanks as earlier, we might not adversely exposure to these cadmium, arsenic or excessive iconicity because of the pollutant degrading functions of the *Thaulla* area of the tank.

2.2.3 Kattakaduwa (Interceptor)

This is an elongated murky meadow with turbid water in between the outer toe of a tank bund and paddy field. When halophytes such as mi (*Bassia longifolia*), kumbuk (*Terminalia arjuna*), lunuwarana (*Creteva adansonii*), thimbiri (*Diospyros malabarica*), val beli (*Lumnitzera litterea*), and vetakeyya (*Pandanus kaida*) are grown in over the rim of the medow salts on the water is reduced (Tennakoon, 2015b). In a preliminary study done by Madduma Bandara et al., 2010 showed that the higher EC levels recorded in *Kattakaduwa* area in all tanks in *Navodagama*, *Kahagollewa* and *Parana Halmillewa* cascades in

Anuradhapura district. This observed higher salinity concentration is due to seepage of water from dead storage area of the tanks where there is a buildup of salinity in most of the tanks (Madduma Bandara 2010). However, this *Kattakaduwa* area also acts as a downstream wind barrier and helps to protect soil from erosion as majority of species consists with well-developed root systems. Hence these ecofriendly structures improve the water quality of the command area by removing excess salts, nutrients and sediments. This command area is the catchment area for the next downstream tank in tank cascade system.

*Iswetiya* or *Potawetiya* is an up stream soil ridge made at either side of the tank bund to avoid sediment particles entering from upper land slopes towards the tank (Figure 3). In addition, *Godawala and Kuluwewa* were constructed to trap sediments reaching from the ephemeral stream to the tank. *Godawala* which is found in association with a small tank, is a manmade waterhole. Whereas *Kuluwewa* a small tank or pond above large reservoirs trap sediments and provide water for cattle and wild animals which may be a strategy to avoid man-animal conflicts (Figure 3). Construction of these *Iswetiya* or *Potawetiya, Godawala or Kuluwewa* ensures the good water quality and arrest siltation of the tank. In addition, villagers used to remove sediments from most silted areas of the tank bed during extended dry spells usually at a frequency of 3 to 5 seasons. This sediment removal (de-siltation) process (*Kattikapeema* in Sinhala folkloristic term) has been considered as a common responsibility of the downstream water users and carried out through community volunteer work. However, de-siltation process was restricted only to well-identified locations of the tank bed and a sediments layer of not more than 15cm deep and the materials removed from the tank bed was not placed on the dam (Dalupota, 2005). Further, early engineers constructed mud sluice to remove the silt emptying the tank. Moreover, the place of the spillway of tank is generally designed to open to a low rock outcrop area (Panabokke et al., 2002) so that erosion is minimized from the water released from the tank. Hence, tank water was sustainably used for drinking, bathing, washing and irrigation. Raising the dam or spill was not required as at present to accommodate a sufficient quantity of water for irrigation.

In the downstream command area of a tank where paddy is grown, old natural stream is used as a common drainage line (locally termed as *Kiul ela*) which collects and removes seepage water usually carry dissolved ions (Dharmasena, 2004). Accumulation of dissolved ions, especially $Na^+$, locally pause risks of salinization and iron pollution within of the local command area and *Kiul ela* facilitates faster drainage minimising such risks (IUCN 2015). In addition, tree species such as *karanda (Pongamia pinnata), mee (Madhuca longifolia)*, mat grass (Axonopus species), *ikiri (Acanthus ilicifolius), vetakeya (Pandanus odoratissimus)* etc., which are capable of trapping excess nutrients and salts are planted along the *Kiul ela*. This vegetation apparently contributes to purification of drainage water to a considerable extent even within the local command area. Drainage water subsequently reaches to the next downstream tank through the *Wew Ismaththa* (closer catchment) and *Wew Thaulla* within the cascade system. However, the reservation of the next tank or *Wew Ismaththa* (closer catchment) of the cascade begins just below the paddy fields of the upper tank. Dharma-wardana (2015, 2017) stated that the origin of kidney disease was linked to water with high ionicity damaging the membranes in the tubules and other components of the kidney via the Hofmeister mechanism. Ionicity of water substantially is reduced in tank water when the water passes though these *Kattakaduwa - Kiwul Ela* system. At present, these systems are neglected in many tanks/cascade systems that might result in increase salinity.

Fluoride in water is also considered to be a causal factor for CKDu. Chandrajith et al. (2011) showed that increased Na/Ca ratio, promotes formation of complexes with Na ions which reduces both the toxicity of fluoride ions in the human body and the absorption of $Ca^{2+}$. Conversely, higher $Ca^{2+}$ activity results in possible lesions on tubular cells leading to their death thus aggravating the damage caused by fluoride. Tank water with the influence of above mentioned ecosystem in tank cascade system may contain less $Ca^{2+}$ as the trees and shrubs absorb $Ca^{2+}$ in tank water. In addition, groundwater is in longer and intimate contact with subsurface rocks than surface tank water. Therefore, groundwater is generally found to be higher in fluoride concentration depending on the mineralogical compositions of the underground materials (Edmunds and Smedley 2013). The Fluoride concentration of deep and shallow groundwater in Anuradhapura area varies from 0 to 2.5 mg/l. According to the Sri Lankan drinking water standards, the Fluoride level should be less than 1.5 mg/l. The occurrence of high fluorides is primarily connected to the geology of the area (Wijesekara 2016). Fluoride in lower concentration becomes nephrotoxic in the presence of hard water Dharma-wardana (2017). Since tank water has generally low concentration of Fluoride, we believe that use of tank water for drinking under the natural agro ecosystem may not be a causal factor for ill-health associated with fluoride.

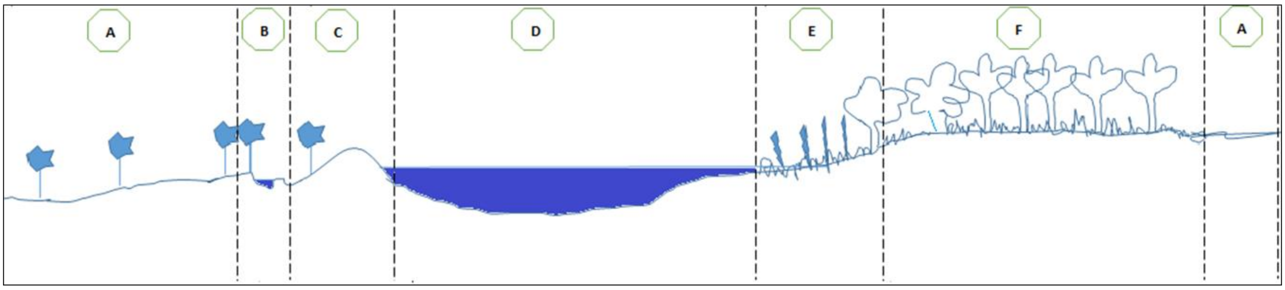


Figure 5. Schematic representation of the profile of small tank and its components (Produce by the Authors)

A : Command area specially paddy ; B : Kattakaduwa; C: Earthen Dam ; D: Water spread area of the tank; E: Thaulla ; F: Closer catchment/ Wew Ismaththa


Figure 6. Key functions of the main components of a small tank (Produce by the

Authors)

Figure 7. *Thaulla* area of ulankulama tank, Anuradhapura in Sri Lanka (Produce by the Authors)

The benefit of tank cascade system is that the downstream tank captures the excess water from the tank above. Thus, water is not wasted and but recycled. Importance of this system has been described by few publications such as Panabokke et al., 2002; Madduma Bandara 1995; Sakthivadivel et al., 1997; Siriweera, 2001; Somapala, 2001; Somasiri, 2001; etc. However, this age old ecofriendly concept/practice had not been taken into consideration during irrigation system restoration and settlement projects in 1950s, 1960s and 1970s where short sighted efforts have been increasingly made by the water resources managers. It is widely accepted that the ancient irrigation system in the dry-zone of Sri Lanka was largely developed during the period up to 12th century. The system faced a decline from 13th century to 19th century (Panabokke, 1999), although the system did not completely collapse. The number of operational and abandoned small tank within each province is shown in table 2. If all these tanks were in operation, we hope there is no need of extraction of groundwater for drinking or farming purposes. Use of groundwater for drinking has been one of the causes of CKDu because of its higher ionicity. We hope still there is a possibility to adopt these tank cascade system and integrate the ancient technology with the novel watershed and water resources management techniques so that we could minimise predisposal factors to CKDu.

Table 2. Number of operational and abandoned small tank within each province (adopted from Panabokke *et al*., 2002)

| Province and area ($km^2$) | Number of small tanks | | Total |
|---|---|---|---|
| | Operating | Abandoned | |
| Northern 3,709 | 608 | 816 | 1,424 |
| North central 10,365 | 2,095 | 1,922 | 4,017 |
| North western 7,760 | 4,200 | 2,273 | 6,473 |
| Southern 2,849* | 653 | 757 | 1,410 |
| Lower Uva 2,901* | 16 | 543 | 559 |
| Eastern ( South of Mahaweli) 3,885* | | 1,017 | 1,017 |
| Eastern ( North of Mahaweli) 3,885* | 48 | 425 | 473 |

| | | | |
|---|---|---|---|
| Total | 7,620 | 7,753 | 15,373 |

*Includes only the dry zone part of the province.

*Note:* The data is based on 1995 Department of Agrarian Services (DAS) data bank and 1982 ABMP maps

The Mahaweli development project is the largest irrigation and hydropower project in Sri Lanka which started its work extensively by 1977 and diverted water to the dry zone. It is reported that by the 2006 the landuse pattern of dry zone (Mahaweli system B, C, G and H) completely changed. As the centralized large-scale schemes were considered to be more efficient than the decentralized small systems, a number of small tank cascades were replaced by large reservoirs and high capacity feeder channels (Geekiyanage and Pushpakumara 2013). Most of the large reservoirs recently built were silted considerably and water quality has been impaired (Hewawasam, 2010) when compared to the small tanks in tank cascade system. Larger tanks at the end of tank cascade will not be silted in a larger magnitude as the total system is amalgamated with the ecosystem. Analysis of sediment profiles at four tank cascade system north of Anuradhapura suggests that after the abandonment of the ancient capital Anuradhapura in the 11th century CE, which was a period characterized by socio-economic instability and increased climatic fluctuations, severe erosion did not affect the decentralize managed small tanks (Bebermeier et al., 2017).However, we could not find considerable studies on tank siltation in dry and intermediate zone in the country except the a simple study conducted by Dharmasena (1992). Therefore, we suggest a siltation study of tank cascade with geochemical analysis of silted layers.

Sediments reaching from the catchment reduce the water holding capacity of the tank and spoil the water quality. Because, these surface sediment has the capability in accumulation of heavy metals, acting as both sinks for and sources of pollutants (Santschi et al., 1997; Chen et al., 2016) while sediment itself is considered as a water pollutant. However, the strategies used by the earlier local people such as the constructions of *godawala*, *Thaulla*, *potawati* etc. may considerably trap the sediments thereby improve the water quality and quantity of the tank.

## 3. Water Quality of Tanks/ Wewa in Dry and Intermediate Zone of Sri Lanka

Bandara et al., 2008 reported higher concentration of Cd in some tanks in the north-central province in Sri Lanka such as *Kumbichchankulama* (0.05 mg/l), *Thuruwila* (0.06 mg/l), *Karapikkada* (0.06 mg/l). However, Chandrajith et al., 2011 found very low levels (average 0.004 µg/l ) of Cd in dry zone reservoirs located within the CKDu prevalent areas and also Diyabalanage et al. (2016) reported lower level of Cd ( average 0.216 µg/l) in six dry zone tanks. Moreover, Perera et al. (2016) analyzed the As and Cd concentration in water and sediments, as well as in fish tissues in *Malwathu oya* river basin upto *Nachchaduwa* in Anuradhapura district. Arsenic concentrations in the canals where water divert to the river from paddy land area ranged annually from 111 to 498 µg/L and Cd concentrations ranged from 76 to 245 µg/L while As and Cd concentrations in the upper *Malwathu Oya* (first 70 Km of the river) ranged from 1 to 48 µg/L and 1 to 134 µg/L respectively. They also found that both As and Cd concentrations were higher in paddy-area-sites than forest-area-sites and further, the mean As and Cd concentration in all sampling sites during first inter-monsoon and second inter-monsoon were higher than the recommended values (As, 10 μg/L; Cd, 3 μg/L) in drinking water proposed by WHO, 2006. Water of *Malwawthu Oya* is associated with the waters of nearby cascades such as *Ulagalla* cascade. These higher concentration of As and Cd indicates the excessive use of agro chemicals containing As and Cd and also malfunctions of the components of tank cascade system in the area. Further, As and Cd has shown to be factor for the genesis of CKDu.

Several studies reported the overuse of agricultural chemicals by farmers in many parts of Sri Lanka (Selvarajah and Thiruchelvam, 2007; Padmajani et al. 2014, Perera 2016). Most of the tanks in dry and intermediate zone of the country shows the signs of eutrophication. The $PO_4^{3-}$ concentrations of six tanks in *Mahakanamulla* cascade in Anuradhapura were greater than the EPA suggested critical value (0.08 $mgL^{-1}$) for the development of eutrophication (Wijesundara et al. 2014). However, nutrient accumulation ($NO_3$--N, $PO_4^{3-}$P and $K^+$) in *Thirappane* cascade in Anuradhapura showed higher concentration just after the fertilizer application for paddy cultivations in the area. Phosphate in drinking water is also a strongly Hofmeisteractive ion and regulatory authorities has not stipulated maximum allowable level in drinking water (Dharma-wardana 2017).

Higher concentration of nutrients lead to eutrophication of tanks and it results in reducing the biodiversity of the tanks. The destructive algal blooms resulted from eutrophication yield toxic substances that kill fish and cause disease in animal and humans (Schoumans et al., 2014). Cyanobacteria a kind of blue green algae grown in nutrient rich water and produce toxins that affect humans and animals. Impacts of extracts of cyanobacteria obtained from *Padaviya* reservoir and canals in Sri Lanka on mice fed by these extracts showed acute tubular necrosis in mice. These observations focused on cyanobacterium toxins as another potential nephrotoxin which may be a factor to cause CKD (Shihana et al., 2012). Sanjeevani et al., 2017 assessed the pollutants levels in agricultural areas in part of North Central Province (Madawachchiya-Ranorawa-Elayapattuwa-Hurathgama-Nawagattegama, central coordinates 8°17′35.43”N 80°14′24.79”E ) in Sri Lanka and found that soil in the area are uncontaminated to moderately contaminated of the elements such as Cu, Pb, Ni, Zn, and Cd. Further, they concluded that agricultural practices has a great impact on the level of Cd and Zn contamination in the soil. These findings further corroborate the importance of reestablishment of essential components of tank cascade system and devastating effects of excessive use of agrochemicals.

## 4. Conclusion

Etiology for CKDu in dry zone of Sri Lanka is multifactorial and is related to water. Use of mainly unfavorable ground water leads to CKDu. Ancient people in the CKDu prevalent area used surface water of tanks in tank cascade system. This review showed the diverse functions of the *Thaulla*, *wew ismaththa*, *kattakaduwa*, *godawala* etc. in relation to improving water quality. Concentration of some nutrients and metallic elements decrease when water flow through the *Thaulla* area of the tank. *Thaulla and wew ismaththa* were customarily conserved by the ancient people and flora and fauna in these areas considerably improve the water quality. However, at present, these components in small tanks are not present or their functions are ignored. Overuse of the agrochemicals are reported in crop lands and signs of eutrophication are observed in small tanks at present. The reconstruction of ecofriendly structural components of tanks and reestablishment of tank cascade system in the area would help to combat the spreading of CKDu in dry and intermediate zone of the country.

## 5. Suggestions

The tanks from which inhabitants of dry zone obtain drinking water need to be ecologically rehabilitated and cultivatio*n of Thaulla and wewismaththa* should be prohibited. Tree species such as*karanda (Pongamia pinnata), mee (Madhuca longifolia),* mat grass (Axonopus species), *ikiri (Acanthus ilicifolius), vetakeya (Pandanus odoratissimus)* etc. which are capable of trapping excess nutrients, pollutants and salts should be cultivated in *Thaulla and wewismaththa of the tanks.* Salt trapping trees and sedges should also be cultivated in *Kattakaduwa* area of the tank cascade system. Until the water in tanks are proved to be safe and devoid of toxic elements such as As and Cd, excess of Ca, Mg and $PO_4^{-2}$, good quality water should be made available. In this regard Reverse Osmosis plants, Rainwater harvesting may be used till the surface water is in good quality for drinking. It is also suggested to dedicate few more tanks with above mentioned ecosystem components to supply only drinking water for the public. Sri Lanka does not have formally approved water policy though it has been discussing since 1982 (IUCN, 2015). Sri Lanka needs a water policy formulation addressing the water quality issues and identifying the tank cascade system as a lifeblood of the dry zone rather than water of trans-basin water diversion system such as *Mahaweli* system. Components of the tanks need to be well delineated and recognized as vital areas in improving the water quality. Long term studies to test the water pollutant status of the entire cascade system is also suggested.

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