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CHALLENGES AHEAD

WATER QUALITY AND HUMAN HEALTH

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TOYAMA PREFECTURAL UNIVERSITY, JAPAN.

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International Symposium on

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Keynote Paper

TERRAIN GEOCHEMISTRY, WATER QUALITY AND HEALTH

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On our planet, the chemical elements flow through the different planetary compartments, including the atmosphere, hydrosphere, lithosphere, and biosphere. Humans and animals are part of these cycles. The chemical elements pass into and out of them, too, in a complex biogeochemical cycle. Obviously, then, the chemistry of any local geological environment must have a direct influence on the chemical make-up of those living there. This is most readily seen in places where humans live in particularly intimate contact with the local physical environment. Sri Lanka provides a very good example where this intimate association with the immediate physical environment is seen. The country is geographically climatically and geologically markedly diverse and there variations in the elemental compositions, their abundances and pathways clearly influence the health of the people living in these particular regions. For example the Jaffna peninsula of Sri Lanka has a unique geochemical terrain and contrasts markedly with the lateric terrains of the South West. Likewise, metal-rich regions along the Highland-Vijayan boundary notably in the Serpentine soils have a different geochemistry.

Even though many other factors—among them life-style, sex, age, migrations, and food habits—affect health, imbalances in the supply of inorganic elements exert marked influences on both human and animal health. Anomalies in the local abundances of trace elements, for example, have a large impact on food chains. As it was more than 500 years ago, it remains relevant to bear in mind the basic law of toxicity as defined by Paracelsus (1493-1541), the father of pharmacology: “All substances are poisons; there is none which is not a poison. The right dosage differentiates a poison and a remedy.” Even water, when consumed too quickly and in inordinate amounts, can be lethal. One of the primary objectives of medical geologists therefore is to determine the optimal exposures for people to the essential elements in order to maintain or improve health.

In Sri Lanka only about 35% of the population have access to clean piped water with controlled mineral content. The rest generally get their drinking water from wells. In some dug wells, and most notably in deep boreholes, the fluoride concentration in water exceeds 1.5 mg/liter. In some cases, the concentration can be as high as 10 mg/liter. The sources of the fluoride are the high-grade metamorphic rocks in the dry zone of Sri Lanka. These rocks include an abundance of fluoride-bearing minerals such as mica, hornblende, and fluorite. From a strictly scientific perspective, one of the most interesting aspects of these studies is the biomineralogy of tooth enamel and the process by which hydroxyapatite, the primary mineral in teeth and bones, transforms into fluoroapatite when fluoride ingestion is excessive.

Iodine deficiency disorders (IDD) are often referred to as “geochemical diseases”. It has been estimated that nearly 30% of the world's population is at risk from some form of Iodine Deficiency Disorder (IDD). Insufficient intake of iodine is the world's most common cause of mental retardation and brain damage with 1.6 billion people at risk, 50 million children already affected, and 100,000 more adding to their

ranks every year. IDDs are particularly severe in tropical regions. The resulting large populations of people with impaired mental function have serious direct and indirect impacts on all aspects of life in these places.

The geochemistry of iodine and its chemical species has a marked influence on the prevalence of IDDs, including endemic goiter. The sea is a major source of iodine, so there often is a relationship between the incidence of IDDs in a region and that region's distance from the sea. In general, the farther away from the sea, the less iodine is available. Other factors such as atmospheric circulation, however, may play a role in iodine availability, as does topography. In many mountainous regions, for example, iodine abundance is quite low, with a concomitant increase in IDD. Several countries notably in the tropical belt suffer from iodine imbalances due to the geographical, climatologically and geological factors.

One of the most tantalizing geology-health correlations involves the incidence of cardiovascular diseases (CVDs) and the water hardness of a particular area. In several countries and regions, a negative correlation between water hardness and deaths due to CVD has been observed. This correlation has been seen in both temperate and tropical countries. Even though a causal effect still cannot be ascribed to this geochemical correlation, the potential role that trace elements in drinking water could play in this relationship has aroused considerable curiosity among medical geologists.

If we accept for now that there is some causal basis to this correlation, then the question to ask is this: What is it in the hard water that is cardio-protective?

Mounting evidence from many studies indicates that this “water factor” is magnesium, with calcium playing a supportive role. The presence of calcium and magnesium in natural water results from the decomposition of calcium and magnesium aluminosilicates, which derive from limestone, magnesium limestone, magnesite, gypsum, and other minerals.

An important point to note is that only two out of every three studies on this topic have shown a correlation between cardiovascular mortality and water hardness. Studies probing the effect of water magnesium alone have all shown an inverse correlation between cardiovascular mortality and water magnesium level—the more magnesium, the lower the rate of CVD mortality.

Even though medical geologists have shown much enthusiasm for the possible cardio-protective role of magnesium, those in the medical profession are yet to be fully convinced of the hard water-CVD connection. More research is needed to clearly pinpoint the elusive “water factor,” if indeed there is one to be found.

The field of Medical Geology is fast gaining recognition as a major scientific discipline. Its very multidisciplinary nature brings to light the importance of the understanding of related disciplines in issues concerning human and animal health.

Keynote Paper

WATER QUALITY AND DISEASE: CHEMICAL AMPLIFICATION OF POLLUTANTS

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Water pollution is due to increased human population and industrial activities. Highest hospital admissions are due to water borne diseases. Water pollution arises owing to a large number of factors. Dumping of human waste and intensive agriculture is the main cause of pollution while industrial activities too contribute significantly to water pollution. Municipal water schemes only disinfect water through chlorination but this does not remove dissolved traces of pesticides often found in the ppb range. Also, no monitoring is done in these schemes to determine pesticides and heavy metals. Some of these are chronic toxins and the bioaccumulation effects manifest only after long years of exposure. Increasing kidney disease and cancer amongst the general population of Sri Lanka is likely due to the chronic exposure to such toxic chemicals. Accumulation of heavy metals such as mercury and cadmium from waste dumps and industry in green vegetables and fish in the aquatic systems is a serious problem which deserves more attention.

The water quality alone does not give a true picture of the pathways for the intake of heavy metals and other toxins into the human body. There are other processes unique to the lifestyles of a particular community which often lead to enhancing the effect of an otherwise innocent pollutant. Water quality standards adopted in developing countries are based on those already in force in developed countries having entirely different life styles to those living in developing countries. While the fluoride standard of 1.5 ppm assumes an average intake of not more than 1 mg per day, farmers drinking several litres of water working in the hot sun results in the intake of several mg a day. Also, the use of acidic spices results in the leaching of heavy metals from sub-standard cooking utensils. Such socio-economic realities should be seriously considered in stipulating water quality standards for developing countries.

The kidney disease of unknown etiology from the North-Central province of Sri Lanka is a case in point. Over 10% of the adult population in the NCP is affected by the chronic renal failure and their numbers are increasing year after year. Analysis of their water does not give any cause for alarm. However, the affected people have consumed water having excessive fluoride for a many years. There has been concern about dental fluorosis but this has largely been a cosmetic problem which people tend to ignore. However, the possible role of fluoride as the causative factor has brought a fresh look at the fluoride removal methods from water.

Another important observation made during this work was that people exclusively use locally fabricated sub-standard aluminum utensils for cooking which develop holes through them after sometime. Previous studies linking aluminium and fluoride to kidney failure have been reported. Al and F levels of 0.5 ppm (Aluminium) and 1 ppm (Fluoride) given to rats caused the death of animals after 45 weeks with only few deaths in the control group. Pathological changes in the kidneys with aluminium

containing deposits located in blood vessels of the kidney were discovered and the rats died due to kidney failure.

People affected by CRF exclusively consume fluoride rich water and almost exclusively use sub-standard aluminium pots for cooking and storing water. Leaching of aluminium under different fluoride stress and under the acidic conditions used in cooking was studied. In the absence of acidic spices, the amount of aluminium leached was quite small with a maximum of 1.20 ppm reached after 10 minutes of boiling in 6 ppm fluoride solution. However, under acidic conditions obtained during the use of tamarind at a pH of 3.02, the aluminum leached was around 18 ppm even in the absence of fluoride with a regular enhancement of leaching at higher fluoride levels. The aluminum leached at 6 ppm fluoride reached 29 ppm after 10 minutes of boiling. Similarly, at a pH of 2.12 in the presence of 0.1 M tartaric acid, the maximum aluminium concentration leached reached ca. 50 ppm. Aluminofluoride complexes may play a significant role in causing chronic renal failure.

Since the aluminofluoro complexes containing up to six fluoride ions per aluminium atom can move across phospholipid membranes and release these fluoride ions inside the kidney cells, their toxic levels will be amplified. We introduce a new term, *chemical amplification*, to explain this type of effect. Chemical amplification refers to the formation of secondary complex compounds between a normal pollutant in drinking water combining with other species such as metal ions found in food, beverages or cooking utensils to enhance the uptake of this pollutant compared to the absence of the complexing species. Leaching of heavy metals such as aluminium and lead under high fluoride stress represents a new way for the entry of toxic heavy metals into the body and the formation of complex fluorides provides a pathway for the chemical amplification of toxins such as fluoride.

Other factors such as cadmium originating from fertilisers have now been proven to be erroneous. Values of cadmium levels reported from water, fish and water plants such as the tubers of water plants such as Nelumbo are quite low to have toxic effects. Also, this does not explain why people in other areas who use similar fertilisers are not affected. For similar reasons, the role of arsenic combined with hardness in water is not an acceptable reason for CRF because there are many areas of high water hardness and similar lifestyles which do not exhibit this disease. The occurrence of CRF only in high fluoride areas is significant and should be considered for more research to conclusively prove that fluoride is indeed responsible for CRF.

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CONTAMINATION OF ARSENIC IN WELL WATER AND RICE IN SRI LANKA

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Chronic arsenic poisoning produces dermal manifestations such as hyperpigmentation and hyperkeratosis. Arsenic contamination of groundwater has caused arsenic poisoning in Bangladesh and neighboring countries. 150 million people in more than 70 countries are thought to be threatened by arsenic poisoning from drinking water. In Sri Lanka, there was a report that arsenic is the cause of Chronic kidney disease with uncertain etiology (CKDu) prevailing in the North Central Province of the country. In this study arsenic in well water was measured in Anuradhapura, Nuwara Eliya, Puttalam, Mannar and Jaffna to understand the spatial distribution of arsenic in Sri Lanka. Arsenic contamination in rice consumed by residents in Anuradhapura area was also measured.

For well water, the water samples were filtrated by a membrane filter with a pore size of 0.45μm on site to stabilize water quality, and were brought to Toyama Prefectural University, Japan to measure concentrations of major ions and heavy metals. For water samples, major ions were determined by an ion chromatography. Metals other than arsenic were determined by ICP-AES, and arsenic was by ICP-MS.

For rice, As, Cd, Pb and Cr were determined by ICP-MS after degradation by nitrate. The results for well water and rice are shown in Table 1 and 2, respectively. The arsenic concentration of well water was low in Anuradhapura and Nuwara Eliya, while it was high in Puttalam, Mannar and Jaffna. Higher concentration of arsenic was commonly found in the wells having soil classified into “The sandy regosols on beach and dune sands”. Thus, the results indicate that, arsenic was not a pesticide origin but a geologic origin. The low concentrations of arsenic in rice consumed in Anuradhapura area also indicated that CKDu in the north central of Sri Lanka could not attribute to arsenic in the environment.

Some samples of well water exceeded the World Health Organization recommendation of 10μg/l of arsenic in drinking water. As this recommendation was established based on the detection limit of available measuring instrument at the time of publication of the WHO water quality guidelines, lower concentration than the guideline could cause adverse health effect. In the northern coastal area of Sri Lanka, chronic poisoning is anxious about.

Table 1: Arsenic concentration in well water in Sri Lanka

	Number of samples	Average concentration (µg/l)	Standard Deviation (µg/l)	Highest concentration (µg/l)
Anuradhapura	45	0.3	0.2	0.8
Nuwara Eliya	14	0.1	0.1	0.4
Puttalam	29	3.7	4.0	15.3
Mannar	32	7.4	13.7	74.0
Jaffna	28	1.9	2.2	8.8

Table 2: Quantitative determination of heavy metals in rice

	Average (mg/kg)	Standard Deviation (mg/kg)	Highest concentration (mg/kg)	Japanese Rice (mg/kg)
Cd	0.01	0.01	0.02	0.04
Pb	0.03	0.02	0.07	0.02
As	0.09	0.07	0.2	0.3
Cr	0.07	0.06	0.24	0.05

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IMPROVED PROGRAM FOR HEALTH CARE WASTE DISPOSAL IN THE GENERAL HOSPITAL, KANDY

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Safe management of healthcare waste is very important to control infections within the hospital and outside environment as well as human community. Improper waste disposal of hospitals could immensely pollute soil and water with potentially toxic chemical waste and hazardous infectious waste. Health care waste (HCW) is defined as all waste generated by medical activities. It can be divided into three risk categories; non risk HCW, hazardous HCW and highly hazardous HCW.

The General Hospital, Kandy, which is the second largest hospital in Sri Lanka having bed strength of 2284 and treating 3500 out patients a day and generates a large amount of waste material. A preliminary survey found that the hospital produced 3032 kg of general waste, 226 kg of paper, 322 kg plastic, 110 kg of polythene, 476 kg of clinical waste, 60 kg of anatomical waste - mainly placentas, 88 kg of sharps and 1 kg of cytotoxic waste a day. As the waste is sorted out, hazardous and highly hazardous waste had been mixed with large quantities of non risk HCW, before the hospital commenced an improved program of waste disposal in September 2010. The program which commenced in 2010 introduced sorting out waste material at the time of generation into colour coded bins.

Non risk HCW, which includes leftover food, general office waste and packaging materials, is disposed by the Kandy Municipality Council. It is proposed to have a biogas plant using disposed left over organic matter. Non contaminated clean glass, polythene, plastic and paper were segregated and sold for recycling purposes

Disposal of hazardous HCW was more challenging and expensive. Improper disposal of chemical waste generated by the laboratories, radiology and radiotherapy units can contaminate soil and ground water with potentially toxic and infectious material. Education of the staff and strict implementation of the colour coded bins for segregation of HCW has to be reinforced as mixing of hazardous and highly hazardous waste would increase the volume of waste and immensely increase the costs of disposal. Until the hospital has its own disposal systems it is decided to outsource disposal of some hazardous wastes to a company certified by the central environment authority. This includes contaminated sharps and used blood transfusion sets. Sharps are to be disinfected before incineration. Used transfusion sets are to be hydroclaved before disposal.

There was no proper way to discard anatomical waste including placentas previously, and it was buried in the hospital premises. Until a proper system is introduced this category of waste is now planned to be segregated into yellow coloured bags and handed over to funeral undertakers to be buried in a cemetery according to a standard protocol. Cytotoxic waste which is highly hazardous is placed in a concreted pit. Radioactive waste is planned to be stored until decayed to background level and disposed accordingly. The containers and remains of such waste is returned to the supplier to be disposed conforming to standards set by the Central Environment Authority.

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WATER QUALITY IMPROVEMENTS IN THE DRY ZONE AREAS IN SRI LANKA.

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Water supply services in Dry Zone areas have about been improved by establishing community based (CB) water supply schemes (4500) which caters to 100 – 300 households. Of these nearly 30% are not used by people for drinking purposes due to the high hardness of water. Water of these schemes have high hardness which can be detected easily by its taste while an invisible poison, excess fluoride, can be known after chemical examination. On the other hand, water from nearly 50% of the dug wells in these areas have high fluoride content in water thus contributing to dental fluorosis of children and may have an indirect effect on chronic renal failure.

This paper highlights studies done in problematic CB water supply schemes in Anuradhapura District to upgrade the water quality. In this study, fluoride levels of 5.5 mg/l and hardness of 350 mg/l $CaCO_3$ had been reduced to less than 1.0 mg/l and 10 mg/l $CaCO_3$ respectively. The methodology used is Electrocoagulation coupled up with sedimentation, sand filtration, water softener and activated carbon filtration.

In this study, fluoride distribution deposition in the cathodes was investigated in order to obtain the optimum conditions of removal. It was found that only 30% hardness is removed by Electrocoagulation technology and hence a water softener was introduced to further reduce hardness to 10 mg/l $CaCO_3$. These water treatment plants are operated by female operators thus empowering the village women. It has a capacity of producing 200 l/hr of processed water, a monthly average production of 10,000 liters being utilised for cooking and drinking purposes.

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MOBILITY AND RETENTION OF PHOSPHATE IN IRRIGATED SANDY AGRICULTURAL FIELDS, KALPITIYA, NORTH WEST SRI LANKA

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Despite high applications of phosphate fertiliser and intensive sprinkler irrigation in sandy agricultural fields of Kalpitiya, ground water in the unconfined sandy aquifer just beneath the fields is remarkably low in phosphate content. This indicates that there is a rapid conversion of soluble phosphate into insoluble form either during infiltration or after entering the groundwater reservoir.

Surface soil samples were collected from 58 locations covering 60 km^2 of the lower part of the peninsula, where different land use patterns can be observed. Major cations and total phosphorus in the soil samples were measured after acid treatment. A laboratory simulation experiment was carried to study the behavior of phosphorous in the sandy soil of the study area. After treating the soil columns with phosphate solution, phosphate leached from treated columns and phosphate retained in samples were colorimetrically measured by the Vanadomolybdate method with HACH DR/2400 spectrophotometer. Mineralogical changes of treated soils were studied using X-ray diffraction (XRD) analysis.

Cations measured in surface soil samples indicate high ion concentrations, while phosphate shows lower values though there was regular addition of phosphate fertilisers. This is caused by rapid leaching of added phosphate followed by its mixing with irrigation water. The conversion of soluble phosphate into insoluble form appeared to be involved in the formation of the mineral *vivianite* in soil and non-crystalline phosphates in calcrets. Phosphate retention in sandy soil within the root zone can be enhanced by adding clay and organic matter. This type of practice in the field scale would be very useful in cost effective fertiliser management, where excessive losses of phosphate applied in sandy soil due to leaching can be minimised.

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ASSOCIATED FACTORS FOR FAECAL CONTAMINATION OF WATER RESOURCES: A CASE STUDY FROM PUSSELLA-OYA CATCHMENT, SRI LANKA

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Water related diseases are highly noticeable during the recent years than other diseases. Infectious hepatitis disease outbreak in 2007 in *Gampola*, Sri Lanka was probably through the faecal contamination of surface and ground water resources. This paper analyses the environmental, socio-economic, technological, and institutional factors associated with such contaminations. Trans-disciplinary research approach adopted in the study includes stakeholder meetings, focus group discussions, social mapping, stakeholder interviews using questionnaires, and field observations. Separate assessments were carried out on knowledge, attitudes and practices of people related to sanitation and water pollution. Data were gathered from three different communities namely Pussellawa town, Blackforest village, and Rothschild estate in the Pussella-Oya catchment.

Environmental factors such as shallow water table (< 1 m), impermeable or highly permeable soil, shallow bed rock (<1 m), limited space (<1 perch/dwelling), and steep slope are the constraints for construction and poor functioning of onsite sewage disposal units at most places. Majority (72%) of the latrines in Pussellawa are connected to cesspits whereas few are connected to septic tanks with or without a soak away pit. Few latrines (3%) are not connected to a disposal unit, thus sewage is directly diverted to a drain. Illegal discharge of sewage from latrine pits is the major reason for the highest faecal contamination of 2650 CFU/100 ml of surface water. In addition, high density of cesspits/ soakpits and shallow water table are the main reasons for contamination of groundwater. Majority of the village community have considerable good access to and maintenance of sanitation facilities. Around 27% of pits in the BF colony are located within a 15 m distance from drinking water source thus proving the potential for groundwater pollution. Around 32% of the latrine pits of the estate are located very close to each other whereas 37% of pits are located approximately less than 20 m distance from the nearest drinking water source. Estate people use stream as a defecation area, and other broken pits and defecation places are also washed down with rains causing faecal contamination.

Faecal contamination of water resources is directly link with poor knowledge of people on both the regulations and technologies, attitudinal gaps, and weaknessess of regulatory mechanism, and lack of "transferring of alternate technologies". Education on safe disposal of wastewater and sewage, and regulations related to sanitation are necessary to prevent water pollution associated with poor sanitation. Improved sanitation does not simply mean the access to a latrine, but it requires fulfilling of two major components named; (a) secure access to hygienic latrine, (b) appropriate treatment and safe disposal. Despite of the community category, environmental, social, technological, and institutional factors are highly related to sanitation and preventing water pollution, which have a direct impact on the health of a community.

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FATE AND TRANSPORT OF POLLUTANTS GENERATED FROM THE GOHAGODA OPEN DUMPSITE, KANDY, SRI LANKA

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The Gohagoda open dump site is a location which generates massive amounts of leachate from the municipal solid waste that are collected daily from the Kandy area. This leachate directly flows to the Mahaweli River which is the main water source for the entire province due to absence of proper lining system or any treatment mechanism before disposal. Hence, this study was focused on characterisation of leachate generated from Gohagoda dumpsite and assesses their spatial and temporal variations. Leachate samples were collected monthly for one year; from early February 2010 to late January 2012 from different points of the leachate drainage channel and tested for quality parameters as pH, temperature, EC, TDS, TS, VS, TSS, VSS, TOC, DOC [including Humic acid (HA), fulvic acid (FA) and hydrophilic fraction (Hyd)], BOD_5, COD, alkalinity, hardness, nitrates, phosphates, ammonium nitrogen, chloride and heavy metals (Fe, Cd, Zn, Cu, Pb, Ni and Cr).

Results demonstrated that the average pH of the leachate was 7.45 and BOD_5 was recorded significantly very high indicating maximum of 27500 mg/L at beginning of the study. However, average values of pH showed an increase to 8.37, but BOD_5 380 mg/L and COD showed a decrease to 1835 mg/L recorded in the late study period. Microbiological analysis demonstrated microbe substrate level and active microbial cells decline towards dry season to wet season and with the distance from the landfill. The DOC contributed for nearly 80% of TOC where the average concentrations were 1220 mg/L TOC and 993 mg/L DOC. In DOC, Hyd accounts for about 58% while FA and HA constituted about 26% and 16% respectively. The pollutants which may form complexes with the DOC fractions could transport over a long distance and eventually enter to food chains.

Nitrate and phosphate ranged in between 1-765 mg/L and 2-258 mg/L and high levels were observed towards wet season exceeding the allowable limits for wastewater discharge. Manual mixing at the landfill was more favorable for releasing high concentrations of nutrient content to leachate. Some of the analyzed heavy metals were reported in high concentrations such as Zn, Pb, Ni, Cu, Cd and Cr in average concentrations of 0.371, 0.217, 0.207, 0.135, 0.092 and 0.061 mg/L respectively. Based on the leachate characteristics, it was observed that the leachate has been transferred from acetogenic to methanogenic phase with time. The results strongly propose that the leachate generated from Gohogoda dumpsite contaminate soils and waters in the near by wetland systems as well as the drinking water sources.

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EFFECT OF CONCENTRATED WATER FROM RESERVOIRS OF HIGH PREVALENCE AREA FOR CHRONIC KIDNEY DISEASE (CKDu) OF UNKNOWN ORIGIN IN SRI LANKA ON MICE

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There is portentously high prevalence of chronic kidney disease (CKDu) ending as chronic renal failure in the North Central Region of Sri Lanka. This kidney disease is not related to any of the known causes, such as diabetes, mellitus, hypertension and infection. However, histopathology of affected kidneys showed tubule- interstitial nephritis which is suggestive of a toxic aetiology. The epidemiology of the disease shows distribution of these patients around some water reservoirs and most of them are farmers. Low prevalence of the disease was observed among villagers who use water from natural springs. Based on the hypothesis that water is the carrier of the CKDu causing agent, the potential effects of concentrated water, collected from a reservoir in the high prevalence area on the kidneys was studied by mouse bioassay.

Water of Padaviya reservoir providing water to a high disease prevalent area was concentrated fifteen times (15) by evaporation. The test group of mice (20) and control group (15) were fed with concentrated water and water from Kandy, respectively for 6 months and then sacrificed to examine the histology of the kidneys. Water samples were analyzed for fluoride, Na and K using the ion selective electrode method, heavy metals using ICP-MS, and cyanobacterial toxins, microcystin and cylindrospermopsin using LC-PDA and LC-MS, respectively. At the end of 6 months, interstitial nephritis was detected in 9/20 (45%) test mice and 2/15 (6.5%) controls ($p < 0.001$). The concentrated water samples showed high concentrations of fluoride, Na, K but not and the other heavy metals investigated. Significantly high content of fluoride (2.25 mg/l) and, sodium (225 mg/l) ($p < 0.05$) were detected compared to that of the control samples.

The cyanobacterial toxin analysis showed low levels (0.05 ug/l) of deoxy-cylindrospermopsin (DCYN) and no cylindrospermospsin (CYN) or microcystin was detected. The analysis showed the presence of deoxycylindrospermopsin (1.28 ug/l - DCYN) as the predominant isomer present over cylindrospermospsin (CYN), which is unusual. The results show the ability of the water of this reservoir to induce interstitial nephritis that could be due to the high salinity, fluoride or due to DCYN. Although present in low levels, the possibility DCYN to induce interstitial nephritis needs to be investigated further as the epidemiological evidence is in favor of a cyanobacterial toxin. The long term effects and safe levels for DCYN in drinking water and the effect of salinity and high fluoride content of water needs to be studied. The study shows the need of alternative, cleaner water supplies (like deep wells or treated water) for these villages, irrespective of the source of contamination of the shallow groundwater supplies. As the identification of the aetiological agent in CKDu is likely to take a longer time, it is advisable to consider the provision of alternate safe water source at least as a pilot project with careful monitoring of the community for new cases of CKDu.

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THE SHORT TERM EFFECT OF CYANOBACTERIALTOXIN EXTRACTS ON MICE KIDNEY

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The epidemiology of the chronic kidney disease of unknown origin (CKDu) in Sri Lanka shows that patients are distributed around irrigation reservoirs. Close similarity between incidence in CKDu and alcoholic liver disease over time in the North Central region indicates the possibility of a common etiological agent for both diseases. The histopathology of the renal disease shows evidence of a tubulointerstitial nephritis indicating a possible involvement of toxic aetiology. Some cyanobacteria that exist in water reservoirs are capable of secreting toxins under certain environmental conditions (e.g, high temperature). Cyanobacterial toxins are known to have hepatotoxic, dermatotoxic and neurotoxic effects in humans, and nephrotoxic effects in experimental animals. The main aim of the study was to find the short term effects of cyanobacteria extracts, isolated from affected reservoirs and canals of the high prevalence area for CKD-U on mice kidneys. Diluted extracts of *Microcystis* bloom, mixed bloom with predominant *Cylindrospermopsis* and *Lyngbia* bloom from Padaviya reservoir and canal were fed to a group of 5, 7 and10 mice respectively for a week. Another 5 mice were fed with diluted extracts of *Microcystis* bloom for one week, followed by 2 weeks of normal water. The control group of mice (10) was given normal water for a week. The diluted crude extracts were analysed for cyanobacterial toxins using cyanobacterial toxins microcystin and cylindrospermopsin using LC-PDA and LC/MS/MS respectively.

The results of analysis of the diluted crude extracts for the cyanobacterial toxins showed the presence of 65 mg/l microcystin and 2.5 mg/l deoxy cylindropspermopsin in *Microcystis* bloom. A mixed bloom from Padaviya reservoir showed 0.7 mg/l CYN and 29.5 mg/l Deoxy CYN. *Lyngbia* bloom from Ulhitiya reservoir showed 1.7 mg/l CYN and 1.7 mg/l of deoxy CYN. Acute tubular necrosis (ATN) was detected in 5/5 mice fed with extracts of *Microcystis* bloom that contained microcystin (65 µg/l), DCYN (2.1 µg/l) and CYN while 2/5 mice had ATN when the extract was followed by 2 weeks of normal water. One out of seven mice fed with *Cylindrospermopsis* bloom that contained DCYN (29.5 µg/l) and CYN (0.7 µg/l) had ATN. Six out of 10 mice fed on *Lyngbia* bloom containing CYN (1.7 µg/l) & DCYN (0.5 µg/l) had acute tubular necrosis. All control mice had normal tubules. Thus the results show the ability of the cyanobacterial extracts to induce ATN in mice in the given concentrations. The ability of the normal water to reverse the activity to a certain extent was seen when fed with normal water for 2 weeks. As DCYN was available in all extracts the ability of DCYN to induce tubular necrosis even at low concentrations need to be investigated.

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MOLECULAR IDENTIFICATION OF CYLINDROSPERMOPSIN PRODUCING *CYLINDROSPERMOPSIS RACIBORSKII* FROM ANURADHAPURA WATER RESERVOIRS

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Most of the world's population relies on surface freshwaters as its primary source for drinking. The drinking water industry is therefore constantly challenged with surface water contaminants that must be removed to protect human health. Most chemicals in drinking water are of health concern only after exposure of several years, rather than months. A number of chemical contaminants have been shown to cause adverse health effects in humans. Among chemical contaminants, cyanotoxins are well recognised as a cause for number of livestock and human poisonings. Therefore, the presence of cyanobacteria and their toxins in surface waters used for drinking and recreational activities are now readily acknowledged as a serious human health risk. Chronic Kidney Disease of unknown aetiology (CKDu) prevailing in Sri Lanka also focuses on a probable cause arising from drinking water. The disease is a major health problem in Sri Lanka. CKDu is likely to be triggered by an environmental factor and therefore, we focused our study on cyanotoxin due to its potentiality to cause adverse health effects.

Among cyanotoxins, cylindrospermopsin (CYN) is one of the potent cyanotoxin which effects to the kidney and liver function. Therefore, this study was performed to identify cyanotoxin; CYN in Anuradhapura water reservoirs using molecular, biochemical and bioassay methods. Water samples were collected from Kala wewa, Nuwara wewa, Tissa wewa and Jaya ganga. Under microscope, *Cylindrospermopsis* species were recorded as the dominant cyanobacterial species along with *Microcystis*, *Anabaena*, *Chroococcus*, *Phormidium*, *Oscillatoria*, which were comparatively moderate to low. In molecular detection, the presence of cyanobacteria, the presence of *Cylindrospermopsis* and *Cylindrospermopsis* strains that have the genetic potential to produce CYN were detected using specific PCR primers targeting 16S rRNA gene, *C. raciborskii* specific cylindrospermopsin synthetase gene and cylindrospermopsin specific peptide synthase (PS) gene respectively. The presence of toxin producing *Cylindrospermopsis raciborskii* in those water samples was reconfirmed by a nested PCR using *C. raciborskii* specific primers cyl2, cyl4 and cyl-int and by direct sequencing the PCR products at commercial facility and NCBI data bases.

All water samples were subjected to cylindrospermopsin ELISA detection kit to confirm the presence of CYN and to quantify the toxin. All were positive for CYN with a mean concentration of 0.137ng/ml. Further, water samples collected from the water purification centre in Anuradhapura showed 0.245 and 0.154 ng/ml of CYN before purification and after addition of chlorine respectively. However, a sample treated with chlorine and alum collected from the same purification centre was negative for CYN. Therefore, water purification processes have been playing a major role in reducing CYN toxin in drinking water. Further, bioassay results also confirmed the presence of CYN in collected water samples.

Therefore, this molecular, biochemical and bioassay findings may be an answer to the prevalence of CKDu in North Central Province and lack of the disease among people in the peripheral areas who consume purified drinking water. However, there is a need of extensive studies to identify the types of cyanobacteria and cyanotoxins

present in those water reservoirs using molecular, biochemical and bioassays methods to assess the present issue of CKDu.

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FIELD ASSESSMENT ON GEOLOGICAL DISTRIBUTION OF POLLUTANTS IN GROUNDWATER: CASE STUDY AT EIGHT AGRICULTURAL DISTRICTS, SRI LANKA.

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Consumption of water with excessive fluoride and nitrate in groundwater is becoming a crucial issue on human health in Sri Lanka. Among the suspected hypothesis on causing chronic kidney disease (CKD), fluoride toxicity is found as one major liable cause. Hitherto, over one thousand people were reported as died due to CKD and more than 25,000 patients have registered at renal clinics of several government hospitals in dry zone of the island. Particularly, since no specific cause for CKD was streamed out, close monitoring of groundwater fluoride level also needed. On the other hand, nitrate levels of groundwater have been increased significantly in many countries, including Sri Lanka due to surplus use of nitrogenous fertilizers. Particularly, nitrogenous compounds in groundwater for drinking have been considered as a possible risk factor for oesophageal cancer and blue baby syndrome.

Sri Lanka is currently recognised as one of the countries with a fast growing economy. End of the three decade civil war has created many novel developments opportunities. Especially, boost in agricultural sector is assisted remarkably by government subsidy given for fertilizer. However, no sufficient attention on investigation are being carried out to evaluate the actual threat from these pollutants. Accordingly, this research was conducted to deepen the understanding on geological distribution of fluoride and nitrate in groundwater at dry zone. Hence, groundwater quality was tested in eight districts which are recognized mostly as agricultural districts in Sri Lanka; named Anuradhapura, Puttalam, Mannar, Jaffna, Trincomalee, Nuwaraeliya, Batticaloa and Hambantota. Both shallow and deep water was tested at selected dug and tube wells. The total number of onsite tested samples from each district was 30. in-situ colorimetric technique was employed for detection of nitrate and fluoride concentrations in field. In addition, same number of samples were collected by filtering through 0.45 µm membrane filters and transferred to the analytical laboratory at Toyama Prefectural University, Japan for further investigations.

Among the eight districts, Puttalam (Kalpitiya area) was found as the area with most polluted groundwater by nitrate (39.8 ±88 mgl^{-1} as NO^{-}_{3}). However, Anuradhapura (12.4 ±30 mgl^{-1} as NO^{-}_{3}), Jaffna (17.2 ±22 mgl^{-1} as NO^{-}_{3}) and Nuwaraeliya (12.1±18 mgl^{-1} as NO^{-}_{3}) are also identified as areas with increasing risk from excessive nitrate concentrations. On the other hand, fluoride was found highest in Anuradhapura (1.2 ±0.6 mgl^{-1}) and also significant in Mannar (0.9 ±0.5 mgl^{-1}), Trincomalee (0.8 ±0.5 mgl^{-1}) and Hambantota (0.9 ±0.3 mgl^{-1}). The results of this study revealed that proper mechanism in groundwater quality monitoring is essentially needed as most of the dry zone area finds very few number of perennial surface water sources. Further, field investigations on both natural and artificial pollutants are very much essential in assessing pollution risk and developing future policy plans accordingly.

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SEASONAL WATER QUALITY CHANGES IN RESERVOIRS IN DIFFERENT CLIMATIC ZONES OF SRI LANKA

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Quality of water can be changed due to natural and anthropogenic factors. Among the natural factors climate and geological conditions, affect water quality parameters both negatively and positively. The current study was conducted to assess if the measurement of important water quality parameters change spatially in Sri Lankan reservoirs located in the Wet, Intermediate, Dry and Arid climatic zones during the rainy and dry seasons.

Fifty eight reservoirs varying in age from a few decades to hundreds of years since the last restoration of their impoundment were selected to cover many areas of the country from a variety of urban, rural and agricultural regions in order to comprehend the diversity of limnological conditions. These sites range in elevation above mean sea level from 5m to over 2000 m. The catchments of the reservoirs sampled include a diversity of vegetation types including: dry evergreen, moist deciduous, moist semi-evergreen, wet semi-evergreen, submontane evergreen, and montane temperate vegetation. The physico-chemical variables measured included, temperature (T), turbidity(TUB), pH, conductivity(Cond), alkalinity (Alk), total phosphorus(TP), dissolved phosphorus(DP), sulphate, dissolved oxygen (DO), chlorophyll *a* (Chl.*a*), Nitrite –N, nitrate-N and ammonia-N. The correlation between measured limnological variables was assessed using Pearson correlation coefficients.

The study reveals that all the reservoirs are eutrophic in both seasons having total phosphorus level more than 30 µg/l. The highest median TP and DP values were recorded from Wet Zone reservoirs during the dry season. However, reservoirs of other climatic regions show elevated levels of TP and DP during the wet season. The same pattern was observed for nitrite –N, nitrate-N and ammonia-N within the study reservoirs. The elevated levels of dissolved oxygen were observed in Dry, Intermediate and Arid Zone reservoirs during the dry season whereas Wet Zone reservoirs show high values during the wet season. The primary production of the study reservoirs does not clearly indicate a relationship with the pattern of precipitation, however many reservoirs show high levels of Chl. *a*. during the wet season. The conductivity and pH values indicate a clear dilution effect during the rainy season in almost all the reservoirs. Although the measurements of major nutrients, conductivity, DO and Chl.*a* were high in majority of reservoirs during the dry season, DP and turbidly were high during the wet season in all the study reservoirs. Among the measured environmental variables alkalinity did not exhibit a significant difference between the dry and wet seasons. Results of the Pearson correlation analysis indicate positive and significant correlation among the measured environmental variables between dry and wet seasons. Total phosphorus (TP) and Chl.*a*, show positive and significant correlation during both seasons. However no such relationship was observed between DP and Chl.*a*. during both dry and wet seasons.

Accordingly, seasonal climatic changes appear to affect the limnological conditions in the reservoirs in different climatic regions of Sri Lanka. Among the chemical variables, conductivity and pH show high values during the dry season in many reservoirs, while nutrients and primary production were high in wet season.

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WATER QUALITY STATUS IN SOME SELECTED WATER BODIES IN ANURADAPURA DISTRICT

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Physiochemical parameters of water are important factors to identify the status of water quality within an aquatic environment. In this context, the main focus of this study was to determine the level of contamination of water in Rajanganaya Tank, Nachchaduwa Tank, Nuwara Wewa and, Tissa Wewa, which are located in the Anuradhapura District. These four reservoirs provide water for irrigation, domestic use, fish production, and recreational purposes, while enhancing the village environment. However, among these four water bodies, Tissa Wewa serves as the main drinking water source for the Anuradhapura urban area. Therefore, water quality parameters were monitored from February to December 2011 on a monthly basis from seventeen selected sampling locations to identify the current status of these water bodies.

Seventeen water quality parameters were measured for the study. Water temperature, pH, dissolved oxygen (DO), salinity, electrical conductivity (EC), total dissolved solids (TDS) and turbidity were measured in in-situ. Water samples were collected to analyse nitrate - N (NO_3^-- N), nitrite -N (NO_2^-- N), ammonical-N (NH_4^+- N), phosphate, biochemical oxygen demand (BOD), alkalinity, total hardness, chloride and fluoride. In addition, samples were collected for analysis of trace metals. All samples collected were stored at 4 ^{0}C and transported to the laboratory. Analyses of the collected samples were carried out in accordance with the Standard Methods for Examination of Water and Waste Water (APHA), 20th edition. Data analysis was done using Microsoft Excel 2007 and Minitab 14 software to identify the water pollution levels.

Results revealed that pH, DO, EC, nitrate-N, nitrite-N, and chloride were within the permissible limits of drinking, irrigation, and aquatic life according to the proposed CEA Ambient Water Quality Standard for Inland Waters of Sri Lanka (2001) and standards limits of Sri Lanka Standard Institute (SLSI,2003). However, the average BOD and phosphate values were slightly above the standard limits for all uses, and turbidity values exceed the limits of drinking water quality standards set from SLSI. The reason for the high values of phosphate detected could be from inflows of agrochemical residues from agricultural areas.

Average water temperature of Rajanganaya Tank, Nachchaduwa Tank,Nuwara Wewa and Tissa Wewa varied from (32.2±2.0^{o}C) (29.2±1.6^{o}C) (31.6 ±2.4^{o}C) (31.1±2.0^{o}C), fluoride (0.75±0.47 mg/l) (0.43±0.43mg/l) (0.42±0.31mg/l) (0.37±0.34mg/l), total hardness (114.7±31.3mg/l) (147.0±43.4mg/l) (111.8±38.9mg/l) (99.5±32.7mg/l), ammoniacal-N (0.15±0.06 mg/l) (0.18±0.05mg/l)(0.34±0.47mg/l) (0.20±0.06mg/l) and total dissolved solids (28.6± 33.8mg/l)(365.5±172.8mg/l) (181.0± 44.7mg/l) (180.9± 50.0 mg/l).

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ASSESSMENT OF BOTTLED WATER QUALITY IN SRI LANKA

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The bottled water industry in Sri Lanka has flourished over the last two decades, while new brands are often introduced to the market. However, the manufacturers' adherence to bottled water regulations is questionable, raising concerns regarding the quality of bottled water. The objective of the current study was to investigate the microbiological and physicochemical quality of bottled water in Sri Lanka.

Microbiological analysis was carried out with 30 brands of bottled water within 1-3, 3-6, 6-9 and 9-12 months after the date of manufacture. Total coliforms (TC) and faecal coliforms (FC) were enumerated by the Membrane Filtration Technique using M-Endo and M-FC media (Himedia, India), respectively. Bacteria were identified using biochemical tests, and API 20E and API 20NE identification systems. The Heterotrophic Plate Count (HPC) was carried out on nutrient agar and fungi were isolated on potato dextrose agar. Electrical conductivity and pH were measured electrochemically whereas the alkalinity, hardness and the chloride content were determined by titration. Anions and cations were determined by colorimetry and atomic absorption spectrophotometry respectively. A further study was carried out with 36 brands of bottled water to detect *Pseudomonas aeruginosa* by the Membrane Filtration Technique using cetrimide agar as a selective medium.

The results indicated that 63% of the brands tested exceeded the levels permitted by the Sri Lanka Standards Institution (SLSI) for presumptive TC (< 10 cfu per 100 mL), whereas 97% brands exceeded the World Health Organization (WHO) permitted level. Thirty percent of brands exceeded the limit for presumptive FC (0 cfu per 100 ml in accordance with WHO permitted levels, SLSI and the Sri Lanka Health Ministry requirement). Eighty percent of brands showed higher HPC which exceeded the WHO guidelines for bottled drinking water. Throughout the shelf life, the counts of TC, FC and HPC bacteria decreased.

Bacteria identified were *Klebsiella pneumoniae* spp. *pneumoniae, Enterobacter cloacae*, *Pseudomonas aeruginosa* and *Pasteurella haemolytica*, the most frequently being *P. aeruginosa*. *Escherichia coli* was not detected in any of the samples tested.

The dominant fungi identified were *Aspergillus* sp. and *Penicillium* sp. Physicochemical parameters were within permitted levels for all brands, except for initial content of ammonia which was higher than the permitted level. *Pseudomonas aeruginosa* was isolated from 50 % of the brands tested. According to procedures carried out as in ISO 16266:2006 for *P. aeruginosa*, a confirmation rate of 58% was obtained from 186 randomly selected isolates investigated. Although *P. aeruginosa* is a quality parameter for natural mineral water according to SLSI, it is not included for bottled drinking water standards. However, according to European Union water criteria, *P. aeruginosa* should be absent in 250 ml for bottled water.

The results of the current study showed that most of the brands exceeded the permissible levels for microbiological parameters, raising concerns over the microbiological quality of bottled water in Sri Lanka. The chemical quality of bottled water was within accepted standards. There is a need for the bottled water industry to

be monitored closely by relevant authorities, and reassess the standards currently stipulated, in order to provide safe bottled drinking water to consumers in Sri Lanka.

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USE OF WATER QUALITY INDEX (WQI) TO ANALYSE POTENTIAL WATER QUALITY THREATS TO GROUND WATER AT NAWAKKADUWA GN DIVISION IN KALPITIYA

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Kalpitiya is the main peninsula in the North Western Province in Sri Lanka. Its Divisional Secretariat Division (DSD of Kalpitiya) has 33 Grama Niladhari (GN) Divisions. The major income sources of the area are agriculture and fishery. Its soil is dominated by 99.96% of sand and 0.04% of clay. Annual mean rainfall of the area is 955 (mm/y), and ground water occurs as a lens floating on the saline waters. The study area of the present project is the Nawakkaduwa (GN No. 605) with a land extent of 3.3 km^2 and with a population of 1839 (in 2009). There are 506 families including 403 agricultural families. The water resources of the area consist of 202 agricultural wells, 36 domestic wells and 137 other sources.

This area is suffering from drinking water quality problems due to extensive agriculture, livestock practices, poor sanitary conditions and soil and climatic characteristics. As a result, the availability of suitable water sources for domestic consumption is scarce. The rate of water intake per unit area is high and excessive use of ground water has caused intrusion of saline water and high leaching rate of pollutants into the ground water aquifers.

The objective of the present study was focused on the following aspects:

1. Interpretation of the status of the ground water quality in Nawakkaduwa area as a case study using a mapping technique (Interpolation of water Quality Index values obtained).
2. Development of a Sri Lankan Water Quality Index criterion (SLWQI) based on the Canadian Water quality Index criterion (CWQI) to calculate the WQI values for Kalpitiya.
3. Development of a WQI map to interpret the water quality risks distributed in the selected areas with domestic wells which could be used in conservation of water resources by identifying sensitive areas of pollution.

The sampling locations at Nawakkaduwa GN Division were selected based on the land use practices and the locations of domestic wells used by the villagers. GPS points were taken from all the sampling points and sampling was conducted twice a month. Conductivity, pH, turbidity were measured at the sampling point and other parameters were measured in the laboratory. The maximum permissible level for each parameter was decided using SLS 614:1983 to calculate SLWQI for each sample. Final results were described using a GIS map to interpret the data.

In the present study, the development of the WQI was based on the criterion used in the Canadian WQI which is based on a combination of three factors:

- The number of variables whose objectives are not met (scope) – F1
- The frequency with which the objectives are not met (frequency) – F2

- The amount by which the objective is not met (amplitude) – F3

Combining all water quality parameters, the water quality index produces a number between 0 and 100, where 0 represents the "worst" water quality and 100 represents the "best" water quality. This WQI helped to map the WQI values in the area using an interpolation technique of GIS. It helps the water managers and decision makers to read this map and to get an idea about the status of water quality to recommend conservation measures in land use practices and to decide suitable areas for the different purposes such as agriculture, domestic use, aquaculture, livestock, recreation, etc.

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BACTERIOLOGICAL QUALITY OF DIFFERENT WATER SOURCES IN SRI LANKA

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The rural community of Sri Lanka obtain their drinking water mainly through ground water wells (66%), springs (7%) and surface waters such as rivers and lakes (2%) while only 25% have access to tap water (WHO/UNICEF, 2010). Since most of these water sources are not properly disinfected or treated before consumption, the bacteriological quality of water is of concern as they can harbor potentially pathogenic organisms leading to outbreaks of water born diseases. Therefore, this study was aimed to assess the bacteriological quality of different water sources and to identify the possible pathogenic bacteria present in those waters.

Samples were collected from 20 shallow wells (depth: 10-20 m), 20 streams and 7 lakes from 5 provinces of Sri Lanka and analysed (in duplicate) for the occurrence of bacteriological contamination (from July 2008 to June 2009). Total coliforms (TC) and *Escherichia coli* (EC) were enumerated by the Membrane Filtration Technique using M-Endo and M-FC media (Himedia, India) respectively (SLS 614, 1982). Bacteriological identification was conducted using biochemical tests (Holt et al., 1994) for pure cultures on Tryptic Soy Agar (Oxoid, UK) plates.

Mean bacteriological counts obtained for all water sources exceeded the WHO permissible levels (WHO, 2008) for both TC and EC (Figure 1). TC and EC counts ranged between (10^2-10^4 cfu/100 ml) for well water samples, having the broadest spectrum of bacteria among all water sources including 5 fecal coliform spp., 3 TC spp. and 8 non-coliform species. Identification of potentially pathogenic Enterobacteriaceae spp. namely *Klebsiella pneumoniae*, *Klebsiella pneumoniae* spp. *Pneumonia, Klebsiella oxicota*, *Enterobacter sakazaki, Citrobacter braakii* and *Citrobacter freundii* and the non coliform spp. such as *Pseudomonas* (3 spp.) *Aeromonas* (3 spp.) *Salmonella* (3 spp.) and *Acinetobacter* sp. in drinking well waters is of concern. It is suspected that the pollution may be due to faecal contamination through contaminated subterranean water flow (through the toilet pits built closer to the wells), heavy rainfall and the sloping terrain patterns and the higher abstraction rates. As disinfection of well water is not practiced in Sri Lanka, boiling before consumption would be a safe way of using well water for drinking purposes.

Surface water samples used for drinking and bathing purposes in Sri Lanka were also heavily contaminated with TC (10^2-10^6 cfu/100 ml) and EC (10^1 to 10^5 cfu/100 ml) respectively (Figure 01). Samples contained potentially pathogenic five Enterobacteriaceae spp. belonging to three genera *Klebsiella*, *Escherichia* and *Citrobacter* and the non coliform spp. such as *Pseudomonas* (3 spp.), *Aeromonas* (2 spp.), *Salmonella choleraesuis* ssp. *arizonae* and *Acinetobacter* (2 spp.). Since 1.8% of these surface waters are consumed without any treatment, there is a potential for water

borne disease outbreaks. Further, these sources are also being used as water intakes for drinking water supply schemes by the National Water Supply and Drainage Board and other small community water supply schemes in the country. However, the conventional treatment methods used for purification might not be able destroy all pathogenic organisms. Therefore, proper management and maintenance of both the surface water bodies and watersheds through government mediated community participation could be recommended. In addition, proper sewage treatment facilities should also be introduced to ensure the bacteriological quality of fresh water bodies.

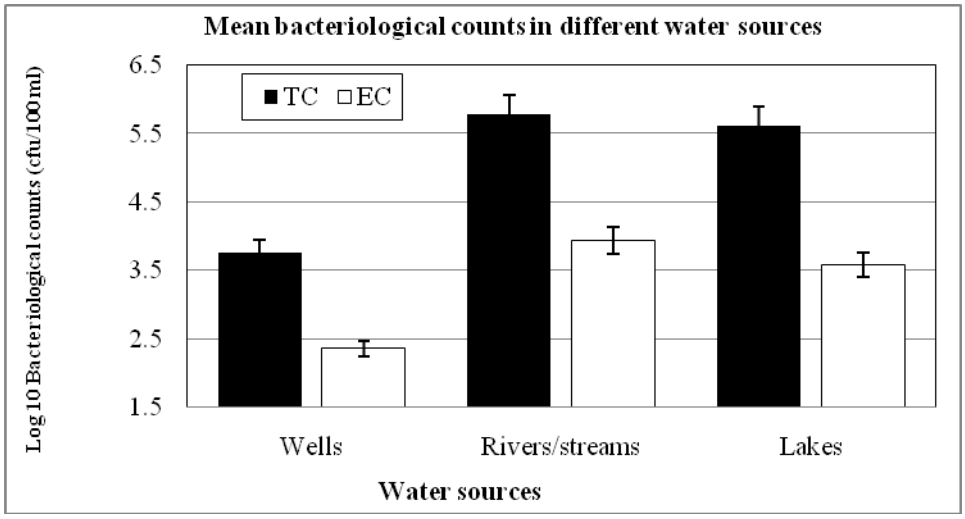

Figure 1. Mean bacteriological counts obtained in different water sources

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AN ASSESSMENT OF HEAVY METAL CONTAMINATION IN MARINE SEDIMENTS OF GALLE HARBOUR, SRI LANKA

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Most of the pollution by heavy metals began with the industrial revolution at the end of the 19th century. As a consequence the fluxes of many trace elements from terrestrial and atmospheric sources to the aquatic environment have increased significantly. After entering the aquatic environment, trace metals are distributed among water, biotic and sediment compartments. Sediment distribution depends on the physical, chemical and biological properties of the sediments. Heavy meals are one of the more serious pollutants in our natural environment due to their toxicity, persistence and increased concentrations associated with bioaccumulation.

Nine metal species (Cu, Hg, Pb, Ni, Cd, Zn, Fe, Mn, and Cr) were analyzed in the marine sediments of inner Galle harbor before initiation of the dredging activities. Sampling sites were selected considering the activities associated with navigation, fisheries and drainage from urban areas. Due to the disturbed nature of the water column, sediment cores were used to collect the samples with the assistance of a trained diver.

Microwave digestion and slurry preparation methods were used independently for the sample preparation. Higher metal recoveries were obtained from the microwave digestion method. Analysis was done by flame and graphite furnace atomic absorption spectroscopic methods. Australian and New Zealand interim sediment quality guidelines (ISQG) were used to evaluate the sediment quality of the selected locations. Some sites had Ni and Pb concentrations higher than the ISQG value. Dramatically all the sediments were polluted with Hg. According to the metal pollution index, sediments collected from the entrance to the inner fisheries harbour was determined as the most polluted site of examined heavy metals. According to the Hg contamination, it was strongly recommended that the dredged sediments of the inner harbour should not be disposed to sea without carrying out proper assessment. Moreover, other possible contaminants such as polychlorinated byphenyls (PCBs), Organohalogens (eg. Organochlorines - OCs) should also be examined prior to the disposal of the dredged sediments. Concentrations of metals from sediments can be used as a starting point to develop Sri Lankan sediment quality guidelines which will assure the safety of our environment more realistic manner.

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RAPID ASSESSMENT SURVEY TO DETERMINE CURRENT STATUS OF WATER QUALITY IN PUTTALAM LAGOON, GIANT'S TANK AND AKURALA WATER BODIES

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Water quality parameters are an important observation that would reveal the current conditions within a catchment and downstream waters. They would assist in understanding the potential impacts on the system if there is any change in conditions. Hence, this rapid assessment is an initial attempt to understand how the water quality of the system may change if the area is altered for commercial utilisation. Therefore, the main objective was to study the current status of water quality to identify the aquatic health of selected eco-systems, such as the Puttalam Lagoon, Giant's Tank in Mannar and Akurala during the year 2011.

The following physico-chemical parameters were selected for this study to ascertain the quality of water and to ascertain changes and effects. In-situ analyses were conducted for the determination of pH, which was measured using a pH meter (Orion 260A), conductivity, measured using Hanna portable multi range conductivity meter (HI 8733), dissolved oxygen (DO) concentration, measured using a portable meter (Orion 830A), and turbidity, measured using portable meter (Hach 2100P). In addition, electrical conductivity (EC), total dissolved solids (TDS) and salinity were measured at the site, during the time of sample collection. Furthermore, laboratory analysis was carried out in accordance with the Standard Methods for Examination of Water and Waste Water (APHA), 20th edition.

According to the results of the Puttalam Lagoon, pH, DO, chlorophyll *a* and nutrient parameters are within the accepted limits for the fish and aquatic life. However, TSS (8.5 ± 4. mg/l), Turbidity (6.9 ± 2.6 NTU) and TDS (23.2 ± 2.7 mg/l) indicated slightly high values. The assessed water quality parameters of Giant's tank indicated that DO, EC, Nitrate-N, hardness, alkalinity, turbidity and BOD were within the acceptance range proposed by the CEA, in 2001. However, the pH and phosphate level that fell slightly above the ideal pH range and the maximum phosphate level presence of soils consisting of sandy clay to sandy clay loams which contain carbonates of calcium, sodium and manganese oxide could be a reason for high pH values (8.48 ± 0.49) recorded within the water body. High concentrations of phosphate (0.87 ± 0.40 mg/L) are possibly due to the discharge of agricultural inputs from the surrounding area.

Results of the Akurala water body revealed that, pH and nitrate-N, were within the ideal levels proposed by the CEA for fish aquatic life. However, the phosphate (0.45 ± 0.18 mg/L) level was slightly above the maximum recommended value of the above standards. Average DO (4.82 ± 0.37 mg/L), EC (630 ± 60.0 mS/cm), TDS (341 ± 25 g/l), ammoniacal–N (0.24 ± 0.15) respectively. Elevated TDS and EC values may due to higher number of ions present in salt water and the presence of limestone in the bed rock which leads to the dissolution of carbonate minerals.

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SEASONAL VARIATION OF MANGANESE SPECIES IN MURUTHAWELA RESERVOIR: A DRINKING WATER RESOURCE IN HAMBANTOTA DISTRICT

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Manganese is an essential trace metal, However, it has direct toxicological effects, as it can influence the concentration of other elements, including toxic heavy metals in surface water. Mn follows similar oxidation-reduction reactions as iron, and Mn ions are oxidised during water treatment. However, after treatment of reservoir water higher levels of Mn species have been detected in some instances. The objective of this study was to monitor the Mn concentration in a drinking water reservoir including seasonal variations and possible reasons for such variations.

Muruthawela reservoir, a large reservoir with the surface area of 516 ha is located at 6° 12/ 20// N and 80° 43/ 29// geographical locations in the Hambantota district, was selected as it is located in an area where seasonal rainfall pattern is comparatively clear Mn was quantified by Atomic Absorption Spectrometry. The results were obtained during a three-month period from early November 2010 to end of January 2011. In addition pH and dissolved oxygen levels of water bond by were obtained fortnightly as they may be related to changes in Mn concentrations.

Results show that there were no significant differences in the concentrations of dissolved and un-dissolved Mn between sampling sites. However, there is an observable variation in both dissolved and un-dissolved Mn over the study period. When the highest concentration of Mn available in water body as dissolved Mn was considered, the lowest concentrations were recorded from bottom sediments suggesting leaching from the sediments. The possible reason for the leaching is likely due to the change in pH. The relationship of pH with Mn concentration in sediment and water is shown in Figure 2.

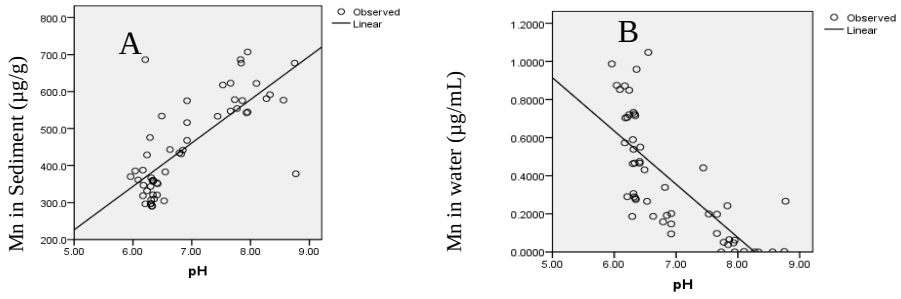

Figure 1: Correlation of un-dissolved Mn (A) and dissolved Mn (B) with respect to pH

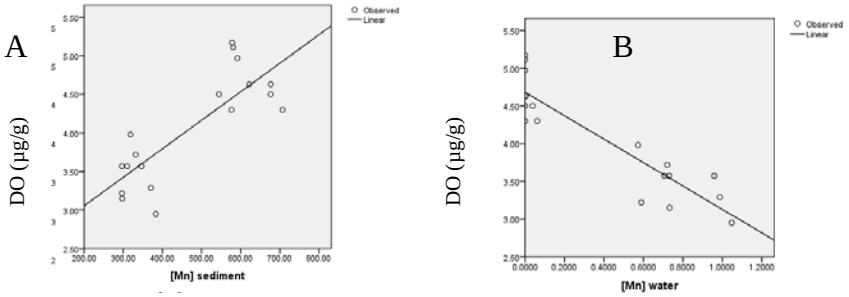

Figure 2: Correlation of dissolved oxygen (DO) with [Mn] in sediment (A) and in water (B)

The Mn concentration in water and sediments shows different relationship with the dissolved oxygen contents in water (Figure 2). The migration of dissolved Mn into sediment layers generally occurs by precipitation as the hydroxide form or by chelating with fine dissolved organic particles available in water. Therefore, a high pH condition supports dissolved Mn species to precipitate and for this precipitation, dissolved oxygen is consumed. Similarly at low pH conditions, the Mn concentration in dissolved form is higher because the acidic condition supports dissolution of Mn from sediment and increases the dissolved oxygen level. In conclusion, it can be revealed that the seasonal rains acidify the water body and dissolve the precipitated Mn to increase the Mn level in water body. During the dry season, the pH of water increases and dissolved Mn species precipitate as hydroxide increasing Mn level in sediments. Due to this phenomenon, Mn concentration of treated water exceeds the maximum desirable levels during rainy seasons.

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PRELIMINARY STUDY ON VARIATIONS OF WATER QUALITY IN SELECTED WATER BODIES IN THE ANURADHAPURA DISTRICT

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Historically, irrigation tanks have been used by humans for various purposes, such as drinking, washing, and agricultural activities and for fisheries in Sri Lanka. Higher density of tanks is distributed in the dry zone of Sri Lanka and human dependence on such water bodies is very high. The Chronic Kidney Disease of unknown atiology (CKDu) prevailing in the North Central Province (NCP) is suspected to have an association with the water quality of the area. However, empirical data to support such an association are scant. The present study aims at evaluating water quality parameters of selected tanks in the Anuradhapura district and to find out their associations with human health issues prevailing among communities living around the tanks.

Physical, chemical and biological water quality parameters of Rajanganaya Wewa, *Nachchaduwa Wewa, Nuwara Wewa and Tissa Wewa in the Anuradhapura district were* evaluated from October to December 2011. Water quality parameters such as temperature, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), turbidity, salinity alkalinity, ammonia, nitrates, phosphates, chlorides, fluorides, total hardness, Zn, Cd, Mn, Fe and phytoplankton were recorded for each tank. In addition, a questionnaire survey was conducted using 139 families around the periphery of selected tanks to gather information on land use, public health issues and tank water utilisation patterns among the surrounding community.

The water quality parameters recorded from the four tanks indicated that most parameters are within the acceptable levels for drinking purposes and for irrigation purposes. However, a significant monthly variation of the water quality parameters was recognized in all tanks. In all tanks, blue green algae *Microcystis* and *Osillatoria* were predominant. Some water quality parameters (conductivity, pH, total hardness, alkalinity, Zn, Cd, Mn and Fe) of Nachchaduwa Wewa showed significant differences from the other tanks. The questionnaire survey revealed that the CKD prevalence among communities around the tanks is considerably low and water from the tanks is predominantly utilised for agriculture and to a lesser extent for drinking purposes.

The findings of this study revealed no clear association between the water quality of tanks and public health issues of the surrounding communities. However, further studies on long-term water quality variation of tank water, contaminants in sediments and food sources from tanks would be needed for better estimation of the impact.

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ANTHROPOGENIC CONSEQUENCES ON FISH POPULATION DYNAMICS IN A MAJOR WETLAND OF CHENNAI, INDIA

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Chennai is the 34th largest metropolitan city in the world, and is set to expand its boundaries further with the advent of the Greater Chennai Plan. The city's landscape is characterised as a mosaic of coastal plains, small pockets of scrub forests and extended wetlands. Despite an annual average rainfall of 1280 mm, the city is known for severe shortage of freshwater. Unplanned and adhoc urbanisation patterns, largely through reclamation of wetlands is believed to be the primary driver of the water shortage. For instance, over the last twenty years, 12 significant wetlands have been lost to anthropogenic activities such as reclamation, sanitary landfills and discharge of sewage. A further consequence of development is the detrimental impact of anthropogenic activities on population dynamics of fish.

The present study was undertaken to assess the physico-chemical characteristics of water on fish population dynamics in Chembarambakkam Lake, Chennai, which recharges the ground water as well as showing a diversity of plant and animal life. This lake suffers from anthropogenic activities including the dumping of wastes and unchecked inflow of domestic and industrial effluents. The variables studied were: colour, temperature, pH, dissolved oxygen, biological oxygen demand, chemical oxygen demand, alkalinity, total hardness, total solids, total dissolved solids, total suspended solids, sulphate, chloride and salinity. In the Chembarambakkam Lake, community structure characteristics of six selected fish species was investigated across seasons. Population dynamics due to physico-chemical variables were assessed. Results show that the total number of individuals of fish observed varied from year to year (2007>2009>2008). Water quality, primarily, total hardness and pH, apparently played a negative role in determining the fish population size. Conventionally monitored pollution variables like sulphate, biological oxygen demand, total dissolved solid and total suspended solid were negatively correlated with the number of individual, thereby highlighting the disastrous consequence of detrimental anthropogenic activities on wetlands and their biological diversity.

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PREVALENCE OF TOXIGENIC CYANOBACTERIA IN DIFFERENT CLIMATIC ZONES OF SRI LANKA

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Cyanobacteria is an important group of prokaryotes among the phytoplankton in aquatic ecosystems. This group occurs in every kind of water body such as fresh, brackish and marine and shows a cosmopolitan distribution. They form algal blooms under extreme environmental conditions which favor their growth and some of them have the ability to produce cyanotoxins. Health problems arising due to cyanotoxins have drawn attention on toxigenic cyanobacteria. About 40 species of cyanobacteria belonging to 24 genera have been reported so far from Sri Lanka's reservoirs (Silva,1999). However, *Anabaena, Aphanizomenon, Cylindrospermopsis, Lyngbya, Microcystis, Nostoc, Nodularia* and *Oscillatoria* are recognised as the most important genera having toxigenic species (Perera et .al. 2011). Throughout Sri Lanka, there are about 10,000 man made lakes that periodically experience extreme dry conditions which lead to eutrophic conditions. Under such conditions cyanobacterial blooms occur in these euptrophic or hypoeutrophic reservoirs. The current study explored the prevalence of toxigenic cyanobacteria in the Sri Lankan reservoirs located in the different climatic zones (dry zone, arid zone, intermediate zone, wet zone and upland wet zone) of Sri Lanka.

Sampling was done from 20 reservoirs belonging to the five different climatic zones. Plankton sampling was done using 10 µm net and Lugol's iodine solution was used to preserve cyanobacteria. Limnological variables were also measured using portable field instruments and laboratory analysis.

According to the results, the highest diversity of cyanobacteria was recorded from the dry zone reservoirs while the lowest was recorded from the intermediate zone. The highest toxigenic cyanobacetrial diversity was recorded from the Ridiyagama tank in the dry zone while the lowest diversity was from the Kandy lake in the wet zone. Almost all the upland wet zone reservoirs show a high diversity of cyanobacteria including all the toxigenic species. During the driest period (August – September,2011), lake Gregory was completely dominated by *Cylindrospermopsis raciborskii*, and this is the first recording of this species from the upland wet zone.

Limnological variables indicated that the Ridiyagama tank has extreme environmental conditions. The total phosphorus level reached 399 µg/l during the high drought period, which is well above even hypereutrophic conditions. In addition, dissolved phosphorus was about 12.3µg/l. Nitrate-nitrogen, nitrite-nitrogen and ammonia-nitrogen were 0.24 mg/l, 0.11 mg/l and 0.65 mg/l, respectively. However, dissolved oxygen was 8.01 mg/l at the surface of the water column during the daytime showing high photosynthetic activity. Water temperature averaging of 30°C was also conducive for the growth of cyanobacteria. In the Kandy lake the total phosphorus, nitrate-nitrogen, nitrite-nitrogen and ammonia-nitrogen were 572 µg/l, 3.23 mg/l, 0.64 mg/l and 0.59 mg/l, respectively. However, dissolved oxygen was 6.08 mg/l at the surface of the water column during the daytime showing a lower photosynthetic activity than that in the Rididyagama tank. It also showed a lower average temperature value of 26.2 °C which promotes a lesser growth of cyanobacteria. As Kandy lake has high total

phosphorus level and nitrogen species, there should be an another accelerating factor of the well growth of cyanobacteria , specially the toxin producing species.

According to the analysed data, the most common toxin producing cyanobacterial species in the Sri Lankan reservoirs are *Microcystis* sp. in the wet zone and *Cylindrospermopsis raciborskii* in the dry zone.

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THREATS TO THE INDIGENOUS FRESHWATER FISHES IN MALWATU OYA IN ANURADHAPURA AREA OF SRI LANKA AND REMARKS ON THEIR ABUNDANCE

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Malwatu Oya (Tamil: Aruvi Aru), which begins 766 m above sea-level from the highest mountain (Ritigala) in the North Central dry plains is a 164 km long river connecting the city of Anuradhapura to the coast of Mannar, Sri Lanka. It feeds several perennial reservoirs among which Nachchaduwa (866 – 90 AD), a large perennial man-made lacustrine reservoir, which lies just outside the city of Anuradhapura is significant. Lotic environment is the ideal ecosystem for different species of local fish, which are evolutionarily adapted to breed and live. Due to interconnected canals and cascade systems, both indigenous and exotic fish species dwell in Nachchaduwa reservoir. A study was carried out to find out the co-habiting fish species (both indigenous and exotic) in Malwatu Oya in Anuradhapura area.

Labeo rohita, *Mystus* spp, *Puntius* spp and *Oreochromis* spp were the prominent fish species found in the study area of Malwatu Oya. More than more than 95% of the indigenous fish could be observed in runs and riffles, while the *Oreochromis* spp were abundant in pool areas. Examination of existing coercion recommends that deforestation, extensive dispersion of exotic species, pollution caused by agro-chemicals and growing pressure from the food fishery in adjoining Nachchaduwa reservoir cause greatest threats to indigenous fish populations in Malwatu Oya. *Oreochromis* population is very significant and it is the major fish species in Nachchaduwa reservoir. *Oreochromis* spp could also be observed in large numbers in 06 adjoining canals that bring water to Malwatu Oya. Indigenous fish populations are higher in Malwatu Oya before the Nachchaduwa inlet and exotic population is higher in the river after the Nachchaduwa spill. Indigenous fish species were found to be higher in areas of the lotic water body where the water is less polluted. Nevertheless, *Oreochromis* spp could be observed in all these areas.

The present study indicates that anthropogenic activities in the area and exotics that have been introduced for fishery in man-made reservoirs have a significant influence to the local fish population of Malwatu Oya.

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SEASONAL INFLUENCE OF WATER QUALITY OF BATTICALOA LAGOON, SRI LANKA ON FISH AND PLANKTON ABUNDANCE

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Assemblage of lagoon organisms varies in time and space, largely because of widely varying environmental characteristics prevailing in the lagoon. This study is aimed to assess the impact of water quality of the Batticaloa lagoon in relation to changes in fish and zooplankton abundance. *In situ* measurements of chemical and physical parameters of the lagoons were recorded fortnightly by calibrated portable water quality Hanna instruments over wet and dry seasons for 15 months from July 2008 to December 2010. Standard methods were used to collect the fish and zooplankton samples from the Batticaloa lagoon.

Dissolved oxygen (4.15 ± 0.40 to 15.66 ± 0.24 mg/L), salinity (8.10 ± 1.35 to 30.16 ± 0.23 ppt), nitrate (2.07 ± 0.22 to 3.71 ± 0.72 mg/L) and pH (8.01 ± 0.02 to 8.16 ± 0.05) showed significant seasonal variation. Analysis elucidated that the existing conditions were found to have strong impact on fish community. Comparatively, a higher number of species was recorded in the dry season than in the wet season. However, there was little variation in species composition with respect to seasons, despite variations in river discharge, salinity and nutrient content. Out of 28 families of 42 species sampled, 4 species were restricted to wet season, while 5 species occurred in both seasons such as the families Mugilidae, Clupeidae and Cichilidae. Seasonal differentiation of all species sampled revealed higher values for the dry season compared to the wet season.

Two holoplankton groups of species increased in abundance during the wet season, while about 4 species lack seasonality. The majority of zooplankton species of the Batticaloa lagoon are typical of strongly brackish water although the northern part of the lagoon shows a mixture of marine species and brackish water. Most of the dominant species of phytoplankton were not considered as harmful and dangerous for human health. However, certain species of *Anabaena*, *Microcystis*, *Oscillatoria* are known to produce certain neurotoxins, hepatotoxins and endotoxins. In addition, *Amphidinium* sp also observed in the lagoon produce biologically active haemolytic compounds and may be implicated in ciguatera (phytotoxin). These have to be viewed as a threat to lagoon food safety. This information enables natural resource managers to determine whether our lagoons are under stress and where to invest in environmental management activities. It also helps State Government agencies to address issues related to monitoring, evaluation and reporting.

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STUDY ON SEASONALITY OF CHIRONOMIDS RELATED TO CLIMATIC FACTORS AND WATER QUALITY IN THE WATER SUPPLY TO THE EASTERN UNIVERSITY HOSTEL.

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Chironomids are important aquatic organisms in the world which cause serious health impacts to humans. The removal of Chironomid larvae (blood worm) from water has become one of the most important, and it is very difficult to remove them effectively by conventional methods. It is essential to study the seasonality of Chironomids and the factors influence in its abundance to implement proper controlling techniques to minimise the larval problem in the water. Therefore, the present study focuses on seasonal variation of Chironomids in the Hostel water supply of the Eastern University in relation to climatic factors and water quality.

The seasonal variation and abundance of Chironomids were studied by weekly counts of the immature larvae in the tap water for one hour. High abundance of Chironomids was observed from May to August, a low abundance in January to April and very low or nil in September to December. The high abundance was observed in dry season and very low abundance in wet season. It was identified that the seasonality of Chironomids is related to climatic factors particularly the temperature and rainfall.The change in maximum temperature has an overall positive effect on the abundance of Chironomid population in the water supply rather than the minimum temperature.Rainfall has a negative effect on the abundance of Chironomids. It was identified that the seasonality of Chironomids affected by the combination of these factors and chlorination.

The study of the water quality was carried out by measuring some selected parameters. The water quality was measured randomly during the period of high abundance notified by the students in the hostel. The mean value of the nitrate content in this water was desirable for bathing (2.7±0.14142mg/l) and the mean value of the phosphate content of this water was very high (0.2±0.081649mg/l).This study suggests that the water is polluted and the water quality parameters have an impact on the abundance and seasonality of Chironomids in the Eastern University Hostel water supply.

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IDENTIFICATION OF THREATS, DISTURBANCE AND DEVELOPMENT OF COMMUNITY- BASED MANAGEMENT FOR FISHERY RESOURCES IN THE KALAMATIYA LAGOON

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Kalametiya lagoon is located in the Southern coastal belt in the Hambantota district of Sri Lanka and has been identified as a coastal wetland. This wetland consists of a brackish water body of which edge is covered with mangroves and salt marshes and is separated from the sea by a narrow strip of beach. This area consists of eight local-level administrative or Grama Niladari (GN) Divisions, of which the Gurupokuna GN Division falls under the Tangalle Divisional Secretariat (DS) Division and the others under the adjacent Ambalantota DS Division. Fisheries are the main resource in the Kalamatiya lagoon. In the past, the lagoon was very popular for fishing activities, which was disturbed due to mismanagement. The average depth of the lagoon has decreased due to the influx of large quantities of sediments. Further, many direct threats and disturbance occur due to various kinds of human activities disturbing the lagoon.

The main aim of this study was to assess threats, opportunities, utilization and management of fish resources in the Kalametiya Lagoon. Specific objectives are interpretation of data, preparing a leaflet on the Kalamatiya Lagoon conservation and propose an environmentally friendly community-based management plan.

Primary data were collected from the peripheral community and visitors, both local and foreign, by questionnaires and interviews. Secondary data were collected mainly from researchers. Finally, data were qualitatively analysed and an environmental friendly community-based management plan was prepared.

This lagoon was affected by the Tsunami event in 2004, and both local and foreign visitors have decreased since this event. Main threats and disturbances identified by research were: waste disposal, decrease in fish population, increase in usage of fertilisers and insecticides, increase in water pollution, low awareness among communities, negative impacts of tourism, and increased sedimentation with sand and silt reducing the depth of the water level, and limited institutional capacity. Further, most of the fishermen moved from inland fisheries to marine fishing activities. The lack of institutional coordination, fisheries management handling problems and illegal activities could be identified as the major environmental impacts during this study. Therefore, immediate action is necessary for proper management of this lagoon.

According to the results of the study, it is evident that inadequate management of fisheries in this lagoon causes threats and disturbance issues to the community who live in the surrounding areas of the lagoon.

Many opportunities can be obtained by implementing effective community participation programmes. An integrated multidimensional approach is required to address the complex problems associated with the lagoon.

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INVASIVE AQUATIC PLANTS IN MIHINTALE SANCTUARY: PRELIMINARY STUDY

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Invasive aquatic plant species have a great impact on the aquatic ecosystem. Hence, this study was conducted to determine the abundance of aquatic invasive plants in three selected tanks within the Mihintale sanctuary, a vital ecosystem located in the Anuradhapura district.

Three seasonal tanks *viz.*, '*Kaludiya pokuna*', '*Kudakirindegama*', and '*Ihalamudawa*' tanks were surveyed. The transect method was adopted and vegetation was sampled using a 1 m x 1 m quadrate along a 30 m transect at 5 m intervals. The 30 m transect was located from the land edge of the tank to its center. Four such random transects were used in each tank. Braun-Blanquet cover-abundance scale was used to measure the abundance of invasive aquatic plants. Information regarding awareness on invasive plants, history of introduction, utilisation and current control measures were also obtained by interviewing 60 residents, using a structured questionnaire.

Three invasive alien plants viz., *Hydrilla verticillata, Salvinia molesta, Typha anguistifolia* and 2 native invasive plants species viz., *Nelumbo nucifera* and *Ipomea aquatica* were recorded during the survey. Of them *H. verticillata* (40%) and *N. nucifera* (42%) were recorded as co-dominant species based on cover values, followed by *S. molesta* (35%), *Ipomoea aquatica* (28%), and *T. anguistiolia*(25%). Highest abundance of *H.* verticillata (52%) and *S. molesta* (40%) were found in '*Kaludiyapokuna*' tank while dominance of *N. nucifera* (68%) and *T. anguistiolia* (40%) were highest in '*Kudakirindegama*' tank. *Salvinia molesta* was absent in '*Ihala Mudawa'* tank where the abundance of *Hydrilla verticillata* (28.8%) was relatively high. Further, *Ipomoea aquatica* (28.3%) was found only in the '*Kudakirindegama*' tank. Among the 60 interviewees, (40%) stated that they have used *S .molesta* as green manure while (25%) had utilised invasive aquatic plants as food and (5%) mentioned that they used *T. angustifolia* for purposes of weaving. About (60%) stated that fishing activities and navigation were seriously affected by invasive aquatic plants such as *S. molesta*, and *N. nucifera*, while (5%) stated that bathing was unpleasant when plants such as *H. verticillata* and *S. molesta* were present. Another (35%) considered them as weeds while (82%) considered these invasive aquatic plants as competitors. (56%) of the respondents eradicated them by burning, and (24%) used manual/ mechanical methods. Another (18%) reduced the density of these plants by using them as fodder or fertilisers. The majority of respondents (87%) believed that, invasive aquatic plants were established with introduced fish varieties to these water bodies.

In conclusion, invasive plant diversity and their distribution are relatively high in Mihintale sanctuary. They were found in greater abundance near the edge of the tanks and hence can lead to transform water bodies into lands. Therefore, it is recommended that serious and immediate attention be given to this problem.

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BACTERIOLOGICAL CONTAMINATIONS OF DRINKING WATER: A CASE STUDY AT RAJARATA UNIVERSITY OF SRI LANKA, MIHINTALE

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In Sri Lanka, only 67% of the human population have access to safe drinking water. In the North Central Province, contaminated water has become a leading cause of death (Bandara *et al*., 2008). This study was designed to assess the microbiology of bottled (volume 20, 5 and 1 liters) and tap water, available at the Rajarata University of Sri Lanka (RUSL) and to determine whether the measured microbiological parameters are within the permitted levels to ascertain the safety. Variation of the contamination levels in bottled water with storage time was also assessed.

Microbiological and physico-chemical parameters (pH, BOD, DO, conductivity, colour, odour and chlorine level) were analysed in bottled and tap water samples as mentioned in the SLS specifications continuously for five months (SLS 894, 2003; SLS 614, 1983). Heterotrophic plate counts (HPC) were determined by the pour plate method and the total and fecal coliform bacteria were determined by the membrane filtration method as described by the SLSI (SLS 614, 1983). Samples were also analysed for the presence of fungi. Sterilized distilled water and *Escherichia coli* inoculated water were used as negative and positive controls respectively. The differences between the counts were considered significant when $p < 0.05$. Mean comparisons between different sources were considered significant when $F > F_{Critical}$.

HPC was highest in the 20 L bottles (Figure 1), possibly due to the improper sterilization during refilling. Tap water showed the lowest HPC due to re-chlorination at RUSL. HPC increased significantly ($F > F_{Critical}$) in 20 and 5 liter bottles, while the HPC increase was not significant ($F < F_{Critical}$) in 1 L bottles and in tap water samples. This increase of HPC could be due to the growth of pre-contaminated bacteria in bottles. The difference of the HPC between the [5 and 1 liter] bottles and between [5 L bottles and tap water samples] were significantly different ($p < 0.05$). Therefore, more concern should be made when consuming 20 L and 5 L bottles. During this study, the total coliform counts in all bottled and tap water samples increased exceeding the permissible levels with time (Figure 2). None of the bottled and tap water samples were positive for faecal coliforms in this study which might be due to the low sensitivity of the method adopted which is based on lactose fermentation. Some fungi such as *Penicillium* spp. and *Mucor* spp. were observed on the PDA plates of 20 and 5 liter bottles.

Physical parameters tested were below the permissible levels. Although the chlorine level (0.05 mg/L) in tap water was within the permissible level, it was lower than the minimum (3.5 mg/L) recommended by the SLSI. This may be due to the distance between the treatment centre at Anuradhapura and the University. Therefore, rechlorination process should be properly monitored at RUSL.

The study showed that only the HPC of the tap water meets the SLS standards, while total coliform counts exceeded the standards in both bottled and tap water at RUSL. The increase of HPC and the total coliform counts in bottled water with time indicates a direct relationship with microbiological quality and the storage time.

Therefore, a proper surveillance system should be maintained during their shelf life. According to the results, it can be concluded that the tap water is microbiologically safer than the 20 L and 5 L bottled water if properly boiled. However, the scope of current study does not address in in detecting chemical parameters, cyanobacterial toxins and the viruses in the drinking water. Therefore, these contaminants should also be considered during future studies in this regard.

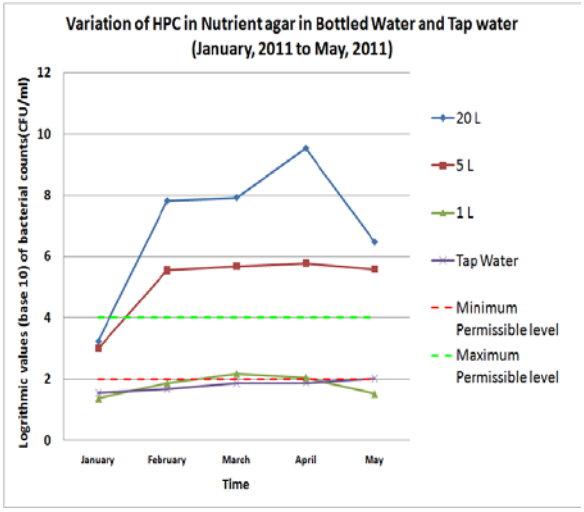

Figure 1: Variations in the HPC Counts in drinking water samples

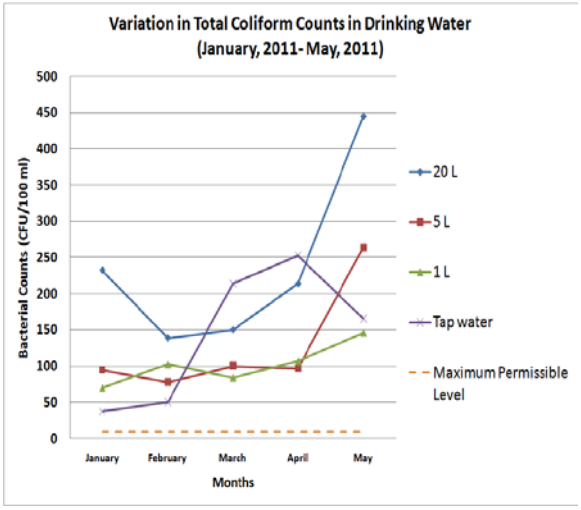

Figure 2: Variations in the Total Coliform Counts in drinking water

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SOCIO-ECONOMIC STATUS OF FISHING COMMUNITY AND THE FISHERY OF THE MAHAKANADARAWA TANK, MIHINTALE

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The Mahakanadarawa tank is situated in the North Central Province of Sri Lanka, about 1.5 km away from Mihintale. It has a water-spread area of 1457 ha (3600 acres) at full supply level (FSL). The tank is considered to be constructed by King Mahasena. Part of the water is received from the catchment and part is supplied through Mahaweli River. There are three feeder channels to supply water. An artisanal fishery has been established in the tank providing nutrition and employment opportunities to the surrounding community. There are six major fish landing sites, named as Karavilagala, Pothana handiya, Galepansal Kudawa, Siyabalagas wewa, Thalagasthulawa and Kudagama.

This study was carried out from March 2008 to March 2009 with the objective of investigating the socio-economic status of the fishing community and fishery of Mahakanadarawa tank. Twenty five fishermen were interviewed using a structured questionnaire to determine their social and economic attributes. The fishing gear, crafts used, fish catch composition and fishing income were investigated. Current fishery management practices and related problems were discussed with fishery officers and with the fishing community. There were 140 members in the fisheries society who belonged to different ethnic, religious groups and age groups with varying educational levels. The majority (52%) of the fishermen were Sinhalese Buddhists who belong to the age category of 35 to 40 years with the educational level of Grade 3-5. Most (40%) of the fishermen have five members in the family. Majority (92%) of the fishermen supplemented their income with other sources, since the monthly income was inadequate. There were 54 boats and about 10 canoes used for fishing. Fish catch per unit effort (CPUE) varied from 5 kg to 20 kg. Rod and line fishery was practiced by a special ethnic group of fishermen, which targeted on Snakehead murrel (*Channa striata*). Utilization of fishery resources by unauthorized fishermen and several illegal fishing methods such as use of nets with mesh size less than 3 ½", use of illegal nets and use of tubes to lay the nets were also observed. Tilapia species (*Oreochromis niloticus* and *O. mossambicus*) dominated among the exotic fish catch. The indigenous species netted include *C. striata, Etroplus suratensis, Anguilla spp., Anabas testudineus, Mastacembelus armatus, Puntius sarana and Glossogobius giuris*. The average price of a kilogram of Tilapia at landing site was Rs. 150 and monthly fishing income fluctuated from Rs. 10,000 to 15,000. Unsustainable and illegal fishing practices contribute to a decline in fish catches. Centralised top-down management which was carried out earlier was ineffective in solving many problems of the fishery. The co-management strategies where the government and the fishing community actively share responsibility in managing the fishery resource are recommended to enhance the proper utilisation of this immense biological resource. It will help to enhance the socio-economic status of the fishing community as well.

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TREATMENTS OF FLUORIDE AND PHOSPHATE IN POLLUTED WATER BY USING SIMPLE CHEMICAL PROCESS

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Removal of phosphate and fluoride is an important aspect in water treatment, which has been studied by many researchers. Although much research has been focused on removal efficiency of pollutants impact and economic efficiency of water treatment has not been well addressed. In this context, we have investigated a novel treatment method for phosphate and fluoride in polluted water by using a simple chemical process.

For treatment of phosphate, chemical property of aluminium ion in aqueous solution was applied. Aluminium salt was added in simulated waste water containing phosphate ion. By shift of pH to neutral, aluminium hydroxide gel formed was separated by decantation. Phosphate ion in the simulated waste water was concentrated in the gel quantitatively. Calcium ion was added into the gel, and the pH of the gel was shifted to alkaline pH, the gel was dissolved and phosphate ion in the simulated waste water was separated in the form of hydroxyapatite (HAp). In this reaction, the gel of aluminium hydroxide seems to act as a reactor for formation of calcium phosphate. Because HAp is raw material of phosphate for fertilizer, this chemical process is applicable to recovery phosphorous resource from polluted water.

For treatment of fluoride in domestic wells, chemical properties of calcium phosphates were applied. Activated carbon incorporated HAp was easily obtained by calcination of chicken bone under anaerobic condition[1)]. Hydroxide ion in the HAp crystal easily exchanges fluoride anion. The hybrid material adsorbed fluoride ion quickly, and applicable to removal of fluoride ion in ground water in domestic wells.

For usage of community water, continuous reaction column packed calcium phosphate (DCPD) based material has been developed. The DCPD reacts with fluoride ion in an aqueous solution, and forms stable fluoroaptite (FAp) [2)]. Activation of DCPD particle has been achieved by induced nano-scale precursor on the surface of the DCPD particles[3)]. The nano-activated DCPD is able to remove fluoride ion in waste water and ground water[4)]. Application of the DCPD-based column for treatment of fluoride in groundwater in Japan is now on process.

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EXAMNATION FOR A BINARY COLOR REACTION FOR THE VISUAL ANALYSIS FOR FLUORIDE

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Fluoride in drinking water causes serious health problems such as mottled teeth and abnormal growth of bone and teeth. Therefore, it is desirable to develop analytical methods for the determination of fluoride in drinking water. Instrumental analytical methods, such as spectrometry, potentiometry and ion chromatography have been commonly used for fluoride analysis. However, these methods are not suitable for on-site analysis of fluoride in drinking water for economical and technical reasons. Colorimetry with lanthanum alizarin complex is an effective on-site analytical technique, because this method does not require expensive instrumentation. However, this method leads to personal errors owing to individual differences in the perception of color.

We have reported a new type of visual analysis by counting the number of wells which change color on a microplate with a dynamic color change reaction [(1, 2)]. Using the proposed method, sample concentration could be clearly judged through visual analysis by monitoring color change. Moreover, this method is an excellent economical method because of portability of equipment since the required amounts of sample and the reagent are in the micro-liter level. The proposed method is also able to determine hydrogen peroxide, boric acid, ascorbic acid and water hardness. However, analytical applications are limited in the proposed method, because it requires a binary color reaction with dynamic color changing. Moreover, there is no binary reaction for visual analysis for fluoride.

For these reasons, we attempted to establish a binary color reaction for the development of visual analysis method for fluoride analysis by monitoring the color change. The concept of the proposed method is shown in Figure1. The experiment was conducetd by adding 1.0 mL of different concentrations of zirconium ion solution to 1.0 mL of solution containing the color reagent for fluoride analysis, such as lanthanum alizarin complex. After addition of 2.0 mL of sample solution, a change in color of the solution was observed. Particularly, the reaction system of zirconium ion and lanthanum alizarin complex shows clearly a change in colour for low concentrations of fluoride.

We could establish a binary colour reaction of the lanthanum alizarin complex. This result indicates that the visual analysis for fluoride by monitoring color change could be possible by the use of the binary colour reaction. Moreover, it is expected that this analytical technique can be applied for fluoride monitoring in drinking water in Sri Lanka.

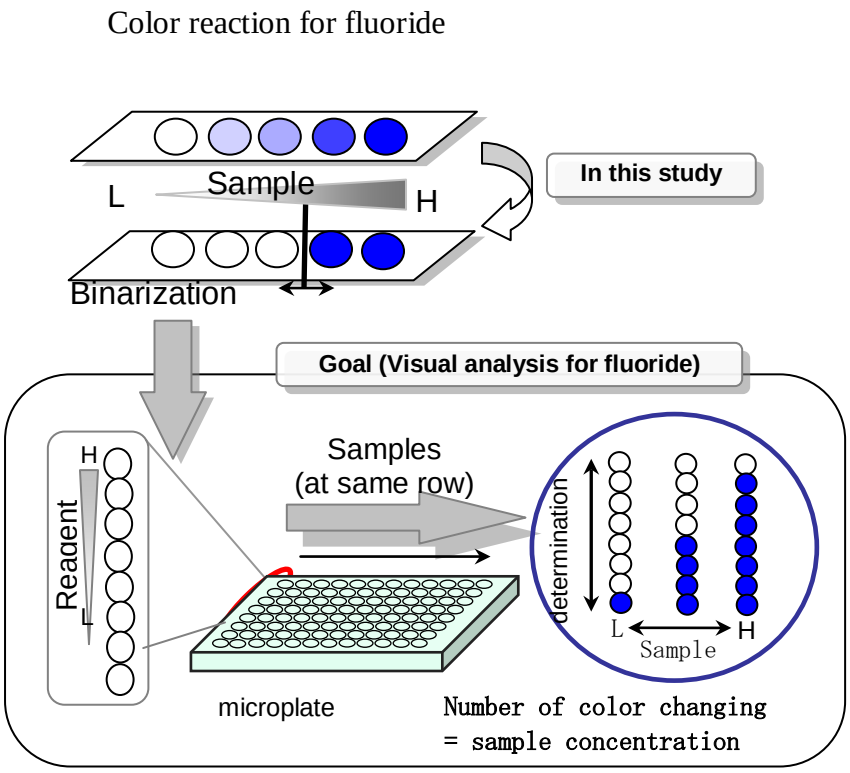

Figure 1: Outline of the proposed method

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ASSESSMENT OF COCONUT COIR FIBER AS MEDIA FOR UP FLOW ANAEROBIC FILTERS

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Treatment of primary effluent from septic tanks needed to be performed to meet discharge standards specified under National Environmental Act (SLS 745, 2003). Although numerous techniques are available in modern wastewater engineering practice, most of them do not satisfy the domestic treatment requirement of Sri Lanka due to their capital cost of construction.

Anaerobic filters are widely used in wastewater treatment all around the world. It is attached growth up flow packed bed filter where anaerobic bacteria grow on the media (http://www.akvo.org/wiki/index.php/Anaerobic_Filter). When wastewater passes over the filter media, the microorganisms grown on the filter consumes organic matter in wastewater producing new cells. If coir can be utilised as an effective attached growth media for anaerobic filters, this need can be fulfilled by constructing portable anaerobic filters for domestic sewerage secondary treatment process. The low unit cost of coir and low specific gravity will reduce the construction cost drastically in comparison to other filter media.

This experiment is performed to test clean coir fiber in a laboratory scale anaerobic attached growth up flow model for synthetic wastewater, prepared with urea [$(NH_2)_2CO$], sugar ($C_{12}H_{22}O_6$) and trace elements. Urea and sugar were mixed with pipe borne water at concentrations 0.425 g/L and 0.35 g/L respectively. A batch of 400 L of synthetic wastewater was prepared every four days. A controlled filter column with other filter columns of other media, broken clay tiles, rock metal media, and plastic media were also tested in parallel with similar hydraulic retention times. The model was tested for start up time of 7 weeks which is the average time period for anaerobic filters in Sri Lanka (SLS 745, 2003) while testing influent and effluent water samples for BOD_5 and its removal efficiency. It was tested with a hydraulic retention time of 36 hours (Young and McCarty, 1969) with surface area of 5.743 m^2 for a coir mass of 500 kg. The BOD_5 testing was tested according to standard methods where each sample to be tested for five times. Out of five results, the averaged results were obtained as BOD_5 value of that sample.

It was revealed that at the end of expected start up time, the filter has reached a removal efficiency of 59.3%. This efficiency was not sufficient to treat pragmatic waste strengths in the range of 120 to 160 mg/L BOD_5 (Mukkulath et al., 2009) to reach below 30 mg/L (Sri Lanka Gazette, 02.02.1990). Since it is internationally accepted that the removal efficiency of anaerobic filters is in the range of 50 to 80% after 6 months(http://www.akvo.org/wiki/index.php/Anaerobic_Filter) of start up time, the removal efficiency achieved is within this range only after 7 weeks of testing. Finally, it can be concluded that coconut coir fiber can be utilised as an effective attached growth media in anaerobic filters.

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INVESTIGATION OF SORPTION CHARACTERISTICS OF PEAT OF BRUNEI DARUSSALAM: INTERACTION OF AQUEOUS COPPER(II) SPECIES WITH RAW AND PROCESSED PEAT

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Environmental pollution has increased tremendously during the recent past due to continuous increase in human population and industrial development. Consequently, environmental scientists are highly concerned with providing pathways to mitigate increasing pollution levels. It is highly desirable that these path ways are economical, environmentally friendly and associated with naturally available substances. In this context, substances, such as different clay types, peat, rice husk, saw dust and plant components, in their raw or/and in modified forms, have been used for the removal of pollutants from waste water. Detailed mechanistic studies of pollutant – sorbent interactions is however lacking in many instances.

In an attempt to fill this void, this research was conducted to provide insight to the equilibrium and kinetics aspects of interaction of aqueous Cu(II) species with peat available in Brunei Darussalam. About 50% removal of Cu(II) from solution under optimized laboratory conditions at ambient pH [50.0 cm^3 of 10 ppm Cu(II) solution, 0.100 g of dry peat, 2 h shaking time and 2 h settling time] was observed with raw peat dried at a low temperature of 60 °C for 3-4 days. This removal is attributed to the functionalities of organic compounds present in peat, such as humic acids, fulvic acids, amino acids, and purine and pyrimidine bases, which show affinity towards Cu(II) species. Acidification of peat with HNO_3 solution as well as the treatment with diluted NaOH solution improve the extent of interaction resulting in a higher removal of about 70%, showing the complex nature of Cu(II) – peat interactions. Acidification introduces protons to the surface functional groups, which would easily exchange with Cu(II) promoting ion-exchange properties. On the other hand, treatment with NaOH would convert functionalities to their anionic forms, which would easily attract Cu(II) ions forming complexes.

Investigation of the extent of Cu(II) sorbed by raw, HNO_3-treated and NaOH-treated peat as a function of equilibrium concentration indicates the agreement with the Langmuir isotherm for lower concentrations, fulfilling the requirement of the mono-layer coverage, followed by removal of more Cu(II) from the solution, which is equivalent to the multi-layer coverage, beyond the initial concentration of 200 ppm Cu(II). The maximum loading for the monolayer coverage with raw peat is 0.10 mmol g^{-1}, which is increased with HNO_3-treated and NaOH-treated peat, due to the activation of more sites during acid/base treatment. Further, the extent of sorption at higher initial Cu(II) concentrations is much higher with HNO_3-treated peat as compared to raw and NaOH-treated peat, supporting the strong contribution of ion-exchange during the interaction of Cu(II) and peat. Further, kinetics data obtained from every 30 s immediately after the progress of the sorption reaction before the equilibrium is reached are in good agreement with the pseudo second order model with an average rate constant of 9.0 mol $dm^{-3}s^{-1}$. Further, enhancement of the extent of removal of Cu(II) can be improved by controlling the medium pH.

Such studies would be important in designing environmentally friendly treatment methods using natural substances, such as peat, for real industrial effluents contaminated with Cu(II) and other metal ions.

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PROCESSED BRICK CLAY FOR POLLUTION CONTROL OF CONTAMINATED WATER

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Pollution of water bodies has been increasing at an alarming rate due to many factors, including industrialisation, population growth and urbanisation. Both the removal of toxic pollutants from contaminated water and the management of water pollution are important aspects to be considered in an attempt to have a safe environment for the survival of living organisms. In this regard, use of low-cost and environmentally-friendly approaches have become attractive alternatives.

Among many natural substances attempted, brick clay, in natural and processed forms, is found be superior, due to the presence of pore and layered structures, and reactive moieties that show strong affinity towards pollutants, especially heavy metal ions commonly found in industrial effluents. The extent of removal of a pollutant by brick clay depends on experimental factors, such as time of exposure, solution pH, processing conditions and ionic strength of the medium. Firing brick clay up to a temperature of 100°C leads to the removal of moisture and the expansion of the pore structure. Increase in firing temperature up to 300°C leads to the combustion of organic substances leaving unburned carbon particles, which are oxidised at higher firing temperatures. Further increase allows the oxidation of metal centres and alteration of the layered structure. Consequently, the optimum firing temperature for the maximum removal and the lowest turbidity should be determined for each pollutant. Removal of Cr(VI), which is present as an anion, is found to be most effective with brick clay fired at 200 °C, while that of Cr(III) and Cd(II) with brick clay fired at 400 °C, owing to the difference between the charges associated with each ion. Additionally acid treatment of brick clay also affects the extent of sorption, indicating the contribution of ion-exchange for the removal process.

The mechanism of the removal of a pollutant is a complex process as it is associated with many modes of mass transfer, namely, surface adsorption, absorption, ion-exchange, inter-particle diffusion, intra-particle diffusion and transfer through pores. Although the relative contribution of each mode to the overall transfer process of a pollutant from the solution phase to the solid phase is difficult to predict, it is evident that surface hydroxide groups and organic functional groups present in brick clay play an important role. Another important finding is that sorption of many pollutants, including heavy metals and dyes, are in good agreement with both the Langmuir and Freundlich isotherms, indicating that the mono-layer formation is initially completed followed by a multi-layer process at sufficiently high concentrations. Intra-particle diffusion also shows a strong contribution to the removal of pollutants from water to the brick clay matrix. Such mechanistic investigation is of great importance to extend laboratory-scale treatment methods to real applications.

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CADMIUM AND OTHER HEAVY METAL REMOVAL FROM CONTAMINATED DRINKING AND IRRIGATION WATER.

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Elevated levels of heavy metals in drinking and irrigation water are a major problem in both industrial and agricultural countries. Among health problems associated with the heavy metal poisoning originated from contaminated water, Minamata disease due to mercury poisoning, arsenic toxicity in Bangladesh and itai itai disease from Jinzu river basin in Japan were some serious issues. Elevated Cadmium levels in irrigation and drinking water has been reported from the North Central Province (NCP) of Sri Lanka, where chronic renal failure among residents is common. This is a result of intensive use of cadmium contaminated fertilisers and other agricultural chemicals over a very long period of time. Cadmium is one of the most toxic heavy metals that could find its way into reservoir water and sediments. In NCP of Sri lanka, natural vegetation and grassland associated with the main reservoirs used for irrigation and drinking purposes are contaminated with cadmium and lead (0.03-0.06 mg/l of Cd and 0.01-0.03 mg/l of Pb). Many farmers and residents of NCP traditionally depend on reservoir water for washing, bathing and drinking in addition to irrigation. The agricultural products were reported to contain high Cd levels (0.09 – 0.20 Cd mg kg^{-1} of rice and 1.07 – 1.35 Pb mg kg^{-1} of rice).

As early detection of Cd poisoning is vital for the reversal of the effect on renal function, and it is extremely expensive to continuously monitor Cd levels in drinking water, an effective approach would be to prevent any exposure to elevated Cd in potable water. In this contest, the main goal of this research was to develop a filtering device using processed rice husk to remove cadmium ions from the drinking water for domestic use.

The amorphous silica derived from raw rice husk adsorbs cadmium ions from water to reduce from 18.44±3.60 mgl^{-1} to 19±0.44 mgl^{-1} within a period of 3 h when pumped under 600 *psi* at a flow rate of 666 lh^{-1} . However, application this methodology for domestic level requires a low-cost approach, a filtering system using PVC tubes was developed. According to laboratory level experiments using the low-cost filtering system, heavy metals in water were effectively removed. Foe instance, removal percentages of Zn (6.7 ppm), Cu (5.5 ppm), Cr (4.1 ppm), Pb (1.9 ppm), Mn (4.75 ppm) and Ni (5.9 ppm) in a mixture were determined to be 91.5%, 99.7%, 30.0 %, 100%, 62.7% and 100% respectively. It is proposed that this cost-effective filtering system could be extensively used for the treatment of the industrial effluents contaminated water with heavy metals.

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PILOT PROJECT FOR THE ESTABLISHMENT OF URBAN RECREATIONAL AREAS IN RIPARIAN LANDS WHILE IMPROVING THE URBAN BIO DIVERSITY

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Urban areas in Sri Lanka currently have a severe shortage of recreational spaces. The impact of this problem can be seen in the rising number of non communicable diseases such as diabetics, neurosis reported from the hospitals. According to a recent survey 10% of the Sri Lankan population is suffering from diabetes and it is very high around urban areas such as Gampaha. According to health officials, the primary reason for this problem is the lack of recreational opportunities close to urban areas. Stream corridors which extend to about 10 to 20 meters in either bank are not actively protected in Sri Lanka. The result is illegal dumping of garbage in to the river near stream corridors or illegal land filling and construction. Many of the scenic stream banks have been lost during the last decades due to this problem. Stream corridors are owned by the government. Therefore public use of this land can be considered as a fair use of the land.

Since it will be near impossible to find large areas close to urban areas to build recreational facilities for jogging, walking, cycle riding, resting etc, narrow strips of stream banks become the only space available for this purpose. Riparian Trees planted along stream banks in developing such recreational areas increase the urban Bio Diversity while reducing stream bank erosion and thereby minimising silt deposition in streams causing floods. Another noteworthy feature of this exercise is that there will not be a net loss in wetland space because the required earth for bank improvement will be obtained only from the vicinity. Earth will be secured from outside only when it is necessary to improve the surface of the jogging paths when the corridor traverses through urban areas. As such there is no major flood damage cost associated with this type of development. Wherever it is possible, wetland plants will also be introduced to lands adjacent to the stream banks as a strategy to improve the water quality of the stream. In the second phase of the program, efforts will also be made to extend the riparian lands to connect to forest patches within the area as a strategy to place them as Urban Wild Life Corridors.

Community involvement specially the participation of paddy field owners adjacent to the stream banks plays a major role for the success of these programs. Unless they are benefited financially from the program the project will not be sustained. Therefore an effort is being made to introduce income generation by planting trees having medicinal value using the diverse ecological properties of the terrestrial aquatic interface of riparian lands.

The main objective of this paper is to present the experience of a project which is now in progress re-configuring the riparian lands into recreational areas. About 10 Km of riparian lands have already been improved and the social acceptance as a recreational area is very encouraging. For example the average number of visitors per day for jogging and other recreational activities in a project completed adjacent to Gampaha town is around 100.

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ASSESSMENT OF WATER QUALITY STATUS OF AQUATIC ENVIRONMENT SUBJECTED TO FREQUENT OCCURRENCE OF FISH KILL INCIDENTS

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Fish kills are important signs of environmental stress and it is important to investigate fish kill incidents to determine the cause. Identifying the cause of fish kills helps fisheries researchers and the public, as they may indicate significant environmental changes, disease conditions and water pollution events. The main objective of this study was to investigate the fish kill incidents occurring in different aquatic environments and identify the cause of pollution and propose recommendations to avoid such fish kill incidents in future.

Seven water bodies which had fish kill incidents during January 2011 to January 2012 were selected for this study. These include Beire Lake, Diyawannawa Oya, Siyabalagamuwa Wewa, Thalan Lagoon and Pamunuwila Canal, Kelaniya. In-situ analysis was carried out to measure pH, Water Temperature, dissolved oxygen (DO), electrical conductivity (EC) and turbidity, whereas laboratory analysis was carried out to determine nitrate - N (NO_3^-- N), nitrite -N (NO_2^-- N), ammoniacal-N (NH_4^+- N), phosphate , biochemical oxygen demand(BOD), and chlorophyll-a concentrations..

For laboratory analysis, samples were stored at 4 ^{0}C and transported to the laboratory. All Water quality analyses were carried out in accordance with the Standard Methods for Examination of Water and Waste Water (APHA), 20th edition. Microsoft Excel 2007 was used as a data analysis tool to identify the water pollution status. Proposed CEA Ambient Water Quality Standard for Inland Waters in Sri Lanka (2001) was used as standard guidelines for fish and aquatic life.

DO levels of water in Thalan Lagoon and Diyawannawa Oya during the period of fish kill were below the acceptable limits for survival of fish and aquatic life. Siyabalagamuwa wewa indicated ammonical nitrogen, pH, biochemical oxygen demand, total dissolved solids, and turbidity levels which did not comply with the standard limits for the survival limits of fish and aquatic life. Investigation done at Beire Lake during the months of October and December 2011 revealed that ammonical-nitrogen, BOD and the phosphate levels at some locations did not comply with the standard limits for the survival limits of fish and aquatic life. Further, it has been identified that, fish did not indicate any external lesions leading to speculate that the mortality was due to any disease condition.

Average chlorophyll-a concentration ranges were (21.03 ± 0.50µg/l) to (20.06 ± 1.37µg/l) and phosphate concentrations were (0.337 ± 0.11 mg/l) to (0.651 ± 0.33mg/l) showing eutrophic conditions in Beire Lake. Fish kill incidents recorded in Siyabalagamuwa wewa and Thalan Lagoon were due to a disease condition and it was identified as an Epizootic Ulcerative Syndrome (EUS). Further, the water quality results of those two water bodies were indicative of pollution conditions, mainly the ammoniacal-N, DO, BOD and pH levels are below the standard limits for the survival limits of fish and aquatic life. High levels of pH and phosphate which did not comply

with the standard limits for the survival limits of fish and aquatic life were recorded in the fish kill event at Pamunuwila Canal.

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CHEMICAL MODIFICATION OF THERMALLY TREATED PEAT FOR REMOVAL OF HEAVY METALS IN EFFLUENTS

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Heavy metals can be considered as one of the most hazardous environmental pollutants. Contamination of soil, and pollution of ground and surface water sources are common adverse effects of heavy metals. Apart from acute health effects, main problems associated with heavy metal pollution are the persistence, and the potential of bioaccumulation and biomagnification, which cause severe damage to some organisms. Therefore, removal of heavy metals present in effluents is a necessity.

Peat is a naturally occurring inexpensive substance which is made up of partially decomposed components of dead plants which have accumulated on top of each other for long periods of time. Its characteristic chemical and physical properties, especially due to the presence of polar organic molecules, such as humic acid, lignin and cellulose, make it an effective solid sorbent for dissolved metal ions. Adsorption, absorption, ion-exchange and complex formation reactions are the principal modes of interaction between a metal ion and peat, each of which is affected by modification of the adsorbent, owing to changes in chemical and physical properties, including topology, surface charge, three-dimensional structure, mineral composition and the organic matter content. Therefore, the mechanism of metal ion removal by peat is complex, and the extent of removal varies depending on the target metal ion.

The extent of removal of Cd(II) by natural peat available in Muthurajawela, Sri Lanka, is very low, suggesting the need for its modification to enhance the interaction ability towards this metal ion. However, thermal modification does not lead to a significant improvement of Cd(II) removal, indicating that the organic matter and other surface functionalities present in peat do not contribute to the removal of Cd(II). Interestingly, chemical modification of peat (fired at 200 °C) performed by treatment with nitric acid is able to improve the transfer of Cd(II) from the solution phase to the solid peat phase. During acid treatment, it is expected that protonation of surface functional groups of the adsorbate, such as carboxyl (COOH) and hydroxyl (OH), and solubilisation of metal complexes and metal oxides occur, promoting the extent of interaction. The optimum values of stirring time, settling time, firing temperature and the strength of the acid for Cd(II) – peat interaction are 5 min, 75 min, 200 ^{o}C and 2.0 mol dm^{-3}, respectively.

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REMOVAL OF AQUEOUS CHROMIUM (III) BY NON-LIVING CABOMBA CAROLINIANA

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Chromium and its compounds are widely used in industries such as leather tanning, chromium plating, glass manufacture, etc. in Sri Lanka and is a common heavy metal in industrial effluents. Cr(III) is one of the two major oxidation states of chromium that exists in waste water. Discharge of untreated effluents causes the pollution of natural water resources. Although Cr(III) is less toxic than Cr(VI), it has the tendency to get oxidised to Cr(VI), which is more toxic to human health. Therefore, the removal of Cr(III) from effluent is important. Biosorption offers an alternative, cost effective and environmentally friendly remediation methodology instead of conventional and expensive physico-chemical methods such as ion exchange, membrane filtration, chemical precipitation, etc. This study shows the potential of dead biomass of the aquatic plant, *Cabomba caroliniana*, to remove Cr(III) from aqueous systems.

Batch sorption studies showed that the dried plant material removed 46% of the Cr(III) in the system and the removal was increased significantly up to 98% by protonation of the biosorbent (Figure 1).The removal capacities at equilibrium were 1.15 mg g^{-1} and 2.45 mg g^{-1} for unprotonated and protonated biosorbent respectively. The percentage removal of Cr(III) increased with the increase of the sorbent dosage. The pH of the medium significantly affected the extent of biosorption and the optimum pH was 5.0. This observation was clearly shown by the results of the surface titration, which showed that the biosorbent surface is positively charged at a low pH and negatively charged at pH beyond 4.0. Fourier transform-infra red (FT-IR) spectral analysis was conducted to characterise the surface of the biosorbent and it confirmed the involvement of –OH groups on the biosorbent surface in the Cr(III) removal process.

The Langmuir and Freundlich equations were used to model the adsorption equilibria data and pseudo-first order and pseudo-second order models were used to correlate the kinetic data. The experimental data fitted well with the Freundlich model which suggests a non-ideal heterogeneous adsorption of Cr(III) on to the surface of the dead biomass of *C. caroliniana.* The kinetics of this adsorption process followed a pseudo-second order model indicating that the rate of the process depends on the concentration of the metal ion and on the concentration of the biosorbent.The analysis of the kinetic data also revealed that the removal of Cr(III) by *C. caroliniana* is a complex process, involving both boundary layer diffusion and intra-particle diffusion. It is concluded that the dead biomass of *C. caroliniana* could be used as an inexpensive and effective biosorbent to eliminate Cr(III) from industrial effluents.

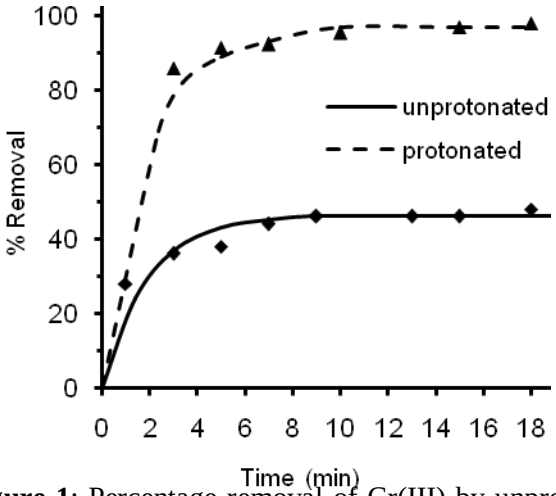

Figure 1: Percentage removal of Cr(III) by unprotonated and protonated dry *C. caroliniana* biosorbent at different shaking times (biosorbent dosage 2.0 g L^{-1}, initial metal ion concentration 5.0 mg L^{-1}, pH 5.0, temperature 25 °C, shaking speed 140 rpm).

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ENDEMIC CHRONIC KIDNEY DISEASE OF UNCERTAIN ETIOLOGY IN VAVUNIYA DISTRICT- A HYDROGEOCHEMICAL STUDY

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Chronic kidney disease with uncertain etiology (CKDu) is an endemic disease in Sri Lanka and a major health issue in dry zone areas of the North Central region of Sri Lanka. In other regions long standing diabetes and hypertension are the main causes of renal failure. Vavuniya District in the Northern Province has also recorded an alarming number of CKDu patients and most of them belong to the low socio-economic group. Groundwater is the main source of drinking water in the region. In this study, drinking water collected from CKDu prevalent villages was analyzed and compared with that of CKDu nonprevalent areas in the Vavuniya district. Sampling was carried out before and after the monsoonal rainfalls. Poonthoddam, Maharambaikulam, Thonical and Cheddikulam were the selected endemic areas while Vairavapuliyankulam was the non endemic area. A total of fifty sampling points were selected from above villages and analysed for their major and minor constituents. In these villages, people mainly obtained their drinking water from deep (57%) and dug (39%) wells. Particularly, in the low prevalence area, a higher number of people (78%) consume water from deep wells as compared to those in high prevalent areas (53%).

Both high and low prevalence regions have hard water where the mean water hardness being 171 mg/l $CaCO_3$ and 243 mg/l $CaCO_3$, respectively in the dry season. The levels were increased with the monsoonal rain up to 288 mg/l $CaCO_3$ and 373 mg/l $CaCO_3$, respectively. Remarkably higher levels of fluoride were observed in both regions, but much higher contents were observed in the CKDu endemic area. The average fluoride content in high and low prevalence areas were 1.59 mg/l and 1.38 mg/l before the monsoonal rain. After the monsoonal rain, it was slightly decreased to 1.50 mg/l and 0.90 mg/l, respectively. Furthermore, before and after the rain events, sodium and chloride contents become higher in low prevalent areas as compared to high prevalent areas. No differences were observed in other drinking water parameters such as nitrate, phosphate, potassium, iron, manganese and cadmium between high prevalent and low prevalent regions. This study indicates that fluoride and hardness of water play a major role in the etiology of CKDu in the Vavuniya district where all other socio-economical and geochemical factors are the same in both regions.

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GEOGRAPHICAL DISTRIBUTION OF CHRONIC KIDNEY DISEASE OF UNKNOWN ORIGIN IN SRI LANKA – IS IT RELATED TO STAGNANT IRRIGATED WATER?

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In early nineties, an alarmingly high incidence of an apparently new form of chronic kidney disease of unknown etiology (CKDu) has been identified in some parts of Sri Lanka. A steady increase of this disease has been observed during the last twenty years. Histopathological studies have revealed a tubulo interstitial nephritis at early stage of the disease, which is suggestive of a toxic aetiology. Similar endemic nephropathy described in Balken region shows a relationship to Danubi river. Aim of the present study is to investigate the geographical distribution of CKDu using modern GPS and GIS based mapping and to relate it to different drinking water sources available in the region.

Information of 11630 patients were collected and used for GIS mapping using AR 9.2 software and GPS mapping. GIS mapping indicated five high prevalent areas in the region, namely Medawachchiya, Padaviya, Girandurukotte, Medirigiriya and Nikawewa (identified 20, 18, 12, 8 and 5 yrs ago). Low prevalence of the disease was noted in communities who consume water from natural springs for drinking. In all five areas, the distribution is related to stagnant irrigated water. GPS mapping shows that most of the cases are located below the level of some and canals, reservoirs and some are related to the irrigation canals.

It has been observed that all five regions affected with the CKDu encompass a well developed irrigation system comprising of reservoirs. Water from these reservoirs is mainly used for agricultural purposes. However, the people who live in these areas consume water from shallow wells and water levels of these shallow wells are proportionate to the water levels of the canals indicating that the ground water table is recharged from irrigation canals and reservoirs. It has been observed that the prevalence of the disease is comparatively low in the villages where natural spring water is available for consumption.

Observations of the study reveals that the exposure to the aetiological agent remains unchanged and new disease foci are reported to be emerging. Disease preponderance in males may be due to their frequent exposure to the aetiological agent than females or due to another unknown contributory factor that operates in males which increases the risk of the disease. The reported familial occurrence of the disease with no evidence of clear Mendelian inheritance could be due to exposure of the siblings to the aetiological agent rather than direct genetic/inherited background for the disease.

All the high prevalent areas are clustered around reservoirs of the irrigation system. The epidemiological data on geographical distribution infers that while older foci of CKDu are persisting, there is an emergence of new foci of CKDu with time. The presence of the affected villages located below the level of the reservoirs and canals indicate the possibility of irrigated water draining to the shallow wells of the households which is the source of drinking water.

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ARSENIC AND OTHER HEAVY METALS IN RICE FROM SRI LANKA- PRELIMINARY RESULTS WITH ICP-MS

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As in most of Asian countries, rice is the main food in Sri Lanka and the cultivation of rice is deeply enmeshed with the culture and traditions of the country. Paddy cultivation is widespread throughout the island and nearly 8,350 km^2 of paddy land are scattered in the island providing 86% of the annual requirements. In recent years, there are some claims that rice consumed in Sri Lanka is contaminated with some toxic heavy metals including arsenic due to excessive use of contaminated fertilisers and pesticides. Most of the elements in rice grains and plants should be related to those in the soil and other associated environments. Sri Lanka is one of the major rice growing countries in which rice is the staple food crop consequently, accumulation of contaminants in rice grains could lead to trace element imbalance in consumers.

In this study, rice samples from various locations in certain parts of Sri Lanka were analysed for their heavy metal contents. In order to obtain a generalised idea of the geographical distribution pattern of the heavy metals in Sri Lanka, 23 rice samples were collected from the dry zone (Padaviya, Medawachchiya, Anuradhapura, Samanturai and Ambalantota) and wet zone (Colombo, Bombuwala, Labuduwa and Bathalagoda) regions, and analysed for As, Cd, Hg, Pb, Zn, Cu, Al, Mn, Ni, U, Cr and Se contents using ICP-MS techniques with appropriate quality control.

The arsenic content in rice varies from 10 to 90 µg/kg dw while the total Hg content is less than 10 µg/kg dw in all samples. There is no significant difference in the arsenic content in rice between dry and wet zones. The Cd content ranged between < 10 µg/kg dw to 40 µg/kg dw while the maximum Zn, Cu and Al contents were 30, 3.5 and 8.5 mg/kg dw, respectively. Compared to rice from other Asian countries and with recommended levels, Sri Lankan rice does not show high amounts of toxic heavy metals.

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GEOCHEMICAL EVIDENCES FROM SOIL AND WATER LEADING TO CHRONIC RENAL FAILURE OF UNKNOWN ETIOLOGY IN THE DRY ZONE SRI LANKA

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Chronic renal failure (CRF) in the dry zone of Sri Lanka has reached a crisis point. Over 5000 patients in the region have been reported and are under treatment. The main objective of this study is to establish the etiology regarding the CRF in terms of soil and water chemistry. Water quality was carried out at one hundred localities around the hotspots, and concentrations of twenty two major and trace elements from soil samples were determined using X-ray fluorescence spectroscopy. Water quality results indicate that arsenic, iron, nitrate and phosphate are not elevated in shallow groundwater where the kidney patients are reported. The relationship between measured fluoride values and the distribution of CRF patients shows that fluoride in water may not influence much on the CRF. Geochemistry of soils shows that concentrations of mobile harmful trace metals such as As, Pb, Zn, Cu. and Ni are mostly at lower levels. Further, it was revealed that weathering of basement basic rocks contributes to the accumulation of significant amounts of V, Mn and Fe into the soil. The amount of V exceeds the recommended levels in contaminated soils, especially in sites located in the areas having the CRF problem. Strong positive correlation among V, Mn and Fe implies that garnet may be the host mineral for such elements. It can be suggested that there is a possible effect from V on the CRF in the region since it can be mobilized into water, plants and subsequently to animals.

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HEALTH IMPACTS FROM HEAVY METALS IN GROUND WATER AND RICE IN ANURADHAPURA, SRI LANKA.

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Various impacts from groundwater pollution due to excessive use of chemicals in agricultural lands of Sri Lanka are increasingly discussed at present because of the increasing death rate due to chronic kidney disease (CKD). Over one thousand people have reportedly died and more than 25,000 patients have registered at renal clinics of several government hospitals in dry zone of the island. Even though, water and food are being suspected as the most reasonable causes of CKD, no definitive causes have been identified up to now. Therefore, this study was carried out to recognize any significant correlation between groundwater contamination and CKD in the Anuradhapura district, Sri Lanka. Puttalum District, which is about 100 km west to Anuradhapura, was chosen as the reference as no CKD cases are reported where the same social, environmental and economical factors exist. Among the total samples of drinking water from Anuradhapura district, 37% represents direct CKD victims and no any case reported from Puttalum..

Sampling was carried out early 2011, jointly by Japanese and Sri Lankan researchers. During this study, samples were collected from dug wells, deep wells and surface of prevalence endemic CKD Anuradapura district. All water samples were filtrated by membrane filters of 0.45µm pore size to stabilise the water quality before transferring them to the chemical analytical laboratory at Toyama Prefectural University, Japan. ICP-MS method was employed in investigating heavy metal concentration. Further, 10 rice samples were collected from Millewa gramaniladari division (N 08°32'45.6" E 80°16'16.4") in Anuradhapura district and tested for Cd, Pb, As and Cr.

Among the tested water samples, 7% exceeded the WHO standards of NO^-_3 and 43 % exceeded the F^- levels. Further, 88% samples were found as very hard. Among the 08 heavy metals tested, 02 samples were exceeded the WHO standards of 10 μgl^{-1} for As and the maximum concentration was recorded as 15.3 μgl^{-1}. In addition, only one sample was found with high concentration of Al and Cu. As the concentration of many heavy metals it is clear that there is a significant impact on human health only due to the excessive presence of F, NO_3 and hardness. On the other hand, consumption of rice has shown no significant impact due to the heavy metals. Increasing trends in As concentration is questionable and hence an extensive study should have to be done. However, no direct correlation was found with As concentration in groundwater and CKD victims. Therefore, research must be directed towards other hypothesis on cause of this issue.

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ARSENIC AND HARDNESS IN GROUND WATER FROM CHRONIC KIDNEY DISEASE OF UNKNOWN ETIOLOGY (CKDU) PREVALENT AREAS AND NON-CKDU PREVALENT AREAS IN SRI LANKA

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Increasing hardness and deteriorating quality of groundwater, the primary source of potable water, has been the general observation of inhabitants of areas where chronic kidney disease of unknown etiology (CKDu) is prevalent. Present study was conducted during 2011, to determine the groundwater hardness and presence of arsenic in Padavi-Sripura, Polpithigama, Moneragala, Thanamalwila in the dry climatic zone and in Pasagoda in the wet zone. Total hardness of the water samples collected from dug wells and tube wells was measured using EDTA titration (EPA 130.2) and arsenic content was measured using GF-AAS after filtration and acid digestion (EPA 7060A). Highest average groundwater hardness (466±34 mg l^{-1}) was observed at Padavi-Sripura (n= 28) and the values ranged from 270±54 – 820±62 mg l^{-1}). Arsenic content in water ranged from 21.07±3.54 to more than 100.91±12.31 µg l^{-1}. The second most hardwater was found from Polpithigama area (n= 16) which ranged 90±8 – 615±47 mg l^{-1}. Arsenic content in water ranged 2.49±0.61 – 60.55±7.21 µg l^{-1}. The lowest hardness in groundwater among the test sites was observed at Moneragala (n=38), where the hardness ranged 10±2 – 340±31. The arsenic content ranged 2.14±0.84 – 52.47±6.71 µg l^{-1}. Groundwater at Thanamalwila (n=19) recorded hardness value, i.e. 279±26 mg $l^{-1}$with a range 170±8 - 500±24 mg l^{-1} and the arsenic content in water ranged 39.37±5.21- >100.42±9.45 µg l^{-1}. Groundwater at Pasgoda, the control site of this study, was not hard (60±5 mg l^{-1}) and arsenic was not detected. Statistical analyses reveal that a positive correlation exists between total hardness of groundwater and the arsenic content in it.

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CONTAMINATION RISKS FROM IMPROPER TOILET WASTE DISPOSALS

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Toilet waste, in addition to organic and inorganic wastes consists of disease causing organisms. Therefore improper toilet waste disposal can adversely affect not only the quality of natural water sources but also the health of its users. In Sri Lanka the problem of water, especially groundwater contamination from improper toilet waste disposal is believed to be very much widespread, as the groundwater table in many areas is shallow. Also the indiscriminate use of cesspits and septic tank that are combined with soaking systems is making this condition worse. Since majority of the Sri Lankan population relies on groundwater for their daily requirements even today (only 36% piped water coverage, NWSDB 2009), ascertaining the risk to groundwater from these improper toilet waste disposals is of prime importance.

In this context, the aim of this investigation was to find out a possible inter-relationship between improper toilet waste disposal and its effect to the groundwater quality. Further this study brings forth some suitable remedial measures to minimise the groundwater contamination by studying this issue at different climatic and hydrogeological conditions. For this purpose Alawathugoda and Ukuwela areas located in the hill country, from mountainous wet region and Aluthwewa area located in Polonnaruwa district from low land dry region is selected as the study locations. In all areas water samples were collected and a questionnaire survey was conducted among randomly selected houses. Collected water samples were analysed for total coliform.

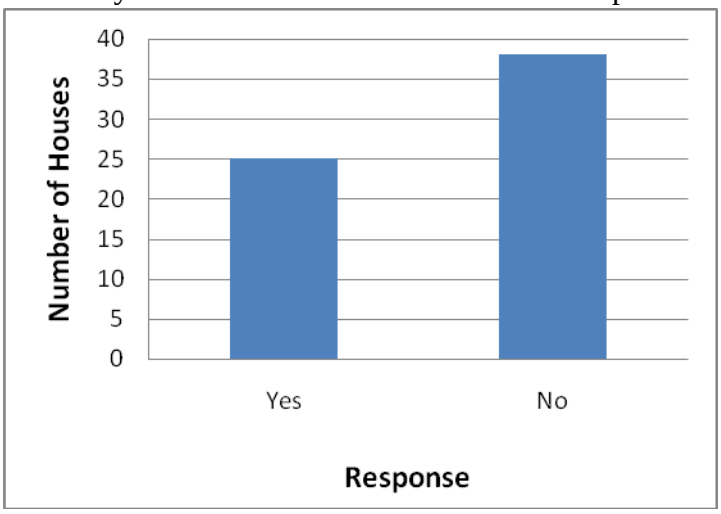

Figure 1: Knowledge on the minimum distance from soakage pit to the drinking water source

It was observed that in hilly areas, out of the 70 locations investigated 49 locations fulfilled the minimum distance of 18m recommended between the toilet disposal unit and the drinking water source for safety. In low land area 21 locations out of 28 confirmed to the guidelines.

Survey further showed that only 40% of the respondents were aware of this safe distance requirement between the soakage pit and the drinking water source. Also the survey showed only 15% had received any kind of advice on this recommendation from a responsible authority during the planning and construction of toilet waste disposal system (Figure 1).

Laboratory testing results showed that in Aluthwewa area 82% of the samples contained total coliform while in Alawathugoda area it was 61%. Further it was observed that the coliform contamination was high even in wells beyond 18m; it was

84% in the Alawathugoda area (Figure 2) and it was 53% in the Alawathugoda area (Figure 3).

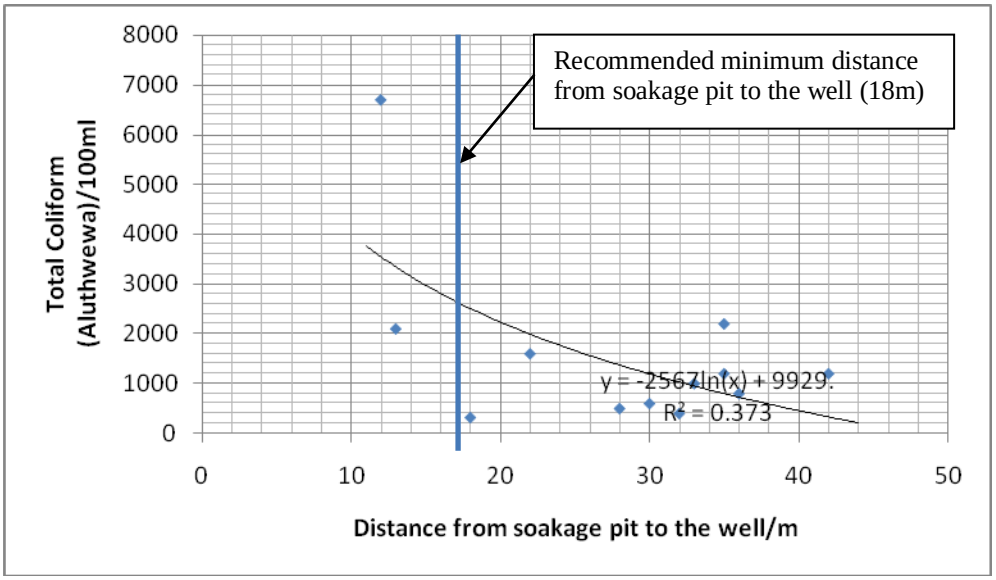

Figure 2: Total coliform with distance from soakage pit to the well (Aluthwewa)

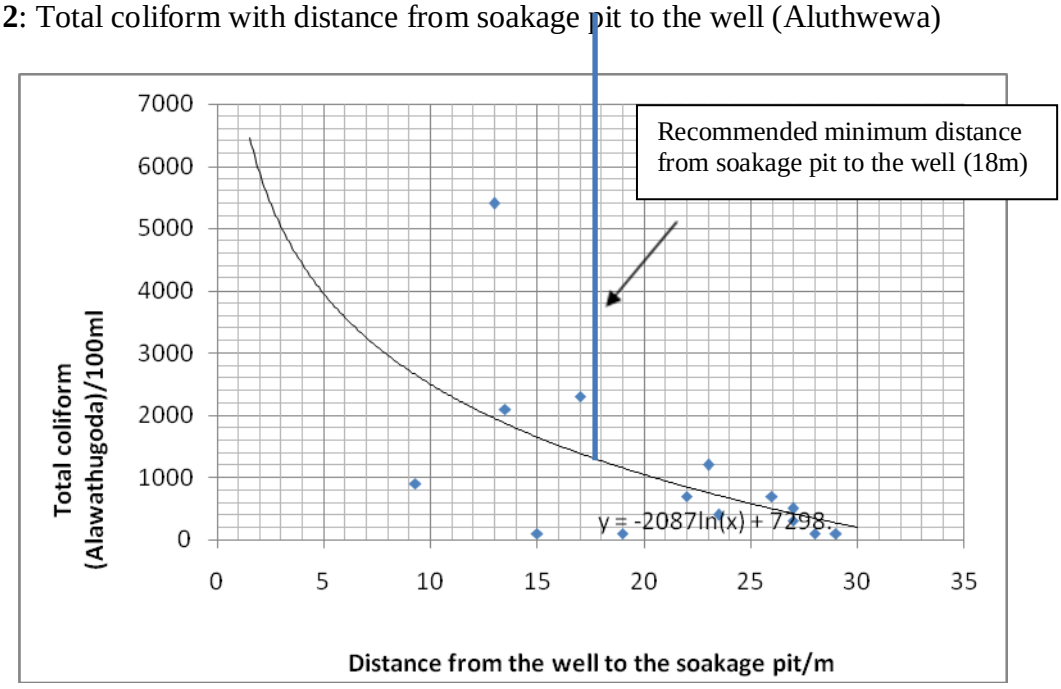

Figure 3: Total coliform with distance from soakage pit to the well (Alawathugoda)

The results obtained from this investigation showed that even though awareness is lacking with many people on the recommended distance, in many instances provision of it does not guarantee the required safety always. Therefore to ensure better security the guidelines need further refining, especially taking in to account the hydrogeological conditions of the area of concern.

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WATER QUALITY AND CHRONIC KIDNEY DISEASE OF UNKNOWN AETIOLOGY (CKDU) IN THE NORTH CENTRAL PROVINCE OF SRI LANKA

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Prevalence of Chronic Kidney Disease of Unknown aetiology (CKDu) is high in the North Central province of Sri Lanka. It is reasonable to hypothesize that CKDu is an environmentally induced disease as the majority of the people are settlers. The majority of the people in these areas consume well water and water from tube wells as well as from reservoirs (tanks) for drinking and other domestic purposes. Since the water is the most commonly consumed commodity, it is logical to assume that the toxin (or toxins) is found in water they consume. Consequently, many research findings have been reported in the recent past with respect to water quality of CKDu prevalent areas although none of them are very conclusive.

Uncontrolled application of fertilisers and pesticide (agrochemicals) on agricultural fields, having both local and foreign origins may have a long-lasting impact on the agricultural ecosystems of Sri Lanka. Erroneous and excessive use of agrochemicals may cause accumulation of metals and toxic organic components in agricultural soils and increases the possibility of leaching them into ground water.

Our research findings related to the water quality of these CKDu affected areas specifically fluorides, heavy metals, organic compounds (mainly pesticides) will be presented. Furthermore, the possible heavy metal-pesticide interactions as evidenced by UV/Vis and FTIR spectroscopy and cyclic voltammetry will also be presented. The necessity of establishing a water treatment facility on a community basis or home water treatment facility which could be based on the traditional knowledge for water purification and, its sustainability through continuous monitoring for CKDu prevalent areas will also be emphasised.

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FACTORS CONTRIBUTING TO POOR WATER QUALITY AND ITS IMPACT ON PUBLIC HEALTH IN KALMUNAI

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In developing countries, the principal risks to human health associated with the consumption of polluted water are microbiological in nature, although the importance of chemical contamination should not be underestimated. The microbiological examination of drinking-water emphasises assessment of the hygienic quality of the supply. This requires isolation and enumeration of organisms that should indicate the presence of faecal contamination. Having noticed certain water borne and/or water related diseases prevailing in densely populated suburbs of Kalmunai, a commercial town in the Eastern Province of Sri Lanka, this study was undertaken to identify the impact of water quality and sanitation conditions on public health of residents in this area (Figure 1). The population density (2,725 PPSK) of this area is 9 times larger than the nation's average population density (307 PPSK).

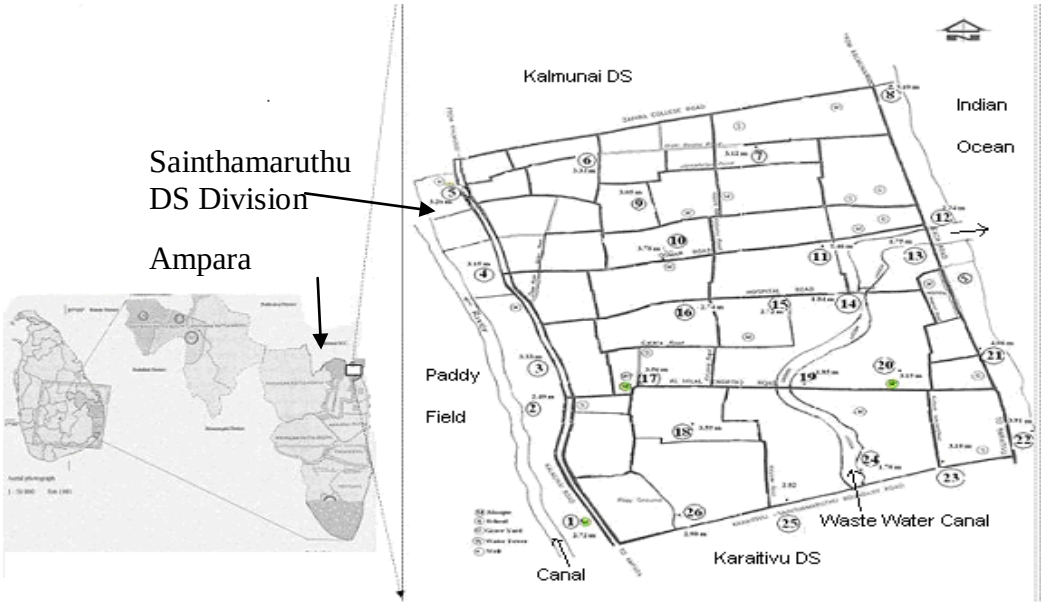

Figure 1: Study area: Sainthamaruthu DS, part of Kalmunai M.C. in the Ampara district

Water samples were drawn from stratified, randomly selected shallow dug wells, the major source of drinking water in the region, located in Sainthamaruthu DS division (numbered in circles, Fig. 1), which is the South-Eastern boundary of Kalmunai Municipal Council. Water quality was analysed, in terms of indicator bacteria and a few other basic physico-chemical parameters, such as pH, electrical conductivity and chemical contaminants. The depth to water table from soil surface was also measured on each sampling occasion. The sanitation facilities were also taken into consideration.

Water quality, in terms coliform (indicator bacteria), was generally very poor throughout the area of study. However, spatial and temporal variations of other contaminants tested were found to be less significant than that of indicator bacteria. Diarrhoea is the most prevalent health problem in the area. Typhoid and paratyphoid fever, and other intestinal infectious diseases are the other major water borne diseases prevailing. Water related vector borne diseases are seasonal and occur during and/or soon after the North- East monsoon rains. The highly permeable sandy regosol soils found in this area simply allow waste waters to easily leach down to the groundwater system rapidly, where as lack of basic infrastructure facilities, poor drainage system and inadequate excreta disposal systems all contribute to the groundwater contamination. Therefore, the probability of groundwater contamination is high. All these problems are aggravated by the very high population density of this area.

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DRINKING WATER QUALITY ASSESSMENT TOWARDS "CHRONIC KIDNEY DISEASE OF UNKNOWN ETIOLOGY (CKDu)" IN NORTH CENTRAL PROVINCE (NCP) OF SRI LANKA.

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The rising prevalence of chronic renal failure (CRF) in the North Central Province (NCP) has profound consequences for the increasing trend in mortality and morbidity. Renal biopsy studies in patients reveal the possibility of a toxin-mediated renal disease. Trace metals in the environment are considered as a major geo-environmental factor that could contribute to the etiology of renal damage. Hence, the exposure of heavy metals has received more attention. There is also a suggestion that, at least to some extent, the fluoride content of drinking water contributes to the CKDu.

Based on observations of this study, there is strong evidence that CKDu has a profound relationship to drinking water consumption. Even in high disease prevalence areas, such as Kebithigollewa, there are certain areas which can be isolated as non-endemic regions, where people consume spring water for drinking. Interestingly no patients have been reported from such areas, where people consume spring water for a considerable period of time.

The objective of this investigation is to study and compare the drinking water quality of comparatively high and low prevalence areas, with spring water quality with respect to CKDu.

Drinking water samples were collected from high prevalence areas (Padaviya, Kebithigollewa and Medawachchiya Divisional Secretariats (DS) divisions); low prevalence areas (Anuradhapura town area and Pulmoddai area); and from springs (four springs in the Kebithigollewa DS). Patient availability in each sampling location was also recorded for further studies. Water samples were analyzed for F, Al, Cd, As, Ca, Mg and water hardness. Fluoride in collected drinking water samples given below.

Area	No.of samples	Minimum(mg/l) (Min)	Maximum(mg/l) (Max)	Average(mg/l) (Avg)
Padaviya (Pad)	120	0.164	1.530	0.554
Medawachchiya (Med)	100	0.231	3.270	1.020
Kebithigollewa(Keb)	80	0.176	3.130	1.336
Anuradhapura town area (Anu)	30	0.121	0.883	0.411
Pulmude (Pul)	30	0.064	1.030	0.412
Springs (Spr)	24	0.061	0.069	0.066

Summary results of the trace metals in drinking water from high and low prevalence area compared to springs.

Element	High prevalence			Low prevalence		Control
	Pad	Med	Keb	Anu	Pul	Spr
Al (µg/l) Min	3.28	9.29	8.34	21.21	11.64	49.18
Max	120.43	248.64	239.57	633.82	226.58	79.54
Avg	16.37	56.42	62.77	362.45	56.48	64.85
Cd (µg/l) Min	0.03	0.27	0.30	0.51	0.55	0.30
Max	2.50	9.53	7.47	3.88	6.59	0.75
Avg	0.49	1.40	1.39	1.99	2.27	0.57
Ca (mg/l) Min	16.79	8.28	15.37	9.35	4.35	1.72
Max	115.28	120.40	62.92	66.99	37.93	6.64
Avg	48.90	40.12	32.41	28.65	22.77	3.11
Mg (mg/l) Min	2.16	6.22	12.25	11.62	6.73	2.49
Max	58.27	179.12	99.40	32.43	38.95	6.30
Avg	21.85	39.51	34.35	17.51	22.52	4.23

Selected set of water samples; (30 samples from CKDu patients' drinking water source + 30 samples from low prevalence areas and springs) were tested for As and levels are much below the WHO standards. (10µg/L)

On the basis of the elemental analysis from this study, compared to drinking water quality in high and low prevalence areas; Fluoride, Ca, and Mg levels are much lower in spring water. Al levels are comparable (except Anuradhapura town area) in other areas with the spring. In all the areas; average Cd levels are below the WHO standards. (3µg/L)
Average As levels are much below the WHO standards. (10µg/L)
Based on this analysis, it is advisable to drink spring water by means of CKDu.

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