

Impact of changing agricultural practices on human health: Chronic kidney disease of multi-factorial origin in Sri Lanka

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Non-harmonious and unsustainable agricultural practices have major impact on the environment, causing animal and human diseases. Agriculture is an essential part of our lives. However, excessive use of agrochemicals, and irresponsible and harmful agricultural habits cause soil and water pollution, and secondary contamination of human food chain. Contamination of soil and water with toxic agrochemicals (e.g., phosphate fertilizer contaminated with heavy metals, pesticides and herbicides etc.) is a particular concern. These pollutants in water generally are in small quantities, and thus, cannot be seen or tasted. Therefore, their harmful effects do not manifest in humans for several years. During the past three decades, an escalating incidence of chronic kidney disease (CKD) of an unusual nature has manifested in agricultural dry-zonal areas in several tropical countries, including Sri Lanka, but no specific cause has been determined to-date. However, current evidence suggests that more than one component is involved in this geo-water-related preventable health epidemic; hence using the terminology, CKD of multi-factorial origin (CKD-mfo). Detrimental agricultural habits, including excessive and indiscriminate use of toxic agrochemicals, not using protective gear when using agrochemicals, drinking contaminated water from paddy fields and from contaminated shallow dugwells, and allowing continued environmental contamination, have led to the escalation of this deadly disease in these regions. The epidemic has detrimental effects not only on affected families, but also on the socio economic aspects of villages, the region, and the entire country. While providing clean water to villages, enhancing awareness and education, and preventing environmental pollution, each country that is affected with CKD-mfo (CKDu) must seek to identify and eliminate the root causes of the disease to prevent its progress, with a specific action plan to eliminate it. Unless corrective steps are taken in a timely and effective manner, the situation is likely to worsen drastically damaging their economies and the humanity. However, it is not too late to reverse this negative vicious cycle of death and destruction, and bring back prosperity to the region.

Key words: Renal failure, CKDu, behaviour, premature death, environment, heavy metals, fluoride, agrochemicals, agriculture.

INTRODUCTION

Worldwide, at least in part, water pollution and water scarcity are caused by the destructive deforestation by private entities and by governments, and other unscrupulous human activities. In addition to the above, the agricultural sector is one of the main culprits polluting the environment (soil and water) through agrochemical pollution, particularly by indiscriminate and over usage of chemical fertilisers, herbicides, and pesticides, and through poor animal husbandry practices (Rice et al. 2010; Sprague and Nowell, 2008; Wittmer et al., 2010).

The overuse of pesticides has led to virtually no living creatures in paddy fields.

Agrochemicals continue to leaching out to streams and shallow wells, contaminating drinking water sources in the areas affected by chronic kidney disease of multi-factorial origin (CKD-mfo) (Susset and Grathwohl, 2011; Thompson et al., 2009). Approximately 90% of the population in this region relies on wells and streams for drinking water. Nevertheless, because of widespread chemical pollution, people have no idea whether their

well water is safe to drink. This necessitates frequent, point-of-origin water testing in the region. In addition, some of the local streams and rivers are also polluted. Most of this pollution is attributable primarily to anthropogenic causes, including human and animal faeces, and agrochemicals pollutants (Burkart 2007; Rychetnik et al., 2002; Weber et al., 2011).

This article seeks neither to review past studies nor attempt to advance any fresh hypotheses concerning CKD-mfo. Rather, it examines certain changes that have occurred in the recent past in the dry-zonal areas in the country, with particular reference to agricultural practices and other habits and are likely to get worse in the future that adversely affecting the water quality and human health.

These acquired recent changes include the excessive and haphazard use of agrochemicals (Heckrath 1995; Wimalawansa, 2014), use of heavy metals in various substances (Ishaque et al., 2006), the decrease in forest cover, and continuing soil erosion and proliferation of toxic wastes, and others lead to a vicious cycle of water contamination. This article also makes suggestions for protecting water quality and water sheads to meet current and future needs.

Environmental pollution and the CKD-mfo

In addition to the soil erosion caused by deforestation and logging, reservoirs and streams are polluted with chemical fertilisers, particularly phosphate, and other agrochemicals (Cao and Kingston 2009; Lecours et al., 2012), heavy metals, and pollutants leaking into streams from the surface runoff from urban areas and from the upcountry wet zone (Jianguo et al. 2004).

Although the incidence of CKD is minimal in the hill country region in Sri Lanka, the farming methods used (e.g., in particular, potato farmers use up to 10-fold higher than the recommended amount of phosphate fertiliser) and soil erosion from that region lead to silting of reservoirs and dissemination of pollutants downstream, which flow to the reservoirs in the North Central Province (NCP) via the longest river in the country, Mahaweli River (Bandara et al., 2011; Wimalawansa, 2013). Considering overall scenarios, the natural and artificial water conveyance system diverting the water draining from the hill country to reservoirs in the NCP, mostly through the Mahaweli Rivervia, its diversion at the Polgolla Dam, may have played a role in the current incidence of CKD-mfo (Wimalawansa, 2013).

It is common for untreated sewage, industrial effluents, and agricultural wastes illegally and indiscriminately discharged into rivers, canals, and other water bodies. These actions endanger the health and well-being of those who live downstream use such waters for domestic purposes. Exposure to such polluted waters causes diarrhoea, respiratory infections, skin irritation and

diseases, and a variety of other diseases, depending on the pollutants involved (Emenius et al. 2004; Engvallet al., 2001; Sahlberg et al., 2009; Smedbold et al., 2001). The incidence of CKD-mfo continues to increase. However, whether this is due to increased awareness, the ability to diagnose early and in higher numbers, or a true increase in the incidence is not known yet (Wimalawansa 2013).

Although no direct links have established between the postulated chemical components and the CKD-mfo, many scientists suspect such links. One of the key requisite to overcome the CKD-mfo is the provision of accessible, affordable, and sustainable clean water supply for households within and near villages. This requires collaborative efforts among the government, private sector, and non-governmental organizations (NGOs) (Writing-Group, 1992), and providing villagers with the information and confidence to acquire and encourage them to use clean water in a consistent manner (Wimalawansa, 2013).

Many theories have been put forward to explain the aetiology of CKD-mfo, but none explains why some geographical areas only are affected, while other areas are spared, despite these different areas use similar quantities of agrochemicals and having similar water quality (Chandrajith et al., 2011; Wimalawansa, 2014). In areas within the same region and in other provinces with similar soil conditions, water hardness, and agrochemical usage, farmers are not contracting CKD-mfo (Chandrajith et al., 2011; Wimalawansa, 2013). Examples of such areas include Moneragala, Kebithigollawe, Kalpitiya, Bibile, Nuwara Eliya, and most areas in the Eastern Province.

Theories related to the presence of hard water and iconicity/salinity are plausible but do not explain why areas where both of these indices are higher than in the NCP, areas such as Jaffna, Matale, Dambulla, and Puttalam (Chandrajith et al., 2011; Wimalawansa 2014), do not have a high incidence of CKD-mfo (WHO-Group: Jayathilaka, 2013; Wimalawansa 2014).

People living in cities such as Anuradhapura and Pollonnaruwa, which have a pipe-borne clean water supply from protected reservoirs, do not have a high incidence of CKD, but surrounding villagers do even though their water supply originates from other partially protected reservoirs (Jayatilake et al., 2013). However, most city dwellers do not engage in farming activities, and thus, may not expose to the same adverse environmental conditions as farmers from the villages that are affected with CKD-mfo.

In contrast to the recent World Health Organization (WHO) CKD-report (WHO-Group: Jayathilaka, 2013), which suggests heavy metals are the cause of CKD-mfo, other data strongly suggest that the environment, soil, and groundwater are involved in this CKD epidemic in Sri Lanka (Chandrajith et al., 2011; Rajapurkar et al., 2012; Van der Hoek et al., 1998; Wanigasuriya et al., 2007;

Wanigasuriya et al., 2008; Wickremasinghe et al., 2011).

Other potential causes

In addition to improving overall health, cleanliness, and the dignity, improved sanitation facilities reduce diarrhoea-related deaths in young children by more than one half. If hygiene promotion is added, such as the provision of safe toilets, and teaching proper and regular hand washing, deaths can be reduced by two thirds (Curtis et al., 2009). These are not only applicable to the NCP, but for the entire Sri Lanka as well as other developing countries.

Such measures also decrease morbidity and mortality, accelerate economic and social development especially in countries where sanitation is a major cause of lost work and productivity (predominantly due to diarrhoeal diseases), and school and workplace absences (Shasha, 2005).

In agricultural production, pesticides are widely used to prevent or control pests, herbicides to control weeds, and fungicide, nematocide, etc. to control other plant pathogens; aiming to reduce or eliminate yield losses and maintain high product quality (Damalas and Eleftherohorinos, 2011; Rice et al., 2010; Wittmer et al., 2010). South-east Asian countries including Sri Lanka do not have appreciable amounts of genetically modified food, so such food is not a potential cause of the CKD-mfo.

Environmental protection agencies provide standards and regulate the amount of contaminants in water provided to the consumers by the public and private water systems. Some of these contaminants include microbial agents, such as bacteria and viruses that may come from sewage and treatment plants, septic systems, livestock operations, and wildlife (Casteel et al., 2006; Fransen et al., 1996). Other contaminants come from chemical pollutants. The cascade of event and chronological steps in the process of the development of CKD-mfo are illustrated in Figure 1.

The effects of CKD-mfo on rice sufficiency and the economy

Almost 2.0 million Sri Lankan farmers are engaged in paddy cultivation; the majority of them live in the NCP. Paddy farming occupies 34% (0.78 million hectares) of the total cultivated land areas in Sri Lanka. During Maha season (the rainy season in the country; October through January), approximately 560,000 hectares of paddy fields are cultivated. During the Yala season (dry season; April through August), the total is 300,000 hectares (total of 2,124,200 acres; or 86,000 square kilometres of paddy is cultivated. There cultivation together produces more than 2.5 million tons of rice, annually (Department of Agriculture data).

In the Yala season, the farmers have to depend on irrigation. Despite these efforts, the paddy shortfalls continue, necessitating importation of rice. Since the end of the war in mid-2008, the arable land has increased, so rice production is expected to rise.

Thousands of farming families in the NCP are affected by CKD-mfo, and the prevalence continue to increase. Consequently, even though more arable paddy lands are available, increasing numbers of farmers are not fully using their paddy lands because of CKD-illness. Therefore, in spite of the expected higher paddy production from the NCP, the overall yield is likely to decrease if the incidence of CKD-mfo continues to rise in the region.

Figure 2 illustrates an estimated annual paddy output, based on the above-mentioned assumptions, demonstrating the potential decline over the next three decades. Data in the figure take into account the increase of the paddy land availability for cultivation in the post-war era in Sri Lanka. The predicted paddy output data for the next three decades are presented in 5-year intervals, assuming the CKD incidence and death rate remain the same. Data presented in the figure, however, do not include the farmers leaving the NCP region because of the CKD-related deaths occurring in their families or due to the fear of death due to CKD-mfo. Once this exodus data are included in the equation, the rice output data are worse than those presented in Figure 2.

If these predictions become reality, it will be a socio-economic blow and will have a disastrous impact on rice sufficiency in the country, leading to major food shortages and forcing the government to increase rice importation, draining the precious foreign exchange. This phenomenon will escalate if farmers collectively decide to move out of the region to protect their families from CKD-related premature deaths (Wimalawansa 2013).

Changes of agricultural practices over the past three decades contributing to CKD-mfo

With the introduction of western technologies and escalating media advertisements, over the past three decades, agricultural methods and dietetic habits have changed (from sustainable, stable and healthy to unstable and unhealthy) in most developing countries (Vardavas et al., 2010). Sri Lanka is not an exception. At the same time, because of the never-ending demand and pressure to increase agricultural output and profits, farmers are pressured to increase their harvests by any means.

Starting in the mid-1960s, successive governments and the agricultural department have encouraged (by introduction of heavy subsidies) Sri Lankan farmers to use chemical fertilisers and pesticides. Instead of the natural harmonious methods, farmers have been using for centuries; they were encouraged to use chemical fertilisers and other agrochemicals (Krauss et al., 2011;

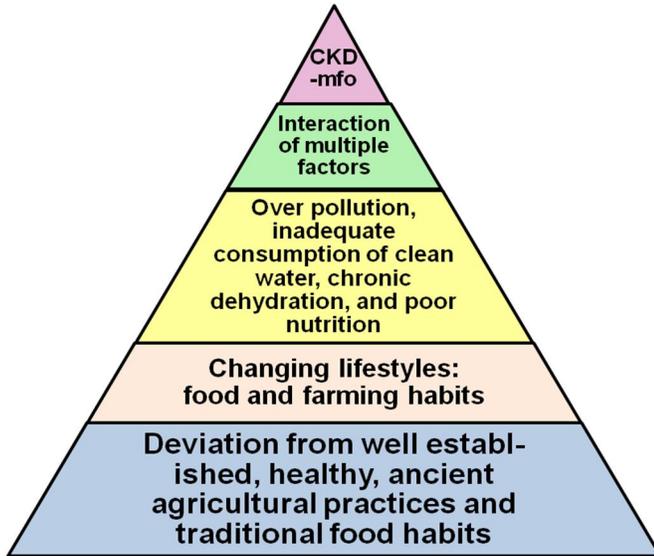


Figure 1. Cascade of events leading to the development of chronic kidney disease of multifactorial (CKD-mfo) origin in Sri Lanka.

Sarkar et al., 2011). Consequently, the traditional, environmentally friendly, sustainable agricultural methodologies that have used for thousands of years in the country gradually have been abandoned.

In fact, chemical fertilisers and agrochemicals, such as insecticides, fungicides, and herbicides, were given to farmers free of charge, four decades previously in Sri Lanka as well as other developing countries by agricultural departments through their extension officers. Once the farmers accepted their use, these agrochemicals sold at greatly subsidized prices to farmers without limitation in quantities.

With the newly introduced agrochemicals, harvests increased and farmers became accustomed to the higher crop yields, which eventually necessitated using more agrochemicals; thus, a vicious cycle of dependence was born. However, these procedures have become unsustainable environmentally and economically for the government, and are unhealthy for humans and animals.

Mostly for economic reasons, governments in many developing countries use the lowest bid for importation of agrochemicals, often while bypassing the required quality control measures. Exporters take advantage of this by shipping lower quality, contaminated fertilisers to these countries, that otherwise would be unmarketable elsewhere. Consequently, emerging economies purchase shiploads of poor quality (contaminated) fertiliser, which pollute the environment of the recipient country.

Both the normal use and overuse of these fertilisers continue to contaminate soil and drinking water sources. Consequently, some of the agrochemicals get into the food chain in land-based fisheries, rice and vegetable crops, and thus, eventually into humans. Many of these

contaminants, once entered into the human body, remain for long periods, irrespective of the age of the consumer. Some of these agrochemicals are fat-soluble and thus, can accumulate in the body's fat stores, and constantly released back into the blood stream, continually exposing human organs to these toxins. However, it is unclear how these toxins affect human health in the long term (Lorgelly et al., 2010).

More is not always better

There is no doubt that the excessive use of artificial, chemical fertilisers and other toxic agrochemicals is not healthy for the ecosystem, environment, or human beings. Farm soils and water in reservoirs are contaminated with chemicals, particularly phosphates because of the excessive use of phosphate fertilisers. These soil and water conditions continue to cause significant environmental damage leading to unintended consequence; decreases of inland fishery and agricultural output. It is important to realise that the agricultural output does not linearly increase with the increased use of agrochemicals (Figure 3).

In fact, the authors' observation is that after a certain threshold (as with any other businesses), agricultural output plateaus or start to decrease mainly because of imbalanced and worsening soil conditions. Despite this, many farmers continue to use excessive amounts of chemical fertiliser and other toxic agrochemicals (pesticides and weedicides) with the false expectation of continuation of higher crop yields. In the hill country of Sri Lanka, as in Nuwara Eliya, farmers who grow potato use as much as ten times than the amount of phosphate fertiliser recommended by the department of agriculture and the manufacturers. In contrast, in the NCP, rice and vegetable farmers useless, but still more than the recommended amounts of fertiliser.

There has been speculation that the herbicide glyphosate contributes to CKD-mfo (Jayasumana et al., 2014), but there is no scientific evidence for this (Multiple-Authors 2014). The use of some herbicides is particularly high in both tea and rubber plantations (two crops that bring foreign exchange to the country), to control weeds. Unfortunately, such excess use of chemical fertilisers has become a practice in farming communities throughout the country, causing water pollution, and contamination of fruit and vegetables. The authors postulate that this might have a link to the current epidemic of CKD-mfo in the country.

Agriculture-related pollution

Modern agriculture is dependent on agrochemicals to produce the world's food demand, despite the potential negative effects of such chemicals on human

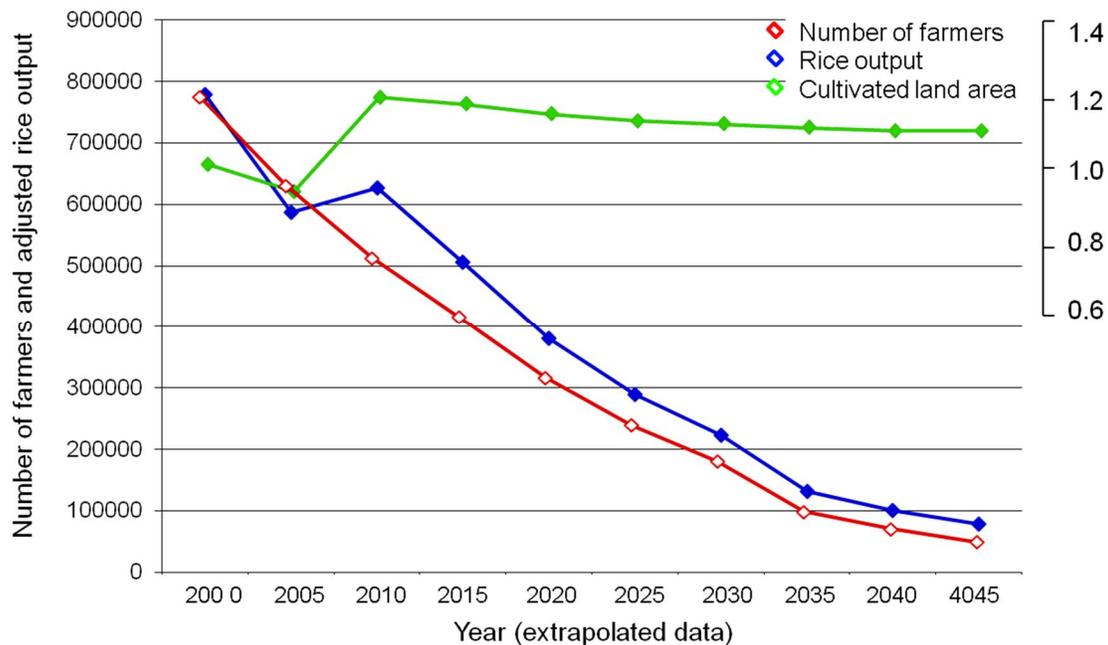


Figure 2. The estimated paddy output over the next three decades (data derived from the estimated number of farmers available, multiplied by the variance of hectares of paddy land, with the year 2000 considered as 100%). The assumptions include the potential increase of paddy cultivation in the post-war era in Sri Lanka since 2009 and the current death rate attributable to CKD-mfo among farmers in the NCP, extrapolated for the next 30 years. For easier understanding, the predicted (hypothetical) data set is presented in 5-year intervals. However, the data set presented does not include the number of farmers potentially leaving the NCP because of fear of death caused by CKD-mfo.

health and the environment. Agrochemicals and petrochemicals are well-known sources of environmental pollution and serious contenders for contributing to the development of CKD-mfo in Sri Lanka and elsewhere. In the future, large-scale settlement projects, such as Mahaweli project in Sri Lanka, which have the objective of settling people, should be critically evaluated in advance, and steps must be taken to minimize long-term, negative environmental and human consequences.

Unfortunately, the main beneficiaries of past projects have now become dependent on unsustainable practices, including the massive fertiliser subsidies. In addition to polluting the environment by mishandling agrochemicals and their containers, most farmers do not use protective gear and thus, expose themselves to higher levels of toxic chemicals (Figure 4). Some of these chemicals likely enter into the human bodies, absorbed through the skin, via inhalation, and through the oral route via the gastrointestinal tract with contaminated water or food.

Approximately 3.5% of the national governmental budget in Sri Lanka currently spent on agricultural subsidies; approximately 50 billion rupees per year. A gradual reduction of this expenditure, of 10% per year, starting in 2014, is reasonable. Issuing fertilisers based on soil requirement, would facilitate achieving the goal of a 10% yearly reduction. In addition, releasing fertilisers to farmers based on judicious soil analysis

recommendations alone, would reduce fertiliser consumption by an estimated 15% to 25%. Moreover, the authors estimate that with this measure alone the government would save 3 to 5 billion rupees per year on fertiliser subsidies and avoid these expenses.

The effects of deviating from the traditional agricultural practices, irrigation, and land preparation

Rajarata (NCP), with its ancient hydraulic civilization, continues to produce half the required amount of rice for the country. A vast, well-designed, interconnected irrigation network had been used successfully for hundreds of years in Sri Lanka, generating a prosperous and sustainable economy with thriving fauna and flora (Wimalawansa, 2013).

Ancient agricultural systems had successfully produced rice for centuries using environmentally healthy irrigation system, making the country self-sufficient in rice. However, after the adoption of new methodologies, the ancient agricultural practices, including the reliance on cascade tanks and the use of animal manure and compost in the fields, have been gradually replaced. To keep agricultural production high while minimising environmental harm, the authors recommend the use of hybrid agricultural methods that employ traditional and

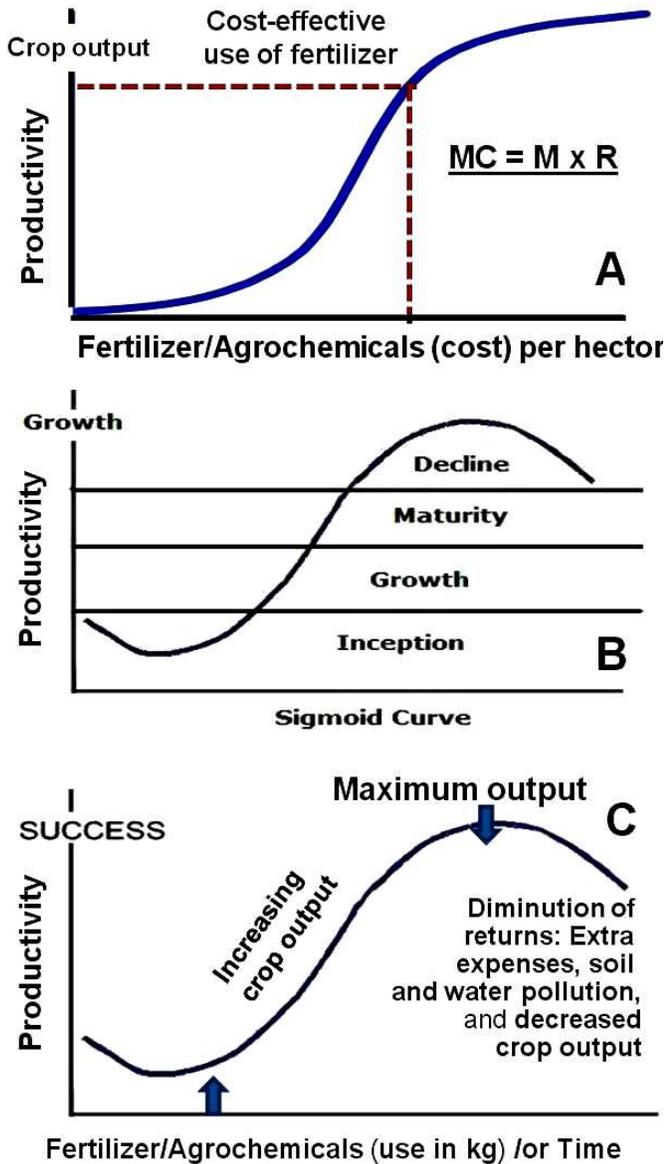


Figure 3. (A) Classic curve of diminution of return with increasing investment. (B) The reality curve—productivity declines with the over usage of fertiliser. (C) A generic productivity curve that is applicable to the use of all agrochemicals in agriculture, and also for the animal husbandry.

new methods to improve production.

Other environmentally sustainable farming practices include multi-cropping of organically grown nourishing food varieties and the use of varied landscapes, such as growing crops under the canopy of natural forests, traditional versions of shifting chena cultivations, crop rotations, and the use of wetlands, and so forth. Such practices also provide healthy bio-diverse spaces for livestock and other living beings.

It is time the country adapted these environmentally healthy sustainable agricultural systems, not only to



Figure 4. The need of education and the necessity of providing protective gear to farmers during toxic agrochemicals application.

improve the environment, but also to increase long-term enhanced agricultural output and for the benefit of healthier future generations. Currently, the development of water resources to maximize the cultivable areas and increase crop output from the irrigated agriculture is measured only in conventional economic terms.

Consequently, attempts to maximise these returns in the long term are done, at the expense of unsustainable environmental damage and the consequent ill health of humans and animals. On the other hand, some of the traditional methods used, such as manual scraping of weeds with *mammoties*, especially in tea plantations, led to excessive soil erosion. Once this practice was replaced with using herbicide, glyphosate (Smith and Oehme 1992), the soil erosion was markedly subsided. If such chemicals are removed from the market, there are no equally effective and less toxic herbicides available.

Therefore, planners must consider continuing with the best, safe, and the most cost-effective practices of the new technologies, and combine these with the best of ancient agricultural methodologies to harmonize and increase the agro-output in a safe and sustainable manner.

Pesticides, herbicide and other chemicals

Over the past four decades, chemical pesticides and herbicides have been freely available over the counter in the country, with no controls or restrictions of quantities one can purchase. In fact, in many villages these highly toxic agrochemicals are sold through grocery stores,

stored alongside with foods (Taylor 1999; Wimalawansa, 2013).

With time, the availability of extension advisory services provided by the Department of Agriculture has dwindled and been restricted to the interprovincial areas. Although the provincial departments of agriculture and the Mahaweli Authority are supposed to provide extension advisory services to farmers, these services are notably inadequate. Such deterioration of services is not unique to Sri Lanka and is observed in other Asian countries. Meanwhile, the sales-driven, attractive promotional strategies of the agro industry continue, with little attention given to educating farmers on how to use the products safely and effectively, while protecting themselves. These factors may also have contributed to the CKD-mfo epidemic among farmers.

The global pesticide market is approximately US\$ 44 billion in 2012 (Group, 2011). Most pesticide companies are also associated with the global seeds market, plant biotechnology, and the selling of herbicides (Network, 2013). It is a market that geared to sell packages of products that are inter-dependent.

It is time for trans-national corporations operating in developing countries to collaborate with the departments of agriculture and environmental protection agencies to do what is right for these countries; put forth resources for educating farmers on correct and safe practices, and provide them with protective gear. Such joint efforts would minimize misuse of agrochemicals, decrease costs, increase crop yields, and restore the safety and self-confidence among farmers in the business, and sellers of these products. These different lines of action would synergise the goal of eliminating agrochemical-associated environmental pollutions and chronic disease, including CKD-mfo.

Pesticides and herbicides mostly come from agriculture (Damalas and Eleftherohorinos, 2011) but may also come from other sources, including residential and urban uses, and storm water runoff (Belden et al., 2000; Chen et al., 2005; Liess et al., 2013; Meyer et al., 2011; Rice et al., 2010; Wittmer et al., 2010). In this regard, it is necessary to minimise the use, not only of agrochemicals but also household and industrial chemical cleaners, insecticides, and so forth (Lee and Maheswaran 2011; Nice 2008).

Considering these multiple factors contributing to the environmental pollution, it is important to educate the end users, of safe use of all agrochemicals and disposal of leftovers and empty containers. Such efforts would likely to reduce the agrochemicals entering into the food chain through careless human handling, waste products, and improper disposal of empty containers.

The role of herbicides

Research has shown the herbicide Propanil and

insecticide chlorpyrifos to be in higher-than-expected amounts in water sources in affected agricultural areas worldwide (Baumgarten et al. 2009; Eddleston et al., 2002; van der Hoek and Konradsen 2005), but other researchers have disputed these findings.

Broadleaf herbicides with auxin hormonal properties have some toxic effects on humans (Miller et al. 2003; Tanney and Hutchison, 2010; Wright et al. 2010). Long-term exposure to higher intakes of Propanil and chlorpyrifos, whether through drinking contaminated water or absorption through the skin, potentially can cause liver and kidney disease. It has been suggested that the systemic herbicide glyphosate also causes CKD-mfo (Jayasumana et al., 2014), but no scientific data provided nor available to support it. Moreover, the cases of CKD-mfo have been reported in Sri Lanka since mid-1990. Whereas, glyphosate was first introduced for paddy cultivation in the NCP only in early 2000, making this proposed hypothetical connection most unlikely.

Glyphosate [N-(phosphonomethyl) glycine, the key ingredient in the herbicide Roundup] is one of the most commonly used herbicides in the world. Small quantities of glyphosate have been detected in some water sources and soil samples (Mink, 2011), which are well below the potential toxic levels. The maximum permissible levels of glyphosate stipulated in the European Union and United States is 0.2 and 0.7 ppm, respectively; the reported levels of this chemical in water is far below these amounts.

Glyphosate tightly binds to soil, making insoluble complexes, which prevents it leaking into water sources (Larsen et al., 2012; Mink et al. 2011; Mink et al., 2012; Shipitalo et al., 2010; Yu et al., 2005). If entered via the oral route, it avidly binds to divalent and trivalent cations in the gastrointestinal tract preventing its absorption. Therefore, it is not absorbed in great quantities in humans (Freuze et al., 2007; Gonzalez-Martinez et al., 2005). Because glyphosate is a phosphonic compound, its oral absorption (as with other phosphonic acids and phosphonates) is very limited. It also tightly binds to calcium ions in food, within the gastrointestinal tract, further decreasing its absorption.

Many of pesticides and herbicides, including glyphosate and its main metabolic product [amino-methylphosphonic acid (AMPA)], when absorbed are detoxified via the enzyme CYP450 system as they pass through the liver, and excreted mostly via bile but small quantities also excreted via urine (Franz 1997; Fujita et al., 2001). Thus, even if it gets absorbed, the concentration of glyphosate or its complexes is inadequate to harm kidneys.

Moreover, no epidemiological study have reported long-term exposure with glyphosate, in the amounts recommended and used by farmers, causing any form of kidney disease in humans (Kimmel et al., 2013; Mink et al., 2011; Mink et al., 2012; Williams et al., 2012). None of the published literature to-date, suggests, such small

quantities of glyphosate have negative effects on human kidneys or causing renal failure (Mink, 2011; Williams et al., 2012; Wunnapuk et al., 2014). Worldwide, after extensive investigations, scientists have failed to link glyphosate with CKD or CKD-mfo (Kimmel et al., 2013; Larsen et al., 2012; Mink et al., 2011; Mink et al., 2012; Mink 2011; Williams et al., 2012; Wunnapuk et al., 2014).

Ironically, many dangerous pesticides and herbicides banned in Western and industrialized countries ended up in emerging markets because of a lack of import safety regulation and quality control inspections (Pellow, 2007; Tynaliev, 1993).

Thus, these chemicals and toxins are concentrated in the agricultural sectors of the receiving countries and eventually end up in the food chain. The latter includes the products exported back to the countries from which contaminated fertilisers were originally exported from. Therefore, these manmade chemicals eventually affect everyone on the planet.

Overuse of low-quality chemical fertilisers

The large-scale use of imported, poor-quality, triple superphosphate fertiliser and other toxic agrochemicals has made the situation worse. Triple superphosphate (TSPs) and single superphosphate fertilisers (SSP) (Topcu et al., 2003), muriate of potash (potassium chloride), pesticides, herbicides (Zejda et al., 1993), and imported low-quality fertilisers have complicated and enhanced the environmental contamination in Sri Lanka. One such example is the low-quality fertiliser that is imported from Eastern Europe, thought to contain high levels of contaminants, including heavy metals (Gutierrez et al., 2008; Ishaque et al., 2006), cadmium, arsenic, and lead (Company et al., 2008; Mitra et al., 2009), and is considered a major source of soil contamination in developing countries.

Because of the terrains of the CKDu-affected countries and communities are flat, these containments remain in the soil for decades. On the other hand, because of the high subsidies for fertilisers, farmers overuse of these products and use them haphazardly with the misguided assumption that increasing fertiliser usage will continue to enhance agro output (Wimalawansa, 2014) (Figure 3). They also have the incorrect assumption that no harm is done to themselves, others, or to the environment by over-using agrochemicals.

Therefore, it is essential (A) to impose strict quality control measures on all imported fertiliser and pesticide shipments (Wimalawansa, 2014); (B) that stringent checks of locally produced agrochemicals before these chemicals are allowed into the market; and (C) to educate farmers in the correct use of agrochemicals. It is ironic that industrialized or economically advantaged countries do not allow importation of such contaminated material, yet allow dumping of these “waste” materials into developing countries, sometimes using

intermediaries to bypass hurdles (Anyinam, 1991; Kim et al., 2013; Needhidasan et al., 2014; Wong et al., 2007).

Overuse of fertiliser in Sri Lanka

The observed differences in CKD-mfo prevalence in the NCP cannot be explained by any one of the pollutants postulated to be the cause at the levels at which they occur and reported to-date. Nevertheless, pollution of drinking water and food secondary to environmental contamination and farmers being excessively exposed to agrochemicals has become common in the NCP and elsewhere in the country.

Currently, Sri Lankan farmers use around 600,000 tons of solid fertilisers and 250,000 tons of liquid fertilisers annually (data from the Department of Agriculture). The current fertiliser used in Sri Lanka include approximately 300,000 tons of urea, 120,000 tons of TSPs, 150,000 tons of muriate of potash, 50,000 tons of ammonium sulphate, and 50,000 tons of TSP from Eppawala apatite. Fertiliser use in the three largest provinces in Sri Lanka is as follows: NCP, 130,000; North Western Province, 96,000; and Eastern Province, 100,000 hectares.

Figure 5 illustrates the quantities of chemical fertiliser used in Sri Lanka in 2012, in comparison with a few other Southeast Asian countries. Sri Lanka uses more phosphate fertilisers and certain other toxic agrochemicals than any other country in the Southeast Asia (World Bank, 2013).

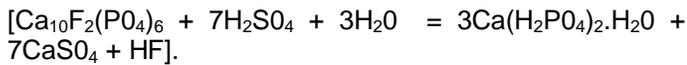
However, other countries, including Bahrain (uses 1,950), Brunei (uses 575), China (uses 548), Egypt (uses 605), Malaysia (uses 1,096), New Zealand (uses 1,272), Singapore (uses 3,131), and Trinidad (uses 660), use much more fertiliser on a per-hectare basis than does Sri Lanka (World Bank, 2013), but do not have CKD-mfo-like disease (the numbers illustrated in parenthesis are the fertiliser consumption, kilograms per hectare of arable land). Considering these data, the overuse of agrochemicals alone seems unlikely to be a cause for the development of CKD-mfo in Sri Lanka.

Issues associated with phosphate fertiliser

Phosphate fertilisers are either water-soluble or relatively water insoluble. Examples of water-soluble phosphate fertilisers are TSP (mono calcium phosphate), which has higher amounts of phosphate. The relatively water-insoluble rock phosphates (calcium fluo-apatite and calcium hydroxy apatite, as present in Eppawala phosphate deposits), which are SSPs.

The fertilisers TSP and SSP have inherent contaminants, such as heavy metals, cadmium, and arsenic. In addition, recent reports suggest that TSPs distributed to farmers may also contain other impurities, including uranium (Chandrajith et al., 2005). Because of their insolubility in water, these phosphate complexes

have to be acid solubilised before generation of SSPs. The equation for this chemical reaction is provided:



Irrespective of the type of phosphate, the excess fertiliser applied to soil leaches into surface water runoff and groundwater, eventually leading into major rivers, water diversions, and reservoirs.

This is particularly a problem with reference to the excessive fertiliser use in the hill country, where fertiliser eventually drains via the Mahaweli River into reservoirs in Rajarata. If agrochemicals have a part in causing the CKD-mfo, within the next few years consequences similar to those seen in NCP are likely to manifest in the Sabaragamuwa and the Southern regions that drain these agrochemicals via the River Walawe, particularly into the Udawalawe region.

In contrast, excess fertiliser that drains into other larger rivers in Sri Lanka, such as the Kalani and Kalu Rivers, flows directly into the sea (Wimalawansa, 2014). Thus, it may not have direct negative health consequences due to agrochemicals in people living downstream areas of these two rivers. These pollutants affect not only the fauna and flora in the rivers, but also the marine life in the canals and reservoirs, disrupting the entire eco-equilibrium (Krauss et al., 2011; Nair 2011; Paez-Osuna, 2001; Sarkar et al., 2011).

The role of contaminated phosphates fertiliser

In general, most phosphate deposits and thus phosphate fertilisers are naturally contaminated with heavy metals. Chemically, phosphate molecules can be attracted to arsenate and cadmium cations, among others, so these heavy metals tend to accumulate with phosphate compounds, because of their chemical behaviour.

Varieties of imported TSP fertilisers have reported to contain between 30 and 50 ppm of arsenic and between 8 and 12 ppm of cadmium (but some consignments are known to contain even higher amounts). Meanwhile, the phosphate deposits from Eppawala contain between 15 and 25 ppm arsenic and between 3 and 8 ppm cadmium, but compared to other phosphates, these contaminations are relatively low (Bandara et al., 2011).

In addition, excess nitrates and phosphates decrease the amount of oxygen dissolved in water, in reservoirs. Moreover, the excessive amounts of these components in water promote the growth of unusual algae; some of these can be potentially harmful to fauna, flora, and also perhaps to humans. This ecological imbalance is affecting the whole environment and all life forms in the area, and may contribute to the already polluted water-soil system before entering into the human food chain (Chandrajith et al., 2005; Chandrajith et al., 2011; Dissanayake and Chandrajith 2007).

Country	Fertilizer consumption (kg/hectare of arable land)
Sri Lanka	284.3
Bangladesh	164.5
Pakistan	163.3
India	153.5
Bhutan	9.0
Nepal	7.7

Figure 5. Annual chemical fertiliser usage in Southeast Asian countries in 2013—fertiliser consumption, kilograms per hectare of arable land; data source (WorldBank 2013).

Excessive use of phosphate fertiliser and soil poisoning

As a result of the overuse of subsidized low-quality TSP and the locally produced SSP, many of the Sri Lankan farm soils are now polluted. In addition, the runoff draining from these farm soils into reservoirs have excessive amounts of nitrates. Despite these, since early 2013, the agriculture department has been promoting the sales of locally produced, SSP fertilisers. Moreover, these have been distributed to farmers without any soil testing or a scientific research.

Considering the excessive phosphate levels in farm soil and in reservoir waters in the NCP, there is no rationale to flood the soil with extra phosphates using either TSP or SSP. Thus, recent initiatives to enhance the locally produce and market SSPs, seem short-sighted. With current farm soil conditions, fertilisers should contain the minimum necessary, not maximum allowable amounts of phosphates.

Much needs to be done to educate the manufacturers and farmers, and to improve their awareness of toxic agrochemicals, soil conditions, and the consequences of environmental pollution. In this regard, the Department of Agriculture has fiduciary responsibility; therefore, it must take proactive steps in this regards.

Other less known causes that may contribute to CKD-mfo

A key issue with many of the theories about the role of heavy metals, hard water, fluoride, and agrochemicals is that none of these explains why only specific geographical areas are affected by CKD-mfo and others are not (Chandrajith et al., 2011; Gutierrez et al., 2008; WHO-Group: Jayathilaka, 2013). Tobacco is a rich

source of arsenic and cadmium. Beyond the Manampitiya Bridge in the NCP region, there are large plots of lands grown over several miles in the embankments of Mahaweli River. These tobacco plantations are continually irrigated using water from the Mahaweli River (leftover water after the Mahaweli River diversion at Polgolla) that itself is concentrated with pollutants, including chemicals that originate from river catchment areas.

Tobacco grown in these local areas contains higher-than-average amounts of arsenic and cadmium; this locally grown tobacco is readily accessible to the population across Rajarata. Thus, the farmers who smoke these tobacco products (exclusively by males), commonly using homemade cigarettes (“beedi”), and also may consume contaminated illicit liquor that contains heavy metals and are likely to be at a higher risk for CKD-mfo.

In addition, some of the recently introduced pesticides, such as neonicotinoids, are incorporated into plants and crops and thus, may directly contaminate the food chain (Obana et al., 2003; Seccia et al., 2008; Wang et al., 2012). The new habit of spraying fruits, vegetables, and grains before and after harvesting with chemicals, pesticides, and preservatives, including carbofurans and anthracols (Jung et al., 2003), needs to stop.

Exposure to toxic contaminants and the effects on the kidney

It has been suggested that ingestion of certain toxins, heavy metals, chemicals, and ionic components may lead to various cancers (Ames and Gold 1990; Gutiérrez et al., 2008; Landrigan and Garg, 2002; Zejda et al., 1993); endocrine-related effects on reproduction, development, and metabolism (Hoekstra et al., 2006; Meeker, 2010; Zhang et al., 2012); and immunological abnormalities (McBride et al., 2005; Organization, 1987).

Data indicate that the cardiovascular system is a critical target of metal toxicity and that actions of toxic metals on the cardiovascular system (Kaji 2004) may intercede cardiovascular deaths (Prozialeck et al., 2008). Others have postulated that such agents negatively affect both blood vessels and the heart, leading to heart diseases, atherosclerosis, and premature deaths (Ritz and Yu, 2000). Consequently, those with CKD-mfo not only suffer from the cardiovascular disorders, but also may die from these associated serious illnesses.

It is possible that the constant long-term exposure to combination of some of these chemicals and toxins even at lower doses, leads to glomerulo-tubular damage, which proceeds to protein leakage from kidneys and kidney failure (Howie et al., 1989; Weber et al., 1989). However, despite 10 years of local research, there is no consensus or scientific proof of heavy metals, fluoride, agrochemicals, hard water, ionicity, fertilisers, or any combination thereof being directly linked as the cause of CKD-mfo (WHO-Group: Jayathilaka, 2013; Wimalawansa, 2013).

Conclusion

By definition, no synthetic agrochemicals are 100% safe (Wimalawansa, 2014). Therefore, these chemicals must be used judiciously in appropriate amounts recommended by the manufacturers and the Department of Agriculture, based on the soil conditions.

In this regard, it is necessary to establish a strong institution, or expand the services of the Department of Agriculture and/or Environmental Authority for regularly soil and water analyse for the presence of agrochemicals; fertiliser components and pesticides. It should mandate that such data be published quarterly, with annual compulsory reporting to the Parliament, on the country-wide information relating to environmental pollution.

Rajarata, with its ancient hydraulic civilization, continues to produce half the required amount of rice [the staple food of the country] for Sri Lanka. A vast, well-designed, interconnected irrigation system with canals and reservoirs successfully used for hundreds of years in the NCP, generating a prosperous, healthy, and sustainable economy over hundreds of years.

Nevertheless, in the past five decades, farmers have adopted modern agricultural methods and deviated from established healthy traditional practices. The multitudes unhealthy agricultural habits that they have implemented are harmful to themselves as well as the animals (Wimalawansa, 2013) and that have increased health risks (Sexton and Hattis, 2007).

Examples include, but are not limited to, unprotected ways of handling and spraying toxic agrochemicals, eating and drinking while using these toxic products, drinking water directly from the paddy fields while spraying chemicals, storing agrochemicals with food in the same room in their homes, and dumping empty chemical containers into streams, etc. (Belden et al., 2000; Chen et al., 2005; Meyer et al., 2011; Rice et al., 2010; Wittmer et al., 2010). All of these actions adversely affect the health of humans and animals.

Another neglected area is the high level of exposure to petrochemicals that are discharged from agricultural equipment. Farmers routinely clean their agricultural equipment including tractors in any water sources that they can access including canals and reservoirs.

Some farmers even discharge used oil into streams, canals, and reservoirs, wherever is convenient to them. There is no control of this dumping, and the spills are not cleaned up. Ultimately, these chemicals find their way into drinking water sources and into the human food chain. One cannot imagine that such environmentally detrimental practices would not come back to harm the population.

Good governance is essential to ensures sustainable and equitable use and distribution of water, and to securing effective delivery of water supply and having good sanitary facilities. However, good governance is not possible unless all stakeholders of the society are allowed to engage and contribute to the decision-making

processes. Clear political commitments, integrity and transparency in the water sector, together with sharing of public information and education are key to improving the stability and the transparency in the water sector, minimizing pollution, and eliminating CDK-mfo.

In addition, the country needs to design and implement a national, forward looking water policy that integrate corruption risk assessments, sound policies that establish mechanisms for the provision of water distribution equity, legislation, and strict implementation of laws. These tailored designs and implementation of nationwide diagnostic studies to identify water integrity risks and to prepare and implement fair and sustainable national water action plans would assist development of a sustainable and fair water management system in the country and minimising water-related diseases.

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For the past 15 years, SJW has been studying issues related to water contamination, environmental pollution, escalating chronic diseases, particularly CKD-mfo in Sri Lanka and elsewhere. He is also involved in the provision of education and clean water supplies to various remote villages (www.wimalawansa.org).

Conflicts of interest

The authors have no conflicts of interest.

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Abbreviations used:

- CKD = Chronic kidney disease;
CKD-mfo = CKD of multifactorial origin
NCP = North Central Province;
WHO = World Health Organization
TSP = Triple superphosphate;
SSP = Single superphosphate fertilisers