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Agrochemical-Related Environmental Pollution: Effects on Human Health

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Abstract

An unpolluted environment is essential for optimum human health. Water polluted with microbes causes noticeable diarrheal diseases, whereas chemical and toxic contaminations make people acutely or chronically sick and kill insidiously. Contamination of soil and water through human and industrial waste and agrochemicals is a universal problem and a major issue in developing countries, where the difficulties are attributable in part to lax environmental laws. Unrestrained industrial and domestic waste in urban and rural situations and pollution of reservoirs caused by agrochemical runoff are an increasing concern. Deforestation and consequent soil erosion further aggravate these issues. Massive contaminations such as oil spills are visible, and the deleterious effects are immediate, but microbial and chemical contamination of water in most circumstances is subtle, and it may be years before people realise their water supplies are contaminated and are adversely affecting human health. Misuse of agrochemicals is a key cause of pollution of potable water, reservoirs, and watersheds. The misuse is mostly attributable to irresponsible behaviour of farmers and agrochemical sellers, and large government fertiliser subsidies that incentivise fertiliser overuse; these are fully preventable. To prevent environmental pollution and occupational diseases, proactive preventative actions are needed, including preserving the environment and enforcing appropriate laws.

Key words: Agriculture, Agrochemicals, CKDu, Behaviour, Heavy metals, Fluoride, Premature death, Renal failure

1. Introduction

Water pollution creates a vicious cycle of contamination of the human food chain. Water and food are interlinked and difficult to separate. Many communicable and non-communicable human diseases are related to water, soil-geochemistry, and environmental pollution. There are a numerous examples of environmental pollution leading to epidemics of serious human disease (1-5).

Excessive use of agrochemicals is a major source of water contamination, especially in agricultural regions in developing countries where environmental laws are lax. When any one of the three main plant macronutrients (nitrogen, phosphorus, and potassium) is lacking in the soil, crop productivity is limited. As a result, these three ingredients in the requisite proportions are frequently added into commercial fertilisers.

However, plants can absorb only limited amounts of these macronutrients from the added chemical or composed fertiliser. With rain, the excess fertiliser in the soil leaches into streams and ends up in distant locations, including reservoirs. Therefore, the recommendations for fertiliser applications and their use should be based on actual crop-soil requirements. However, such soil testing or information is not readily available in farming areas in most developing countries. Consequently, farmers are using quantities of fertiliser blindly and excessively, wasting resources and polluting the environment, with the expectation that more is better, which is not the case (6). This leads to under- and over-fertilisation of agricultural fields. For example, phosphate is one of the most commonly used components in chemical fertiliser mixtures (7) and the one most abused by farmer in some regions. Excessive use of phosphates has led to hyper-eutrophication of phosphate (and in certain instances nitrates as well) in canals and reservoirs (8-11).

1.1 Water cycle:

The provision of and access to water depend on multiple factors, including locality, geographical distribution and terrain, water quality, method of distribution, cost, affordability, and policies and politics. The distribution of water also has to be tied to an understanding of groundwater and surface water management, as well as drainage systems.

The groundwater table fluctuates and is dependent on the pattern of rain, regolith and ground cover. For example, large storms result in an increase, although temporarily, of groundwater in the upland and wells, whereas drought does the opposite. In addition to rain, water supplies are based on the availability of an adequate amount of forest (particularly in the highland), ground cover, and ground conditions to retain rainfall waters, as well as the rate and frequency of the rainfall. Forest, ground cover, and evaporation rates affect the absorption of water into the ground and thus the retention of water after precipitation; an alteration of any of these could negatively affect the entire water cycle.

Ongoing climatic changes and alterations to any of the above-mentioned items will continue to have adverse effects on the water cycle (12). Because water quality changes within a short distance even within a local area, conclusions based on inadequate sampling or sporadic analysis of water samples (13-15) can be misleading. Thus, it is risky to draw conclusions and make extrapolations based on such analytical data from random water samples (irrespective of how good the analysis is) and apply such conclusions to an entire region or correlate them with a particular illness or disease.

2. Water Pollution Due to Agrochemical

2.1 Large governmental subsidies encourage irrational use of phosphate fertiliser:

Chemical fertilisers increase crop yields up to a threshold. Over-fertilisation beyond this will not further increase agro output (6). Because of the initial increase in agro output, farmers get hooked into using chemical fertilisers and other toxic agrochemicals. This is in part attributable to the false expectation of "more is better" (6). As an incentive to use more to increase agricultural output and as a political manoeuvre, most governments have introduced large-scale fertiliser subsidies for farmers at the expense of taxpayers. "Most farmers who do not pay taxes exploit this situation" by using more than the recommended amounts of fertiliser (6) and vehemently object to losing government subsidies.

On one hand, subsidies assist and encourage farmers, but on the other hand, the resultant over-use of fertiliser burdens the taxpayers, drains the foreign exchange and national budget, and causes environmental pollution. A healthy balance is necessary between these two extremes. The choice for governments is to continue the status quo, getting into greater debt and increasing the environmental harm, or change policies for the good of the country and the well-being of its citizens. However, the political consequence of decreasing agro subsidies often prevents politicians from making the right decision.

Farmer education and training via an extension service is the most effective means of creating the awareness and understanding of right and responsible fertiliser use. With proper education, farmers are likely to accept a reduction in subsidies for their own good. One of the easiest and most productive ways to decrease the over-use of fertilisers by farmers is to issue fertiliser based on soil analysis and estimated crop output data (16, 17). By doing so, farmers will be benefited by (A) the need for less fertiliser and thus decreased cultivation costs, and (B) the decrease in environmental damage and the associated potential health hazards to the entire community. The use of the correct quantity of nutrient-balanced fertiliser should enhance crop output. Crop output could further increase with the use of new, hybrid, naturally pest-resistant crop varieties (18). Most importantly, decreasing chemical fertiliser use will reduce fertiliser costs to farmers, reduce public health risks, and morbidity and premature mortality, thereby decreasing health care costs and increasing savings for the government and improving the country's foreign exchange reserves.

2.2 Excess use of phosphate fertilisers:

Phosphate fertilisers are either water-soluble or relatively water insoluble. An example of water-soluble phosphate fertiliser is triple superphosphate (mono calcium phosphate, commonly referred to as TSP). Relatively insoluble phosphates are rock phosphates (calcium fluorapatite and calcium hydroxyapatite) (18, 19), which require solubilisation of phosphates through chemical reaction before its use (6).

In each country, the relevant agricultural institutions provide recommendations for the correct amounts of fertiliser to be used, based on field experiment data, costs, and returns. However, because of high subsidies (in some countries, fertiliser is subsidised as much as 90%) and the consequently cheap price, many farmers are tempted to use higher-than-recommended amounts of fertiliser, particularly phosphates (and in some instances, nitrates) for certain crops (6). Most farmers believe that the higher use of fertiliser will generate more crop output but are unaware or neglect that their actions damage the environment and potentially cause human ill health. Such ignorance and neglect lead to serious pollution problems and manifestation of human and animal diseases.

2.3 Potato cultivations and the excessive use of phosphate fertiliser in Sri Lanka:

Potatoes are grown successfully year-round at high elevations. In most developing countries, potatoes are grown in the mountainous areas in temperate climates. In Sri Lanka, potatoes are grown in the central region of the hill country, around Nuwara Eliya. Despite the fertiliser subsidy, import restrictions and governmental taxes keep the prices of locally grown potatoes artificially high. However, recently a project was launched to grow seed potatoes in dryer areas in the low country, such as in Jaffna and Puttalam, during the cooler months, which should decrease the cost of seed potatoes.

These favourable conditions encourage potato cultivators to overuse fertiliser in the hill country, using as much as 10 times the recommended quantity of phosphate fertiliser (6). Recent Department of Agriculture (DoA) soil analyses in the hill country revealed that in more than 70% of farms, soil phosphorus levels are in excess of the agronomic critical level, and more than 50% had soil phosphorus levels exceeding the environmental critical level (DoA data).

Adding phosphate beyond the agronomic critical level is economically wasteful and environmentally harmful. Because the hill country is subjected to frequent rain, excess phosphates and other agrochemicals continually leach into the waterways and end up in water bodies. Consequently, many of the reservoirs at lower elevations, particularly in the rice-growing regions in the North Central Province (NCP), experience eutrophication (8, 20) and frequent algal blooms (21).

Despite the high cost of good quality seed potatoes, which currently cost more than Rs. 300,000 per hectare, the crop remains a highly profitable investment in Sri Lanka. With such high initial investment, understandably, potato farmers want to maximise their profits and crop yields. Thus, farmers use excessive amounts of fertiliser indiscriminately because the fertiliser is inexpensive to them because of the government subsidy (20). The excessive use of phosphates is a futile attempt to increase output because all plants, including potatoes, have a limited capacity to absorb the nutrient phosphorus. Such excess only increases costs, wastes taxpayers' money, and pollutes the environment (6).

2.4 Consequence of discharging excessive amounts of plant nutrients into water:

Some of the issues related to ongoing over-usage of agrochemicals in the hill country have been discussed previously (22, 23). In addition to phosphate, nitrate fertilisers (including organic material) are discharged from these farm soils into water bodies but in lesser quantities (7, 10). Excess phosphorus and nitrates leach from farm soil into streams and end up in the lower regions, including the NCP via the diversion of water from the River Mahaweli, causing algal blooms in reservoirs in the region that are most affected by chronic kidney disease of multi-factorial origin (CKD-mfo) in Sri Lanka.

These excess nutrient loads (eutrophication) in the water alter the natural vegetation (20), fauna and flora (24, 25), and lead to surfeit of algal growth (26-28). At times, such algal bloom not only discolours reservoir waters but also makes water relatively unsafe for human consumption (10, 16, 21). With reference to CKD-mfo, researchers have looked at several algal, bacterial, and fungi toxins in the region (29, 30). Compared with the phosphates in fertiliser, the amounts of pesticides and herbicides in the region's water are miniscule and mostly unmeasurable. Unlike plant macronutrients, these

chemicals are unstable and degradable, and unlike fertiliser, they are used in relatively small quantities. Considering these facts, unlike phosphates, very little pesticide or herbicide (in fact, the quantities are unmeasurable in water) ends up in downstream water and reservoirs in the NCP.

3. Commonalities of the CKD Problem in Other Agricultural Societies

A similar phenomenon seems to be happening in other equatorial countries where the CKD of unknown aetiology (CKDue/CKDu) is prevailing. These episodes of unusual chronic kidney diseases have been reported in a number of Central American countries, including Nicaragua (31) and El Salvador (32, 33), and other parts of Mesoamerica (34), as well as in China (35, 36), southern Europe (37, 38), and India (39). Although there are differences in crops and the quantities of agrochemical use in these regions affected by CKDu, some commonalities exist, including dryer climate, prolonged droughts, lower socio-economic status, poverty, insufficient access to health care, harsh working and living conditions, lower levels of education, and poor quality drinking water.

It is not necessarily the farmers who pollute the water bodies with phosphates (potato and vegetable farmers who are the primary polluters of phosphate in the hill country) who are affected with this deadly disease, but those who live hundreds of miles downstream in the NCP in Sri Lanka. Paradoxically, the true victims are the innocent residents—mostly the farmers living in the NCP. In fact, despite gross over-usage of agrochemicals, no case of CKD-mfo has been reported among the residents in the hill country, where most of these fertilisers are used.

Unfortunately, because of the lack of awareness, the desire to generate higher yields, and the highly subsidised fertilisers, farmers continue to overuse these chemical agents, particularly in the hill country. These activities may bring health hazards to the residents in the dryer and relatively flat regions in the country, the NCP. It would not be surprising if such a scenario eventually led to social unrest on a large scale.

4. Water Pollution Due to Non-Fertiliser Components

Broadleaf herbicides 3,4 DPA and 2,4 D, both of which are phenoxy herbicides with hormonal properties, are known to have some properties that are toxic to humans (40-42). Glyphosate [*N*-(phosphonomethyl)glycine is one of the most commonly used herbicides worldwide and is sold under a variety of trade names. The maximum permissible levels of glyphosate in water within the European Union and United States are 0.2 and 0.7 ppm, respectively. Small quantities of glyphosate have been detected in some water sources and soil samples in Sri Lanka (43), but the levels are well below the Environmental Protection Agency (EPA)-stipulated standards.

There are no scientific data to confirm measurable levels of glyphosate or any other herbicide or pesticide in water bodies, including reservoirs in the NCP, nor do scientific data support glyphosate causing kidney failure in humans (43-49). However, there are data on harmful effects of ingestion or exposure to large amounts of concentrated glyphosate, as in suicide attempts (48, 50, 51). These harmful effects include death, potential carcinogenicity, and endocrine disruption (49, 52-54); however, the levels causing these effects are several times greater than those to which paddy and vegetable farmers are exposed during their routine cultivation practices.

Within the first few inches of the soil, glyphosate binds tightly to soil and clay making insoluble complexes, which prevents its leaching into the water table. Glyphosate avidly binds to cations and clay particles, inactivating and making glyphosate insoluble, and it is degraded gradually by soil microbes; thus, in comparison to most other pesticides and herbicide, glyphosate is safer for the environment (48, 55). Moreover, glyphosate interferes with the synthesis of the aromatic amino acids phenylalanine, tyrosine, and tryptophan (working as an anti-metabolite), starving plants to death. It does so by inhibiting the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), which catalyzes the reaction of shikimate-3-phosphate (S3P) and phosphoenolpyruvate to form 5-enolpyruvyl-shikimate-3-phosphate (ESP). This enzyme system is not present in other living beings; thus, glyphosate action is highly specific to plants (56), and as a herbicide used at the recommended doses glyphosate does not kill animals or humans.

Like other agrochemicals, glyphosate has some toxic effects, but compared with other commonly used pesticides and herbicides, it is a relatively safe compound. Nevertheless, no agrochemical is totally safe. In this regard, we need to recall the wise words of the father of pharmacology, Professor Bombastus Paracelsus: "all substances are poisons, there is none which is not a poison; it is the dosage and the exposure that differentiates a remedy from a poison."

Organochlorine compounds that are found in pesticides include dichloro-diphenyl-trichloroethanes (DDTs), hexachlorobenzene (HCB), hexachlorocyclohexanes (HCHs), and polychlorinated biphenyls (PCBs) (57-59). Repeated exposure to excessive quantities of any of these agents without protective gear can lead to bio-accumulation of the compounds in muscle and fat tissues; in addition, the chemicals are difficult to rid from the body (60). As with chemical fertiliser, some farmers use higher-than-the-recommended amounts of pesticides and herbicides. Because these are not subsidised (or at least not to the same extent as fertiliser), there compounds are abused less. However, when these agrochemicals are used at the recommended quantities with protective gear, there is no evidence of toxicity to humans (18).

4.1 Water pollution from sewers and livestock:

Untreated sewage, industrial effluents, and agricultural wastes discharged into rivers, canals, and other water bodies endanger the health of those who consume such water. Some of these contaminants include microbial agents, such as bacteria and viruses that originate from sewage and treatment plants, septic systems, livestock operations, and wildlife, and may cause dangerous health conditions to humans (19, 61).

Exposure to microbe-polluted waters causes acute and chronic disease, including diarrhoea, respiratory infections, skin irritation, and several other diseases, depending on the type of pollutants involved. Meanwhile, whether the reported increasing incidences of CKD-mfo in Sri Lanka and other countries is caused by escalating environmental pollutants (19, 62), increased awareness, or a true increase in the incidence is difficult to recognise (63). Although no direct links have

been established between these pollutants and chronic kidney disease, many scientists speculate that one exists (13, 14, 64-67). Figure 1 illustrates a number of causes and their interactions leading to contamination of the environment.

< Figure 1 >

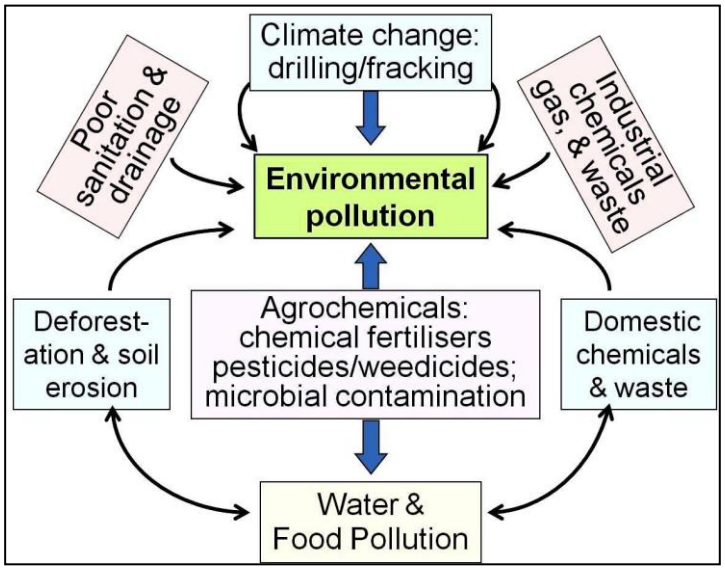

Figure 1: Environmental pollution is a complex problem. Contamination of air, soil, and water results in pollution, which causes numerous human and animal diseases and leads to premature deaths.

4.2 Population growth and environmental pollution:

The world population is more than 7.0 billion; if the current growth rate continues, world population could reach 10 billion in 2050. Thus, discussions about and actions concerning protecting the environment, sanitation, potable water, and food security must include strategies on how to accommodate or control population growth. In addition, it is necessary to consider continuingly shifting demographics and climatic changes in all new human settlement during the planning stages. This should encompass not only food and water security, but also cost-effective ways to supply clean water and safe sanitary facilities to increasing numbers of households while keeping the environment clean.

The United Nations Conference on Environment and Development at Rio de Janeiro in 1992 declared that countries should promote appropriate demographic policies to assure a higher quality of life for all people (68). A national consensus on policies regarding this issue in many developing countries and emerging economies, including Sri Lanka, is long overdue (6).

What usually is ignored are the consequential quantities of waste and toxic products and chemicals generated in households and from industry, both of which continue to increase with the population explosion (69). As the population increases, the quantities of waste products also increase. Unless countries have the built-in capacity and effective methods to handle the waste products, they inevitably will harm the environment.

4.3 Rapid economic development, changing lifestyles, and the environmental stresses:

Opening new lands for agriculture, coal-powered electricity plants, irresponsible disposal of mercury-carrying fluorescence (CFL) bulbs, batteries containing heavy metals, the use of gasoline-guzzling automobiles, and various types of mining all systematically contribute to environmental contamination. According to the 2001 Blacksmith Institute of New York City Report, lead poisoning from mines is one of the biggest polluting events in the world (70, 71). Recycling is in its infancy in most emerging economies, so governments need to invest in recycling, encourage recycling, and develop relevant legislation to incentivise, support, and sustain it.

In addition, de-sedimentation or dredging of reservoirs and canals re-exposes centuries of deeply deposited toxic products and heavy metals and returns them to the water system (19). The sediments have settled for thousands of years without disturbance, and dredging brings them back to the water bodies and the food chain (6). Considering these factors and the over-exploitation of natural resources, the ethics and human values associated with these issues need to be examined to protect the next generation.

4.4 Climate change, deforestation, cultivation on sloping terrains, and soil erosion:

Nowadays, a cloudy or muddy river is a common sight, which reflects the degree of deforestation and forest degradation, mining, and environmentally harmful farming activities occurring upstream (72). When the tropical forests are replaced by cash crops or degraded pasture, there is an increase in surface temperature and a decrease in evapo-transpiration and precipitation, leading to local climatic changes, including the length of the dry seasons (73). Moreover, these tropical deforestations play a key role in the build-up of greenhouse gases, adding to climate change and associated problems (74). Forests are environmentally valuable assets and remain critical for climate change mitigation (75).

High-intensity, sporadic rains leading to floods and droughts, in part because of climate change, increase soil erosion, especially from sloping lands and those without adequate vegetative cover. In addition to the erosion of highly fertile topsoil, such water prevents penetration of light to billions of aquatic organisms and causes injury to fish and other aquatic living beings. Lost topsoil may take hundreds of years to re-form. Major climate changes and the unpredictable weather patterns of recent years have made these problems worse (Figure 2).

< Figure 2 >

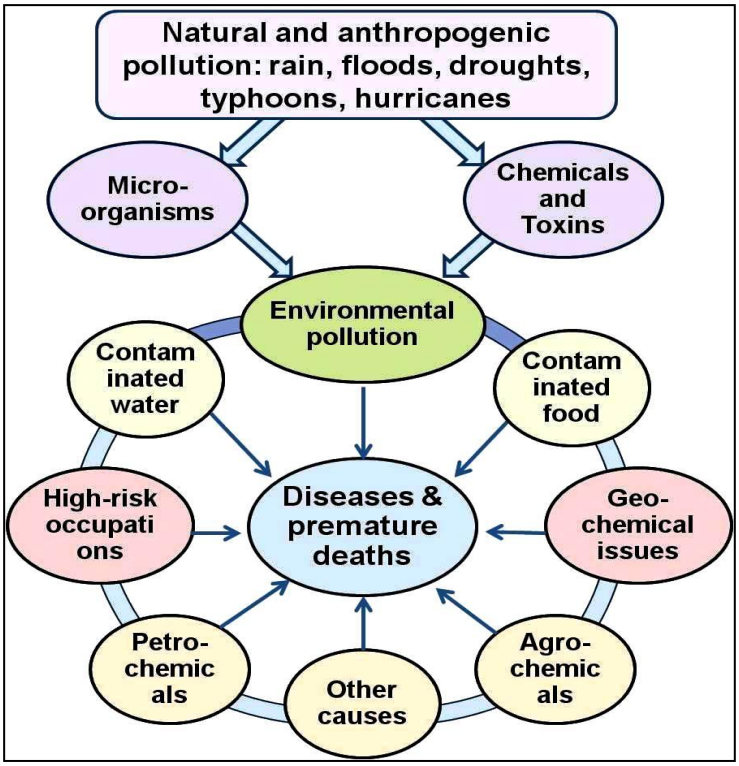

Figure 2: Climate change, deforestation, excessive use of agrochemicals, and other manmade contaminations are responsible for the vast majority of environmental pollutions.

5. Socio-Economic Impact of Water and Soil Pollution

Soil erosion and runoff from exposed sloping lands continue to pollute rivers, reservoirs, and groundwater, and bring sickness, premature deaths, economic calamity, and grief to communities through no fault of their own. Most of the time, people affected are those who live hundreds of miles away from the sites of pollution and polluting acts. Overall, the damage done via pollution to socio-economic situations and health is enormous and cannot be measured merely in financial terms.

In addition to enforcing environmental protection laws, proactive actions are needed to preserve the vegetative cover in all sloping lands. Shortcuts taken by farmers and governments alike, including illegal construction, deforestation, planting, and constructing in protected nature reserves (all of which are done for short-term financial gain), will cause harm for generations to come. Protection of the environment is the right of those living today and those yet to be born. Therefore, those who continue to harm the environment, even those who happen to be governmental authorities or politicians, must be exposed and brought to justice to protect future generations. Governments must get their policies and fundamental action plans right with regard to these issues and ensure strict enforcement of the laws, without any exceptions, related to the prevention of environmental pollution.

6. Modes and Issues Related to Water Contamination

Many people judge the quality of water by how it is supplied (by public or private water systems; tap water or bottled water, etc.), its taste, odour, and appearance. However, the risk to one's health cannot be judged by any of these factors. Most toxic chemicals or biological organisms that affect human health cannot be seen, tasted, or smelled; these assessments require specialised testing.

The groundwater table fluctuates depending on the farming season, water utilization, rains/flooding/droughts, and agricultural practices; in addition, the timing of water sampling for analysis may lead to seeming fluctuations. The soil water content also is affected by groundwater extractions, including the use of tube wells for domestic and agricultural purposes. Monsoon rain and intermittent storms could result in temporary replenishment of the groundwater table and wells, whereas flooding causes contamination of many water sources, including dug wells.

In agricultural areas, water can be contaminated with microbes (such as *Escherichia coli*, salmonella, parasites, or toxic algae); toxic heavy metals, such as lead, cadmium, or arsenic; fluoride; or various toxic agrochemicals (the herbicide propanil or the insecticide chlorpyrifos), and so forth (57-59, 76). Most of these are anthropogenic, man-made contaminants. This is in part due to (A) lack of understanding, education, greed, and lack of concern about others and the environment; (B) importation of cheap, contaminated fertilisers (i.e., the dumping of toxic material into developing economies); (C) inducement by importers, middlemen, and profit makers for their own personal gain and commissions, and (D) encouragement of excessive use of fertilisers because of the high fertiliser subsidy. Nevertheless, in some situations the groundwater is naturally contaminated, as in the case of fluoride and arsenic pollution, as in some deep tube wells.

Mechanical drilling and hydraulic fracturing (fracking) and the use of coal-powered power plants add to the misery of air, water, and soil contamination (Figure 2). The cumulating pollutants continue to aggravate acute and chronic human diseases, particularly non-communicable chronic health problems, including CKD-mfo (77, 78). The latter mostly affects people in the dry zonal agricultural regions in economically poor, equatorial countries. The NCP region in Sri Lanka fits

into this category. For the past two decades, this disease was limited to the NCP, but it has begun to spread to other areas in the country (13, 14, 19). The prevalence is doubling every three to four years (19).

6.1 Critical issues related to the pollution:

Most larger organizations concerned with clean water worldwide focus on water sterilization methods to remove or destroy microorganisms, which is relatively easy. However, globally a third of the water-related deaths and approximately half of the disease burden can be attributed to poisoning from chemicals and toxins—i.e., non-microbial contaminants. These organic and inorganic pollutants cannot be filtered or removed by boiling, traditional filtering, or sedimentation. Therefore, heavy metals, toxins, and agrochemicals are not only difficult to detect in water, but also hard to remove without using sophisticated methods.

In the absence of the provision of safe potable water to communities, inhabitants have to rely on contaminated water, which at times may cause serious illness and premature death. In addition, the incidence and the prevalence of CKD-mfo are under-estimated. Moreover, many CKD-mfo–related deaths are mistakenly attributed to other disorders. This mislabelling of the cause of deaths is in part attributable to the lack of facilities and medical expertise necessary to make the correct diagnosis, and in part to avoiding the societal stigma (79) (usually at the request of relatives) that is increasingly attached to CKD-mfo. Therefore, death registries have become unreliable in identifying the true cause of deaths caused by water pollution or CKD-mfo, so mortality associated with CKD-mfo is further underestimated.

People in affected areas suffer not only from chronic diseases such as CKD-mfo but also from other undiagnosed, non-communicable chronic disorders that affect the heart, liver, and brain. The latter includes behavioural and mental health problems and lower intelligence quotient caused by heavy metals such as lead (80) and possibly fat-soluble toxic agrochemicals. Children and pregnant women are the most vulnerable. Therefore, provision of cost-effective and efficient water purification methods and point-of-testing methods for drinking water are paramount for reducing morbidity and mortality in these vulnerable populations.

6.2 Safe water required for all living beings, not only for humans:

Providing clean water for areas affected by CKD-mfo remains a priority. However, clean water also is needed for animals and plants, and this need must be met. In the areas affected by CKD-mfo, as a stopgap measure, adequate numbers of reverse osmosis (RO) plants (81) could be installed to provide safe drinking water to humans, but irrigation and well water may continue to contain higher concentrations of potentially harmful substances that eventually enter the human food chain via plants, meat, and fish. Unless attitudinal and behavioural changes occur, people will continue to pollute the environment, which emphasises the importance of education.

In some areas, many marine animals including fish have high concentrations of mercury and cadmium, which contaminate the human food chain. One well-studied example of the poisoning of people by the consumption of mercury-contaminated fish occurred in and around Japan's Minamata Bay in the 1960s. Water that was contaminated with mercuric oxide was discharged from a plastic and chemical plant to the restricted ocean bay; the contamination led to a large number of deaths associated with mercury poisoning (82, 83). Therefore, vigilance and proactive preventative steps are essential prerequisites to maintaining a safe environment and human health. The solution lies in keeping watersheds and water bodies free from harmful contamination with pollutants. Doing so is the responsibility of everyone and costs much less than cleaning the mess and treating affected people after the fact.

7. The Way Forward

7.1 Current realities and strategies to purify water and protect the environment:

Most of the water filtration systems remove particulate matter by a mechanical process, sequestering dirt. Some other methodologies, such as nano- and ultra-filtration, remove bacteria, viruses, and particulate forms but not the inorganic molecules, heavy metals, fluoride, and other smaller dissolved molecules and toxins. Home water filters sold in areas affected by CKD do not have the capability to remove potential toxins and chemicals effectively. Because contaminants that cause CKD-mfo potentially include agrochemicals, heavy metals, and fluoride in dissolved forms, filtration devices, including low-capacity activated carbon-based filters (with a limited capacity to adsorb chemicals), are ineffective in removing contaminants (62), and thus no better than a placebo. Using other traditional methods, such as rice husks, moringa powder, broken pieces of bricks, or clay, has some potential to "adsorb" some contaminants, but the capacity is too small to be used effectively. Thus, most home water filters are inefficient, and few families actually use them even when they are provided free of charge (personal observation). Thus, none of the home water filters available can be recommended to generate clean water to alleviate CKD-mfo in this region. Such filters provide a false sense of security to the consumers without decreasing the risks or incidence of CKD-mfo.

Boiling water or the use of hypochlorite or ultraviolet light can effectively eliminate microorganisms, but no such economical method is available to remove dissolved inorganic and organic contaminants. To overcome this issue, a novel "out of the box," cost-effective method of water purification and point-of-care testing is needed. The reverse osmosis method, commonly used in the West, is one such highly effective, but relatively expensive, way to purify and generate safe, potable water (81).

Alternative options include provision of clean water using routine transportation of clean water to villagers for domestic consumption, rainwater harvesting, and identification of safe sources of water, such as natural springs within the local areas, supplying bottled water, and desalination. The provision of sterilisation tablets and chemicals, using water pots, the use of domestic water filters, the use of ultraviolet and solar power for elimination of microorganisms, and digging wells and deep tube wells will not remove the potential contaminants that may cause the CKD-mfo. Except for tapping water upstream, rainwater harvesting, the use of locally available natural spring water, and the use of reverse osmosis to generate clean water locally, other methods mention above are either too expensive, unsustainable, or add to the environmental damage.

To prevent water pollution, many countries have introduced various legal instruments, including (A) mandatory soil testing of farmlands once every five years; (B) a period of mandatory fertiliser use embargo (i.e., prior to rain), (C) annual mandatory filing of plant nutrient management by farms; (D) prohibition of growing annual crops in lands with high slopes (soil conservation); (E) monitoring and reporting of water quality by the water authorities to the parliaments at specified intervals; and (F) elimination of phosphates in laundry detergents, etc. Figure 3 illustrates the complex interactions between the environment, social needs, the economy, and public policies.

< Figure 3 >

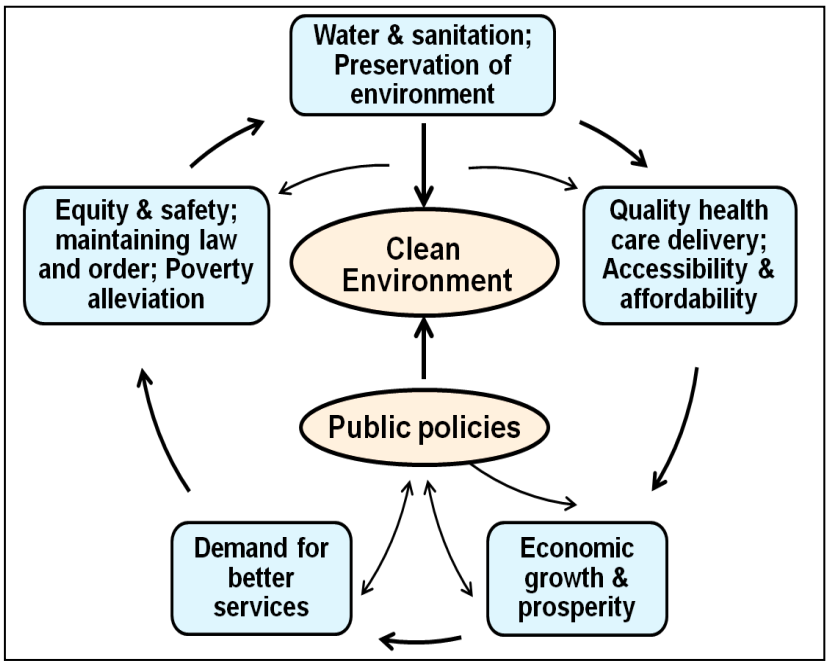

Figure 3: The synergy between public demand and key interactions among various components that influence public health and affect human diseases. Correct public policies and law enforcement (e.g., environmental protection) necessary to keep a positive cycle of healthy environment, clean water, and optimal health of the population are important.

7.2 The past and the future; health of the nation:

Comparisons have made between new large-scale irrigation engineering projects and the ancient irrigation systems that have been described as "water and soil conservation hydraulic-ecosystems" (84). The ancient irrigation and the ecosystems based on thousands of networks of gravity-driven canals and small tanks were the heart of village-based human settlements for thousands of years (85). It is essential to revitalise the neglected network of small tanks scattered throughout the NCP; doing so would lead to social and economic empowerment of villagers in a sustainable manner. In addition, enforcing environmental laws is critical to the prevention of the current exacerbation of pollution and associated health problems.

If the people in the NCP (also known as Rajarata–Kingsland) opted to move elsewhere due to the panic of deaths caused by CKD-mfo, it would markedly affect not only rice production but also the economy of the entire country. This was what happened hundreds of years ago, when South Indian invaders destroyed large reservoirs in the region; rulers then were unable to get the reservoirs repaired promptly because of a lack of cooperation from the public (85). This led to abandoning the region (i.e., Rajarata) because of rampant epidemic malaria. A voluntary trend has already begun in relocating some affected families out of the NCP. Unless the government takes prompt, fair, and effective actions to control the environmentally induced, occupational disease of CKD-mfo, the history is likely to repeat. The government has the fiduciary responsibility to prevent such a disaster.

7.3 Lack of Consistent National Water Policy:

Sustainable water policy in a country must include prevention of water pollution and waste, the ability to recycle water, and ways of working and living that balance the immediate needs for commerce, living, habitation, food, transportation, energy, and entertainment. The lack of such a comprehensive policy would have profound negative impacts on the ecosystem and humans (22). Nevertheless, planning must also account for the future needs of resources, as well as a sustainable livelihood of the current and future generations (86, 87). However, the policy must encompass environmental conservation and preservation of all natural resources (88-90).

Provision of clean water and a national water policy should be at the heart of reconciliation and ethnic harmony (90). A country must have a master plan for water; the lack of such in the longer-term is suicidal for the country. This global plan must incorporate water and food security; equitable distribution of freshwater for domestic, industrial, and commercial uses; irrigated water; prevention of contamination; and environmental protection (91). However, the plan must be fair and just, and attention and priority must be given to optimising human health (12).

For long-term success and sustainability, it is important that the central government maintain the control of managing water bodies, with operations delegated to municipalities but with full accountability. Deviation from the master plan with regard to water distribution should not be allowed, and steps must be taken to avoid harmful water management practices. The provision of safe, clean water and sanitation will not only benefit human health and humanity but also increase ethnic

and regional harmony, and the prosperity and survival of life on earth. A government cannot abandon its responsibility and accountability with reference to water, sanitation, and food security.

8. Conclusions

The water retention in catchments depends on the availability of forest and the ground cover, soil conditions, erosion, and the intensity of rainfall. Thus, proactively preserving these is important. Climatic changes are affecting the pattern of rain and drought. However, the global effects of the climate change are seen not only in rising sea levels and temperatures, but also in unusually high levels of ultraviolet radiation in certain parts of the world, which may cause cancers, cataracts, and immune system damage and increase incidences of infectious diseases (92, 93). All of these can interact with the environment and aggravate human and animal health conditions.

Achieving the provision of clean water to households within and between villages in the CKD-mfo–affected region requires collaborative efforts among the government, private sector, and nongovernmental organisations. For such efforts to be successful, the provision of accurate and honest information and the development of confidence to acquire and use clean water by the villagers are required. To date, there is no trend of or encouragement seen with reference to active collaborations and partnerships between the public and private entities or with the philanthropic sector in preserving the environment, education, provision of clean water and sanitation, or controlling agrochemical-induced water contamination. Governments must take the leadership in this regard and proactive steps to preserve the environment as a key means to preventing escalating non-communicable diseases.

All countries need to adopt, introduce, and enforce environmental protection legislation. Successful implementation of these proactive, effective preventive methods is a major step toward the maintenance of a healthy environment, national reconciliation, and sustaining ethnic harmony and optimising human health in a given country, including Sri Lanka. Nevertheless, provision of basic human needs, such as water, sanitation, food, and education, must be devoid of conflict of interests and political interference (which are major obstacles in most emerging economies); these basic human needs must be made available equitably to all in an affordable manner.

Making politically motivated decisions without considering scientific data, long-term consequences, or common sense would not only lead to further environmental instability, but also would expose the country to unwanted intrinsic unrest and open to new security threats. Environmental protection agencies should provide guidance and standards, while making all governmental officials and politicians accountable for their actions or inactions. The environmental protection agency, in collaboration with other entities, must regulate the amounts of contaminants in water provided by both the public and private sector and make clean water available at an affordable cost for all citizens. However, whether these standards are actually enforced depends on the administrators, politics, and policies of an individual country.

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References

1. Kolpakova AF**.** Role of environmental pollution with heavy metals in chronic pulmonary diseases pathogenesis in North regions. Med Tr Prom Ekol. 2004(8):14-9.
2. Muller M, Bartsch P**.** Environmental diseases, diseases of the 21st century? II. Asthma and atmospheric pollution. Rev Med Liege. 1997;52(12):768-75.
3. Orlandella BM, Foti M, Orlandella V, Daidone A**.** Environmental pollution and infectious diseases. I. Isolation of a new serovar of the Salmonella genus, S.V 13.22:r: from a Periplaneta americana cockroach. G Batteriol Virol Immunol. 1994;86(1-12):101-15.
4. Trakhtenberg IM, Faktorov IE, Verich GE**.** Industrial and environmental chemical pollution as risk factors for cardiovascular diseases. Gig Sanit. 1984(9):61-5.
5. Deleanu M, Lenghel I, Zubac I**.** Data regarding the incidence decrease of some diseases under the conditions of urban environmental pollution reduction. Sante Publique (Bucur). 1981;24(2-3):239-48.
6. Wimalawansa SA, Wimalawansa, S.J**.** Impact of changing agricultural practices on human health: Chronic kidney disease of multi-factorial origin in Sri Lanka. Wudpecker Journal of Agricultural Research. 2014a;3(5):110-24.
7. Li QH, Xia PH, Wu H, Lin T, Zhang YC, Li CX, et al. Eutrophication control in local area by physic-ecological engineering. Huan Jing Ke Xue. 2012;33(7):2303-8.
8. Carpenter SR**.** Eutrophication of aquatic ecosystems: bistability and soil phosphorus. Proc Natl Acad Sci U S A. 2005;102(29):10002-5.
9. Jia H, Cheng S, Ding J, Li J**.** Relationship between eutrophication control and reservoir operation. Huan Jing Ke Xue. 2001;22(4):104-7.
10. Lewis WM, Wurtsbaugh WA, Paerl HW**.** Rationale for control of anthropogenic nitrogen and phosphorus to reduce eutrophication of inland waters. Environ Sci Technol. 2011;45(24):10300-5.
11. Nagarajah S, Emerson,B.N., Abeykoon,V., Yogalingam,S**.** Water quality of some wells in Jaffna and Kilinochchi with special reference to nitrate pollution. Tropical Agriculturist. 1988;144 61-78

12. HDR-2013 U. Beyond scarcity: Power, poverty and the global water crisis. Human Development Report-2013; 2013.
13. WHO-Group: Jayathilaka N MP, Mendis S, Mehta FR, Dissanayake LJ, Janakan N. . Investigation and evaluaiton of chronic kidney disease of uncertain aetiology in Sri Lanka (Final Report). In: Organization WH, ed. http://www.lankaweb.com/news/items12/WHO%20final%20report%20on%20CKDu%20SL.pdf. Colombo, Sri Lanka; 2013.
14. Wanigasuriya KP, Peiris-John RJ, Wickremasinghe R. Chronic kidney disease of unknown aetiology in Sri Lanka: is cadmium a likely cause? BMC Nephrol. 2011;12:32.
15. Jayatilake N, Mendis S, Maheepala P, Mehta FR. Chronic kidney disease of uncertain aetiology: prevalence and causative factors in a developing country. BMC Nephrol. 2013;14(1):180.
16. Wimalasurendre C, Amarasiri, S. Scientists warn of time bomb: Phosphate and algae boom in reserviours in Sri Laka, http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=90856. 2013.
17. Wimalawansa SA, Wimalawansa, S.J. Escalating incidence of chronic kidney disease of multi-factorial-origin (CKD-mfo) in Sri Lanka and its long-term consequences. Scandinavian Journal of Work, Environment & Health. 2014b(submitted).
18. Wimalawansa SJ. Agriculture and chronic kidney disease [http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=98247; http://www.dailynews.lk/features/knocking-kidney-killer; http://www.sundayobserver.lk/2013/11/24/fea06.asp]. 2014a.
19. Wimalawansa SJ. Escalating Chronic Kidney Diseases in Sri Lanka: Causes, Solutions and recommendations. Journal of Epidemiology & Community Health. 10.1007/s12199-014-0395-5. 2014c.
20. Wimalawansa SA, Wimalawansa, S.J. Protection of watersheds to prevent phosphate eutrophication and consequent environmental health hazards in Sri Lanka. J. Agric. Food Sci. (submitted). 2014.
21. Heffernan JB, Liebowitz DM, Frazer TK, Evans JM, Cohen MJ. Algal blooms and the nitrogen-enrichment hypothesis in Florida springs: evidence, alternatives, and adaptive management. Ecol Appl. 2010;20(3):816-29.
22. Amarasiri SL. Caring for Water. Sri Lanka Nature Forum. Nugegoda, Sri Lanka; 2008:161.
23. DOA. Agricultural Phosphorus and Eutrophication. In: Agriculture USDo, ed. Washignton D.C.: Agriculture Research Service; 2003:43.
24. Middlebrooks EJ, Pearson, E.A., Tunzi, M., Adinarayana, A., McGauhey, P.H., Rohlich, G.A. Eutrophication of surface water: Lake Tahoe. Water Pollution Control Federation. 1971;43(2):242–51.
25. Rodhe W. *Crystallization of eutrophication concepts in North Europe*. Washington D.C: National Academy of Sciences; 1969.
26. Li Y, Cao W, Su C, Hong H. Nutrient sources and composition of recent algal blooms and eutrophication in the northern Jiulong River, Southeast China. Mar Pollut Bull. 2011;63(5-12):249-54.
27. Rouco M, Lopez-Rodas V, Flores-Moya A, Costas E. Evolutionary changes in growth rate and toxin production in the cyanobacterium Microcystis aeruginosa under a scenario of eutrophication and temperature increase. Microb Ecol. 2011;62(2):265-73.
28. Paerl HW, Otten TG. Harmful cyanobacterial blooms: causes, consequences, and controls. Microb Ecol. 2013;65(4):995-1010.
29. Desalegn B, Nanayakkara S, Harada KH, Hitomi T, Chandrajith R, Karunaratne U, et al. Mycotoxin detection in urine samples from patients with chronic kidney disease of uncertain etiology in Sri Lanka. Bull Environ Contam Toxicol. 2011;87(1):6-10.
30. Wanigasuriya KP, Peiris H, Ileperuma N, Peiris-John RJ, Wickremasinghe R. Could ochratoxin A in food commodities be the cause of chronic kidney disease in Sri Lanka? Trans R Soc Trop Med Hyg. 2008;102(7):726-8.
31. Ramirez-Rubio O, Brooks DR, Amador JJ, Kaufman JS, Weiner DE, Scammell MK. Chronic kidney disease in Nicaragua: a qualitative analysis of semi-structured interviews with physicians and pharmacists. BMC Public Health. 2013;13:350.
32. Orantes CM. Clinical Characterization and Histopathology of Nephropathy in Salvadorian Agricultural Communities. Proceedings of The International Conference on Saptial Ecotoxicology. San Salvador, El Salvador; 2013.
33. Orantes CM, Herrera R, Almaguer M, Brizuela EG, Hernandez CE, Bayarre H, et al. Chronic kidney disease and associated risk factors in the Bajo Lempa region of El Salvador: Nefrolempa study, 2009. MEDICC Rev. 2011;13(4):14-22.
34. Wesseling C, Crowe J, Hogstedt C, Jakobsson K, Lucas R, Wegman DH. The epidemic of chronic kidney disease of unknown etiology in Mesoamerica: a call for interdisciplinary research and action. Am J Public Health. 2013;103(11):1927-30.
35. Zhang J, Zhang L, Wang W, Wang H, China National Survey of Chronic Kidney Disease Working G. Association between aristolochic acid and CKD: a cross-sectional survey in China. Am J Kidney Dis. 2013;61(6):918-22.

36. Bi SH, Cheng LT, Wang T. A survey of chronic kidney disease in a large hospital in China. Ren Fail. 2008;30(5):541-5.

37. Stefanovic V, Radenkovic S, Cukuranovic R, Kostic S. Balkan endemic nephropathy. Slowed progression of kidney disease by avoidance of etiological factors. Nephron. 1999;83(1):85-6.

38. Stefanovic V, Polenakovic MH. Balkan nephropathy. Kidney disease beyond the Balkans? Am J Nephrol. 1991;11(1):1-11.

39. Reddy DV, Gunasekar A. Chronic kidney disease in two coastal districts of Andhra Pradesh, India: role of drinking water. Environ Geochem Health. 2013;35(4):439-54.

40. Wright TR, Shan G, Walsh TA, Lira JM, Cui C, Song P, et al. Robust crop resistance to broadleaf and grass herbicides provided by aryloxyalkanoate dioxygenase transgenes. Proc Natl Acad Sci U S A. 2010;107(47):20240-5.

41. Tanney JB, Hutchison LJ. The effects of glyphosate on the in vitro linear growth of selected microfungi from a boreal forest soil. Can J Microbiol. 2010;56(2):138-44.

42. Miller RP, Martinson KB, Sothern RB, Durgan BR, Gunsolus JL. Circadian response of annual weeds in a natural setting to high and low application rates of four herbicides with different modes of actions. Chronobiol Int. 2003;20(2):299-324.

43. Mink PJ MJ, Lundin JI, Sceurman BK. Epidemiologic studies of glyphosate and non-cancer health outcomes: a review. Regul. Toxicol. Pharmacol. 2011;61(2):172–84.

44. Wunnapuk K, Gobe G, Endre Z, Peake P, Grice JE, Roberts MS, et al. Use of a glyphosate-based herbicide-induced nephrotoxicity model to investigate a panel of kidney injury biomarkers. Toxicol Lett. 2014;225(1):192-200.

45. Williams AL, Watson RE, DeSesso JM. Developmental and reproductive outcomes in humans and animals after glyphosate exposure: a critical analysis. J Toxicol Environ Health B Crit Rev. 2012;15(1):39-96.

46. Multiple-Authors. Glyphosate does not cause CKDu: http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=109472; http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=100347 ; http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=98864 ; http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=101248 ; http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=100405 ; http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=99203 ; http://www.island.lk/index.php?page_cat=article-details&page=article-details&code_title=101392 ;http://www.lankaweb.com/news/items/2014/07/06/there-is-no-scientific-evidence-that-herbicide-glyphosate-causing-chronic-kidney-disease-of-multi-factorial-origin-ckd-mfo-in-sri-lanka/. 2014.

47. Cerdeira AL, Duke SO. The current status and environmental impacts of glyphosate-resistant crops: a review. J Environ Qual. 2006;35(5):1633-58.

48. Kimmel GL, Kimmel CA, Williams AL, DeSesso JM. Evaluation of developmental toxicity studies of glyphosate with attention to cardiovascular development. Crit Rev Toxicol. 2013;43(2):79-95.

49. Mink PJ, Mandel JS, Lundin JI, Sceurman BK. Epidemiologic studies of glyphosate and non-cancer health outcomes: a review. Regul Toxicol Pharmacol. 2011;61(2):172-84.

50. Talbot AR, Shiaw MH, Huang JS, Yang SF, Goo TS, Wang SH, et al. Acute poisoning with a glyphosate-surfactant herbicide ('Roundup'): a review of 93 cases. Hum Exp Toxicol. 1991;10(1):1-8.

51. Lee HL, Chen KW, Chi CH, Huang JJ, Tsai LM. Clinical presentations and prognostic factors of a glyphosate-surfactant herbicide intoxication: a review of 131 cases. Acad Emerg Med. 2000;7(8):906-10.

52. Smith EA, Oehme FW. The biological activity of glyphosate to plants and animals: a literature review. Vet Hum Toxicol. 1992;34(6):531-43.

53. Mink PJ, Mandel JS, Sceurman BK, Lundin JI. Epidemiologic studies of glyphosate and cancer: a review. Regul Toxicol Pharmacol. 2012;63(3):440-52.

54. Kier LD, Kirkland DJ. Review of genotoxicity studies of glyphosate and glyphosate-based formulations. Crit Rev Toxicol. 2013;43(4):283-315.

55. Larsen K, Najle R, Lifschitz A, Virkel G. Effects of sub-lethal exposure of rats to the herbicide glyphosate in drinking water: glutathione transferase enzyme activities, levels of reduced glutathione and lipid peroxidation in liver, kidneys and small intestine. Environ Toxicol Pharmacol. 2012;34(3):811-8.

56. Steinrucken HC, Amrhein N. The herbicide glyphosate is a potent inhibitor of 5-enolpyruvyl-shikimic acid-3-phosphate synthase. Biochem Biophys Res Commun. 1980;94(4):1207-12.

57. Wittmer IK, Bader HP, Scheidegger R, Singer H, Luck A, Hanke I, et al. Significance of urban and agricultural land use for biocide and pesticide dynamics in surface waters. Water Res. 2010;44(9):2850-62.

58. Sprague LA, Nowell LH. Comparison of pesticide concentrations in streams at low flow in six metropolitan areas of the United States. Environ Toxicol Chem. 2008;27(2):288-98.

59. Belden JB, Hofelt CS, Lydy MJ. Analysis of multiple pesticides in urban storm water using solid-phase extraction. Arch Environ Contam Toxicol. 2000;38(1):7-10.

60. Hosseini SV, Behrooz RD, Esmaili-Sari A, Bahramifar N, Hosseini SM, Tahergorabi R, et al. Contamination by organochlorine compounds in the edible tissue of four sturgeon species from the Caspian Sea (Iran). Chemosphere. 2008;73(6):972-9.

61. Chase E, Hunting J, Staley C, Harwood VJ. Microbial source tracking to identify human and ruminant sources of faecal pollution in an ephemeral Florida river. J Appl Microbiol. 2012;113(6):1396-406.

62. Wimalawansa SJ. Water pollution-associated ill health: Special emphasis on chronic kidney disease in Sri Lanka: https://wimalawansa.org/sites/all/files/Olcott_Oration_2013_b.pdf; http://www.anandacollege.net/document/14011809Olcott%20Oration%20Book.pdf Olcott Memorial Oration. Colombo, Sri Lanka: Ananda Collage; 2013b:1-12.

63. Brown KG, Ross GL, American Council on S, Health. Arsenic, drinking water, and health: a position paper of the American Council on Science and Health. Regul Toxicol Pharmacol. 2002;36(2):162-74.

64. Chandrajith R, Nanayakkara S, Itai K, Aturaliya TN, Dissanayake CB, Abeysekera T, et al. Chronic kidney diseases of uncertain etiology (CKDue) in Sri Lanka: geographic distribution and environmental implications. Environ Geochem Health. 2011;33(3):267-78.

65. Hossain MP, Goyder EC, Rigby JE, El Nahas M. CKD and poverty: a growing global challenge. Am J Kidney Dis. 2009;53(1):166-74.

66. Senevirathna L, Abeysekera T, Nanayakkara S, Chandrajith R, Ratnatunga N, Harada KH, et al. Risk factors associated with disease progression and mortality in chronic kidney disease of uncertain etiology: a cohort study in Medawachchiya, Sri Lanka. Environ Health Prev Med. 2012;17(3):191-8.

67. Soderland P, Lovekar S, Weiner DE, Brooks DR, Kaufman JS. Chronic kidney disease associated with environmental toxins and exposures. Adv Chronic Kidney Dis. 2010;17(3):254-64.

68. U.N. Report of the United Nations conference on environement and development. Rio de Janeiro: U.N.; 1992:A/CONF.151/26 (Vol. IV).

69. Group W. Philippines: country wide water development projects and funds needed. Water crisis in Manila coincide with parliamentarians seminar on water resources and population. Asian Forum Newsl. 1997:9-11.

70. Baasch A, Tischew S, Bruelheide H. Twelve years of succession on sandy substrates in a post-mining landscape: a Markov chain analysis. Ecol Appl. 2010;20(4):1136-47.

71. Tayfur G, Kirer T, Baba A. Groundwater quality and hydrogeochemical properties of Torbali Region, Izmir, Turkey. Environ Monit Assess. 2008;146(1-3):157-69.

72. Kohl M, Baldauf T, Plugge D, Krug J. Reduced emissions from deforestation and forest degradation (REDD): a climate change mitigation strategy on a critical track. Carbon Balance Manag. 2009;4:10.

73. Shukla J, Nobre C, Sellers P. Amazon deforestation and climate change. Science. 1990;247(4948):1322-5.

74. Cramer W, Bondeau A, Schaphoff S, Lucht W, Smith B, Sitch S. Tropical forests and the global carbon cycle: impacts of atmospheric carbon dioxide, climate change and rate of deforestation. Philos Trans R Soc Lond B Biol Sci. 2004;359(1443):331-43.

75. Bala G, Caldeira K, Wickett M, Phillips TJ, Lobell DB, Delire C, et al. Combined climate and carbon-cycle effects of large-scale deforestation. Proc Natl Acad Sci U S A. 2007;104(16):6550-5.

76. Meyer B, Pailler JY, Guignard C, Hoffmann L, Krein A. Concentrations of dissolved herbicides and pharmaceuticals in a small river in Luxembourg. Environ Monit Assess. 2011;180(1-4):127-46.

77. Castleden WM, Shearman D, Crisp G, Finch P. The mining and burning of coal: effects on health and the environment. Med J Aust. 2011;195(6):333-5.

78. Noyes PD, McElwee MK, Miller HD, Clark BW, Van Tiem LA, Walcott KC, et al. The toxicology of climate change: environmental contaminants in a warming world. Environ Int. 2009;35(6):971-86.

79. Wimalawansa SJ. Stigma of obesity: A major barrier to overcome. J. Clin. & Translational Endocrinology. 2014d;1:73–6.

80. Wang JD, Soong WT, Chao KY, Hwang YH, Jang CS. Occupational and environmental lead poisoning: case study of a battery recycling smelter in Taiwan. J Toxicol Sci. 1998;23 Suppl 2:241-5.

81. Wimalawansa SJ. Purification of contaminated water with reverse osmosis: Effective solution of providing clean water for human needs in developing countries. Journal of Emerging Technology and Advanced Engineering. 2013a;3(12):75-89.

82. Southcott RV. The neurologic effects of noxious marine creatures. Contemp Neurol Ser. 1975;12:165-258.

83. Kudo A, Miyahara S. Effect of decontamination project at Minamata Bay, Japan. Dramatic decrease of mercury dispersed into Yatsushiro Sea. Ecotoxicol Environ Saf. 1988;15(3):339-43.

84. Asians-Studies-and-Windows-in-Asia. Historical Settings-Ancient hydrolic irrigation systems [http://asia.isp.msu.edu/wbwoa/south_asia/sri_lanka/history.htm]; Traditional Sri Lanka [http://www.shsu.edu/~his_ncp/SriLanka.html]; 1998.

85. Wimalawansa SJ. *The intertwined histories of Buddhism and Sri Lanka*. 1,0 ed. Colombo, Sri Lanka: Karu Sons; 2012.

86. Chapple RS, Ramp D, Bradstock RA, Kingsford RT, Merson JA, Auld TD, et al. Integrating science into management of ecosystems in the Greater Blue Mountains. Environ Manage. 2011;48(4):659-74.

87. Barrick KA. Protecting the geyser basins of Yellowstone National Park: toward a new national policy for a vulnerable environmental resource. Environ Manage. 2010;45(1):192-202.

88. Rudden PJ. Report: policy drivers and the planning and implementation of integrated waste management in Ireland using the regional approach. Waste Manag Res. 2007;25(3):270-5.

89. Scholz G, VanLaarhoven J, Phipps L, Favler L, Rixon S. Managing for river health--integrating watercourse management, environmental water requirements and community participation. Water Sci Technol. 2002;45(11):209-13.

90. Wang K, Ou Y, Ge QS. Perception of residents in world heritage site to the effects of ecological migration: a case study of three migrant resettlement spots in Wulingyuan, Hunan Province of South-central China. Ying Yong Sheng Tai Xue Bao. 2012;23(6):1663-70.

91. Rathnamalala NK, Nagodavithana KC, Mihirini AT, Lanerolle RD. Patient perceptions of risk factors for chronic kidney disease and methods of delaying progression of the disease in a tertiary care setting in Sri Lanka. Int J Clin Pract. 2011;65(10):1108.

92. Bezirtzoglou C, Dekas K, Charvalos E. Climate changes, environment and infection: facts, scenarios and growing awareness from the public health community within Europe. Anaerobe. 2011;17(6):337-40.

93. Environmental problems and developing countries. Finance Dev. 1992;29(2):22-3.