2015

CHALLENGES AHEAD

WATER QUALITY AND HUMAN HEALTH

International Symposium

PROCEEDINGS

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01st & 02nd August 2015

Postgraduate Institute of Science (PGIS) University of Peradeniya - Sri Lanka

Organized by the

POSTGRADUATE INSTITUTE OF SCIENCE (PGIS), UNIVERSITY OF PERADENIYA, SRI LANKA
in collaboration with the
International Research Center, University of Peradeniya
and in technical association with the
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4th International Symposium on

WATER QUALITY AND HUMAN HEALTH: CHALLENGES AHEAD

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Message from

the Director
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I am pleased to issue this message to mark the "4th International Symposium on Water Quality and Human Health" to be held on the 01st and 02nd of August 2015 at the Postgraduate Institute of Science (PGIS).

Ever increasing health problems and irreparable damage to the entire ecosystem due to water pollution problems have no doubt stimulated scientists to conduct research on identifying the root cause of problems and to propose remedial measures. The public is also keeping attention on issues related to water pollution expecting viable solutions. I believe that it is the duty of educational/research institutions to make arrangements to disseminate knowledge of scientists through appropriate mode of action.

In this respect, the Organizing Committee of this Symposium has taken a keen interest to conduct this timely and globally important Symposium at international level. More than fifty abstracts will be presented in diversified fields within the broad area of "Water Quality and Human Health". Scientists from many other countries, including Japan, India and Brunei Darussalam have made a significant contribution to the Symposium. I am certain that this Symposium would be a great success as in the past, and expect that the fifth Symposium on the same theme be conducted in the year 2016.

I congratulate the Organizing Committee of this workshop, headed by Dr. Sudharma Yatigammana of the Department of Zoology of the University of Peradeniya for organizing the Symposium.

Prof. H.M.D. Namal Priyantha
Director
Postgraduate Institute of Science, University of Peradeniya, Sri Lanka.

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PHYSICO-CHEMICAL CHARACTERISTICS OF GROUNDWATER IN A SELECTED AGRICULTURAL AREA IN NEERVELY, JAFFNA

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Groundwater is the main source of freshwater for people in the Jaffna peninsula. One of the causes of ground water pollution in Jaffna is excessive use of agrochemicals. Nutrient leaching from agricultural soil into groundwater could cause degradation of groundwater quality. During the preliminary investigation, six dug wells (four wells within the paddy field and two wells 1 km away from the paddy field) were selected in Neervely, an important agricultural area of the Jaffna peninsula. Water quality parameters including pH, alkalinity, Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), potassium(K^+), calcium(Ca^{2+}), magnesium(Mg^{2+}), chloride(Cl^-), nitrate (NO_3^-), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}) and conductivity were monitored periodically over a period of four months from October 2013 to February 2014 (paddy cultivation period).

The pH values of the well water samples indicated slight alkalinity in all the water samples. pH of wells located inside paddy fields increases slightly during the cultivation period. However, it remains within the maximum desirable level (7.0 to 8.5) for drinking water. Both TDS and TSS of wells within the paddy field increase during the cultivation period and they were found to be higher during December to January. However, TDS and TSS of wells away from the paddy field remains around 200 mg L^{-1} over a period of four months. COD of wells within the paddy field was above 10 mg L^{-1} in December. However, COD of wells away from the paddy field range between 0.7 - 0.8 mg L^{-1} throughout the study period. Calcium content of wells within the paddy field increased during the cultivation, recording the highest value in December (168 mg L^{-1}) and it range between 92 - 120 mg L^{-1} in wells away from the paddy field. Concentration of magnesium of wells within the paddy field increases during the cultivation period with the maximum concentration of 58 mg L^{-1} in December and it ranges between 21 - 27 mg L^{-1} in wells away from the paddy field. Potassium content of wells within the paddy field increased from 13 mg L^{-1} to 28 mg L^{-1} and for wells away from the paddy field values range between 1 - 7 mg L^{-1}. Concentration of chloride was between 200 - 255 mg L^{-1} in wells within the paddy field and 89 - 115 mg L^{-1} in wells away from the paddy field. Concentration of sulphate varies between 270 - 309 mg L^{-1} in wells within the paddy field and 117 - 125 mg L^{-1} in wells away from the paddy field. Higher concentration of phosphate (2.3 mg L^{-1}) was recorded in December in wells within the paddy field and the phosphate content of wells away from the paddy field range between 0.1 - 0.8 mg L^{-1}. Nitrate content varies between 7 - 11 mg L^{-1} in wells within the paddy field and 1 - 3 mg L^{-1} in wells away from the paddy field. Results of this study show that the concentrations of Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, PO_4^{3-} and NO_3^- were higher than the maximum desirable level according to the Sri Lankan standard for drinking water for wells within the paddy field mainly during December. However, they were below the maximum desirable level for wells away from the paddy field.

Keywords: Agrochemicals, groundwater, Jaffna peninsula, pollution

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STUDY OF THE EFFECTS OF SOIL ACIDITY AND SALINITY ON ALUMINIUM MOBILITY IN SELECTED SOIL SAMPLES

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Aluminium is the most abundant metal in the earth's crust. Aluminium in soil is found to be incorporated into aluminosilicate soil minerals thereby forming stable inactive form. Very minute quantities appear in soluble forms capable of influencing biological systems. Aluminium mobility and as a consequence aluminium toxicity, is mainly restricted to acid environments. Aluminium has low mobility under most environmental conditions. However, below a pH of 4.0 its solubility increases and aluminium is released from silicate rocks under such acidic conditions. The levels of dissolved aluminium in natural groundwater samples are generally low, probably due to its low solubility at neutral pH values. Release of acids by anthropogenic activities influence the soil acidity levels. Therefore, elevated levels of aluminium have been found in acidified soil solutions and surface waters causing harmful effects to living organisms.

The present study was aimed at proving the above theoretical hypothesis and existence of a possible relationship between soil salinity and soil acidity on the concentration of mobile aluminium ions in samples obtained during the location surveys. Samples were collected from selected locations in Ratnapura, Rathupaswala, Marawila, Mabima and Muthurajawela to get different soil types and the survey results were used to test the hypothetical relationship between the presence of the stated factors, and the existence of a high concentration of mobile aluminium in the soil water samples. The analysis covered basic parameters such as soil pH, soil cation exchange capacity (CEC), soil organic matter, soil electrical conductivity and the influence of the concentration of mobile aluminium at different pH and Na^+ concentration levels. The total aluminium concentration in the soil was assayed by digesting samples with strong acid. Concentration of mobile aluminium in soil samples were analyzed using the flame atomic absorption spectrophotometer (Analytikjena Nova 400p). The results indicated that there is no clear relationship between mobile aluminium and total aluminium in the soil. It was also found that the concentration of mobile aluminium released increased with decrease in soil pH and that the increase was marked when the pH of soil water was less than 4.0. Highest mobile aluminium release to the soil solution was found from Mabima sites. This result confirmed that there is a relationship between soil acidity and concentration of mobile aluminium in the soil. Results also showed that the concentration of mobile aluminium released increased with increasing soil salinity and that the increase was rapid when the Na^+ ion concentration was higher than 2.0 %. Highest mobile aluminium release to the soil solution was found from Muthurajawela sites, confirming the relationship between soil salinity and the concentration of mobile aluminium in the soil. The study also points towards the future opportunities for research to confirm these findings using wider samples and employing more vigorous research methodologies.

Keywords: Mobile Al, total Al, soil acidity, soil salinity, cation exchange capacity.

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DUG WELLS LOCATED AT THE RECOMMENDED MINIMUM SAFE DISTANCE FROM SOAKAGE PITS ARE AT A RISK OF FAECAL CONTAMINATION

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The major source of drinking water in Sri Lanka is ground water drawn from dug wells. One of the major problems associated with drinking water from dug wells is microbial contamination due to migration of faecal effluent from nearby soakage pits. The Ministry of Health (MOH), Sri Lanka has recommended a minimum safe distance of 15 m between dug wells and soakage pits to safeguard the consumers of water from dug wells. The objective of this study was to determine the relationship of the distance between dug wells and soakage pits and seasons (dry and rainy seasons) on the faecal contamination of dug wells through the migration of bacteria from soakage pits.

Twenty dug wells (n = 20) belonging to different households in two newly urbanized areas (Ragama and Ganemulla) of the Gampaha District, Sri Lanka were categorized into four groups as dug wells positioned 9 - 12 m, 13 - 14 m (wells positioned closer to the recommended minimum safe distance from the soakage pit), 15 - 16 m and 16 - 18 m away from the soakage pit. Water samples were collected from wells (five wells for each of the distance category range) during the period from April to October, 2014 and handled according to relevant ISO guidelines (ISO 19458:2006) and analyzed for total coliforms, faecal coliforms and *Escherichia coli* (Most Probable Number method, MPN) according to the Sri Lankan standard (SLS 614 part 2: 1983).

Ninety percent of the wells studied were located at a shorter distance than the recommended minimum distance (15 m) from the soakage pit and fifty percent of wells studied positioned according to the MOH guidelines (distance from the soakage pit ≥ 15 m) were found to be contaminated with faecal bacteria. Therefore they were not up to the World Health Organization standard (WHO, 2008) which states that coliforms, faecal coliforms or *E. coli* must not be detected in any 100 mL portion of drinking water (Figure 1).

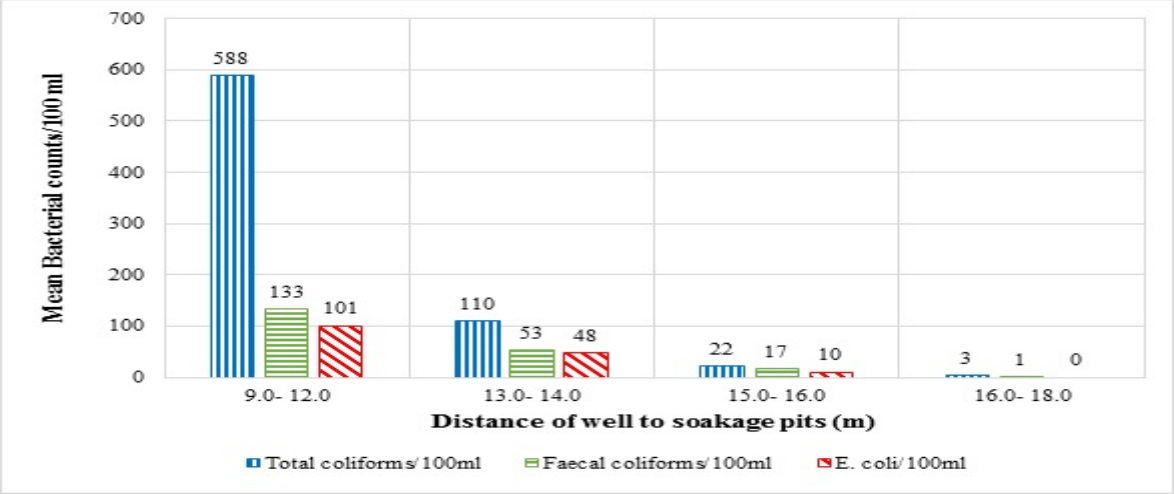

Figure 1. Mean coliform bacterial counts of wells in different distance category ranges from soakage pits to wells

One way ANOVA of data gathered in this study indicates that there is a significant ($p < 0.05$) relationship between decreasing distance from wells to soakage pits and increasing *E. coli* concentration in well water.

A higher coliform concentration was observed in samples collected during the rainy season compared to the samples collected during the dry season. The study shows that the season has a significant influence on the microbiological quality of water from dug wells and wells which are safer and free from fecal contamination during the dry season could enter into the risk group during the rainy season.

This study reveals that the dug wells located at the recommended minimum safe distance given in relevant MOH guidelines (15 m) and even beyond (18 m) from soakage pits are at a risk of faecal contamination which is consistent with the results of previous studies. This could be the reason for WHO to give 30 m as the minimum safe distance between dug wells and soakage pits. Therefore, it is important to reconsider the minimum safe distance by taking all possible factors that could affect this distance, such as sub-surface geology and hydrogeology of the area, into account. In risk areas where maintenance of a safe distance is not practical and possible, educating consumers to treat water before consuming or providing them with treated water from centralized facilities would be of utmost importance to assure its safety.

Keywords: Drinking water quality, dug wells, faecal coliforms, soakage pit distance

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EVALUATION OF THE RELATIONSHIP BETWEEN SOIL ORGANIC MATTER CONTENT AND GROUNDWATER pH IN MUTHURAJAWELA AREA

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Wetlands are ecotones between land and aquatic systems where the water table is usually near or at the soil surface. They are also one of the most fertile ecosystems found in Sri Lanka. The Muthurajawela wetland is a unique wetland in terms of its attributes, operations and uses. Throughout generations, Muthurajawela wetland has played a significant role in contributing eco-system services towards fisheries, agriculture, wildlife, nutrient retention, and as a drainage basin in the Gampaha district.

Wetlands are composed of unique characteristics of soil and groundwater. The groundwater chemistry will vary depending on the chemical composition of the contact soil. According to the literature, wetland soil naturally contains a high amount of organic matter, and this leads to high cation exchange capacity (CEC) in soil. High CEC enables wetland soil to hold higher amount of cations including hydrogen/metal ions creating a dynamic equilibrium between soil and these cations. However, if high concentrations of metal ions enter to the soil, it will alter the dynamic equilibrium causing impacts on the groundwater chemistry. The objective of this study was to highlight the relationship between soil organic matter content and groundwater pH in Muthurajawela wetland. For the study, soil and groundwater samples were collected from Muthurajawela wetland using random sampling techniques. The analysis was conducted in two phases; initially some selected properties of wetland soil were analyzed according to Food and Agriculture Organizations (FAO) procedures and subsequently the relationship between those properties and the soil organic matter content were investigated. It was observed that there is a high percentage of soil organic matter content in Muthurajawela wetland which ranges from 7.3% - 84.1% per dry weight basis. Also, the soil organic matter content positively correlate with soil CEC and soil electrical conductivity which ranges from 4.79 – 29.37 $meq100^{-1}$ g per dry weight and 2420 µS cm^{-1}– 932 µS cm^{-1}, respectively. Even though the soil showed strongly acidic pH values in this area (2.55 – 5.63), groundwater showed almost neutral pH values (6.28 – 6.88). In the second phase of the study, the effect of salinity/cations such as metal ion concentrations in soil on ground water pH was investigated. This model analysis was determined by introducing different concentrations (Na^+ = 0.98 g L^{-1} - 3.92 g L^{-1} and Ca^{2+} = 0.02 g L^{-1} – 0.10 g L^{-1}) of metal ions to soil. The analysis revealed that the high metal ion concentrations in soil will shift the equilibrium in soil with hydrogen ions and there by alter the groundwater pH, from neutral to acidic as soil bound hydrogen ions will be replaced by metal ions and the released hydrogen ions will leach to groundwater changing the pH. Using the findings, it can be concluded that even though Muthurajawela wetland has a high CEC due to high organic matter content, there is a potential of altering the groundwater pH from almost neutral to acidic, through addition of high concentrations of metal ion. This can be anticipated as a potential threat to this studied ecosystem in the future.

Keywords: Muthurajawela, organic matter content, cation exchange capacity, soil pH, soil salinity

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APPLICATION OF WATER QUALITY INDEX (CCME-WQI) IN ASSESSING WATER QUALITY FOR GROUND WATER IN KELANI RIVER BASIN, SRI LANKA

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Kelani river basin is one of the important river basins in Sri Lanka and contributes for agriculture and operation of several industries. Kelani river basin covers nearly seven districts and also cover Colombo city which is the commercial capital city of Sri Lanka. The river basin is subjected to the pollution by various sources such as land use practices (paddy, tea, rubber, coconut, vegetables and other export agricultural crops cultivation), industrial wastes and several other anthropological activities (urbanization, agriculture, sand mining, gem mining, domestic activities and several other constructions). These pollutants directly and indirectly affect the quality of groundwater and surface water as well. Majority of the human population in the river basin depend on the shallow groundwater for their daily needs. Thus water quality management of the river basin has become an urgent requirement to safeguard the human health. Water Quality Index (WQI) is a key to solve the problems of data management and to evaluate management strategies for improving water quality.

A WQI developed by the Canadian Council of Ministers of the Environment (CCME) provide a convenient mean of summarizing complex water quality data. The present study describes the application of WQI for groundwater in Kelani river basin to evaluate their suitability to use especially for drinking, livestock and irrigation purposes. Thirty (30) groundwater sampling locations in the Kelani river basin were selected for the WQI assessment and sampling was done from October 2012 to September 2013. CCME WQI was applied for eighteen water quality parameters: pH, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), total phosphate, conductivity, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nitrate, nitrite, hardness, total coliform and feacal coliform bacterial counts, Cr, Pb, Cu, Zn, Al and Cd. Based on the results, the index values and their ranks for drinking recorded as poor (33). Water quality for irrigation (80) and livestock (100) were recorded as good and excellent respectively. The results strongly suggested taking actions to develop proper management strategies to safeguard the river basin as the Kelani river serves for more than 80% of water supply for recipients living within the premises of the river basin.

Financial support by the NSF, Sri Lanka is acknowledged.

Keywords: Water quality index (WQI), Kelani river basin, groundwater

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SEASONAL VARIATION OF WATER QUALITY STATUS OF MENIK GANGA, KATARAGAMA, SRI LANKA

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The Menik Ganga which flows through the holy city of Kataragama is located in the southern semi-arid part of Sri Lanka. The catchment of the river (1,272 km^2) receives its annual rainfall (1496 mm) mainly from northeast monsoons (from November to January) and the dry season lasts from June to September. The river supplies water for rice and sugarcane agriculture and also for domestic purposes. During the Kataragama festival season (July and August) over 0.1 million pilgrims utilize the river water per day, over a period of 15-days which can easily lead to epidemic conditions.

A comprehensive study was done for three consecutive years (2012 - 2014) to understand the seasonal variation of water quality status of Menik Ganga. Twenty crucial physico-chemical and microbiological parameters (pH, colour, TDS, sulphate, nitrate, nitrite, free ammonia, chloride, fluoride, total alkalinity, conductivity, hardness, iron, COD, DO, BOD, phosphate, turbidity, total coliform and faecal coliform) were measured monthly from year 2012 using standard techniques. The highest pH was recorded in 2013 (8.1 ± 0.31) and the lowest in 2012 (7.1 ± 0.12). The nitrate (0.007 - 0.13 mg L^{-1}), sulphate (8 - 39 mg L^{-1}), TDS (203 - 560 mg L^{-1}), free ammonia (0.01 - 0.3 mg L^{-1}), fluoride (0.29 - 1.03 mg L^{-1}), hardness (69 - 206 mg L^{-1}), COD (3 - 37 mg L^{-1}), total coliform (240 -22000) and faecal coliform (11 - 4600) varied during the study period. Principal Component Analysis (PCA) was done using the twenty environmental variables which were used to determine the water quality. The results of PCA clearly indicate that rainfall and Kataragama festival season help differentiate the monthly water quality of the river. PC1 score into one-way ANOVA test was also done to confirm the separation of water quality in different months and showed that there was a significant difference between January, April, October, November, December and other seven months.

Financial support provided by the National Water Supply and Drainage Board of Sri Lanka is acknowledged.

Keywords: Water quality, microbiological parameters, PCA

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ASSESSMENT OF CADMIUM ION CONTAMINATION IN SELECTED WATER RESERVOIRS IN NORTH CENTRAL PROVINCE OF SRI LANKA

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The study was based on possible contamination of water reservoirs owing to inorganic agricultural inputs in agriculture. The levels of accumulation of cadmium ions in the water and sediments of twenty water reservoirs in the North Central Province of Sri Lanka were assessed. The study consisted of a network of twenty reservoirs connected to each other in a cascade pattern with one feeding the other and with the main source being the Mahaweli river. Collected water and sediment samples at different time intervals and at different locations within the reservoirs were subjected to analysis by Atomic Absorption Spectroscopy to determine levels of cadmium ion concentrations. A subset of collected water samples were filtered by passing the water through a bacterial filter of pore size 0.2 µm in diameter and cadmium ion concentrations of filtered water were analyzed.

The cadmium ion concentrations in the unfiltered water ranged from 0.349 µg L^{-1} (Eppawela reservoir) to 7.313 µg L^{-1} (Epalogama reservoir), whereas for the filtered water, levels ranged from 0.081 µg L^{-1} (Dombagahagama reservoir) to 2.025µg L^{-1} (Epalogama reservoir). Cadmium ion concentrations in the sediments of the twenty reservoirs ranged from 0.2901mg kg^{-1} (Dombagahagama reservoir) to 4.64 mg kg^{-1} (Pahalahalmillawa reservoir). The pH levels of sediments and water ranged from 7.57 (Pahalahalmillawa reservoir) to 8.47 (Rajanganaya reservoir) and 6.99 (Dombagahagama reservoir) to 7.46 (Pahalahalmilla reservoir), respectively.

In this study we observed that the filtered water samples of the twenty reservoirs did not reach the cadmium ion concentration to the maximum contaminant levels defined by the World Health Organization (WHO) (3 µg L^{-1}) though the unfiltered water sample of the Epalogama reservoir showed a higher value (7.313 µg L^{-1}). None of the other reservoirs showed higher values above the standards. Determined pH of the water samples were compared with the defined standard values (WHO - pH 6.5 to 9.5) and the data of the water samples for pH were within the said standard range.

All the reservoirs sediment samples indicated the presence of deposited cadmium and there was no significant relationship observed between the deposited cadmium levels and sediment pH. The difference between deposited cadmium levels in the reservoirs is owing to the dynamic nature of the reservoirs, the capacity, feeding area, number of paddy fields surrounding a reservoir, number of canals feeding it through cascade and the soil type in the reservoir.

Financial support provided by the Postgraduate Institute of Agriculture, University of Peradeniya is acknowledged.

Keywords: Cadmium ion concentration, sediments, water, pH, North Central Province

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DISTRIBUTION OF PHOSPHOROUS IN SURFACE SEDIMENTS OF FLOODPLAIN LAKES (*VILLUS*) AND ASSOCIATED WATER BODIES OF MAHAWELI RIVER BASIN: A PRELIMINARY STUDY

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Sedimentation of inorganic phosphorus (P_i) occurs through co-precipitation with calcium and iron compounds in aquatic systems. These phosphorous containing compounds are usually trapped in sediments under aerobic conditions. Under anaerobic conditions, phosphorous present in sediments of lacustrine systems act as a phosphorous resource through releasing mobile form of phosphorous (P_m) to the water column by mineralization. An increase in concentration of P_m in water causes an increase in primary production. Floodplain lakes (*Villus*) associated with Mahaweli River (MR) of Sri Lanka are natural fresh water aquatic ecosystems located at the hindmost part of the river Mahaweli. *Villus* fed mainly by periodic floods of MR, especially during the North-Eastern monsoon season. Mahaweli System C (MSC), an agricultural scheme established under the accelerated Mahaweli Development Project, is located upstream of the *Villus* of MR. In addition agricultural drainage of MSC also help feed these *Villus*. As MSC has been established for more than thirty years, movement of phosphorus (P) to *Villus* has become unavoidable. Therefore, the current study was initiated to understand the presence of P in *Villus* and the associated systems. Thirty two surface sediment samples from *Villus* and associated agricultural drainage canals, and sixteen surface soil samples from paddy fields and forest lands of the catchment of *Villus* were analysed. The results indicated that the maximum level of available phosphorous (P_{AV}, P extracted with Na_2CO_3 at pH 8.5) of 76.4 ± 7.1 mg kg^{-1} in sediments of *Villus*. P_{AV} among river sediments, paddy soil and forest soils was significantly lower and varied in the range of 30.8 – 48.6 mg kg^{-1}. Average levels of total phosphorus (TP) were 546.9 ± 69.2 mg kg^{-1}, and there was no significant difference of TP between paddy soil and natural soils of the catchment of *Villus*. This indicates the minimum accumulation of phosphorous in surface soils of paddy land which use inorganic fertilizer. Levels of TP in sediments (635.8 ± 67.3 mg kg^{-1}) are significantly higher than those of surface soils. Moreover, the difference of TP levels of sediments between MR and *Villus* was high with the levels of 648.6 ± 38.0 mg kg^{-1} and 626.1 ± 88.4 mg kg^{-1}, respectively. Thus it is clear that the transfer of mobile P_i is generated in sediment of *Villus* to water column is a function of P_i for primary production.

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Keywords: Sedimentation, phosphorous accumulation, primary production

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EVALUATION OF WELL WATER QUALITY IN MAHARAGAMA WITH SPECIAL EMPHASIS ON PRINCIPAL COMPONENT ANALYSIS (PCA)

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Groundwater contamination adversely affects the health of the individuals who consume well water. In the present study groundwater samples were collected from Jambugasmulla, Navinna, Wijerama, Gangodawila South B, and Wattegedara including University of Sri Jayawardhenapura premises to cover five Grama Niladhari (GN) divisions situated in Maharagama. The area is continuously populated and highly urbanized with different anthropogenic activities and groundwater aquifers are very shallow and susceptible for human induced pollution. The purpose of the study was to analyze and compare overall well water quality in Maharagama area using Principal Component Analysis (PCA) with the aid of microbiological and some physico-chemical parameters with reference to SLS drinking water standards. Eighty wells were sampled monthly using simple random sampling method from January 2012 to October 2012 for microbial and physico-chemical parameters by standard analytical methods and the PCA was carried out to evaluate the relative water quality among GN divisions.

According to PCA analysis**,** both Jambugasmulla and Wijerama showed similar characteristics. They are clustered together with high BOD_5 indicating high organic pollution and the relationship with high total coliform and faecal coliform counts suggesting as unacceptable for drinking purposes. The pH values were also higher than other GN divisions recorded. Wattegedara GN division contained the highest polluted wells with the highest nitrate (77.31ppm), COD (27.40 mg L^{-1}) and salinity (0.0078 mg L^{-1}) with high total coliform (412CFU/100 mL), faecal coliform (250CFU/100 mL) indicating both chemical and microbiological pollution. Navinna GN division had a distinctly high conductivity value (70000 µS cm^{-1}) and located separately among other clusters. Apart from PCA analysis, results showed that both total and fecal coliform counts ranged between 0 to >1100 CFU per 100ml ($p<0.001$), sometimes exceeding more than1100 CFU/100 mL. On average the total nitrate concentration was significantly high ($p<0.001$) and in some locations in the Wattegedra GN division nitrate concentration exceeded by more than 60 mgL^{-1}. Mean ranges of nitrate (0.64-77.31 mg L^{-1}), pH (4.11-7.14), conductivity (114-70000 µS cm^{-1}), BOD_5 (0.03-19.40 mg L^{-1}) and COD (0.14-64.13 mg L^{-1}) were recorded, respectively.

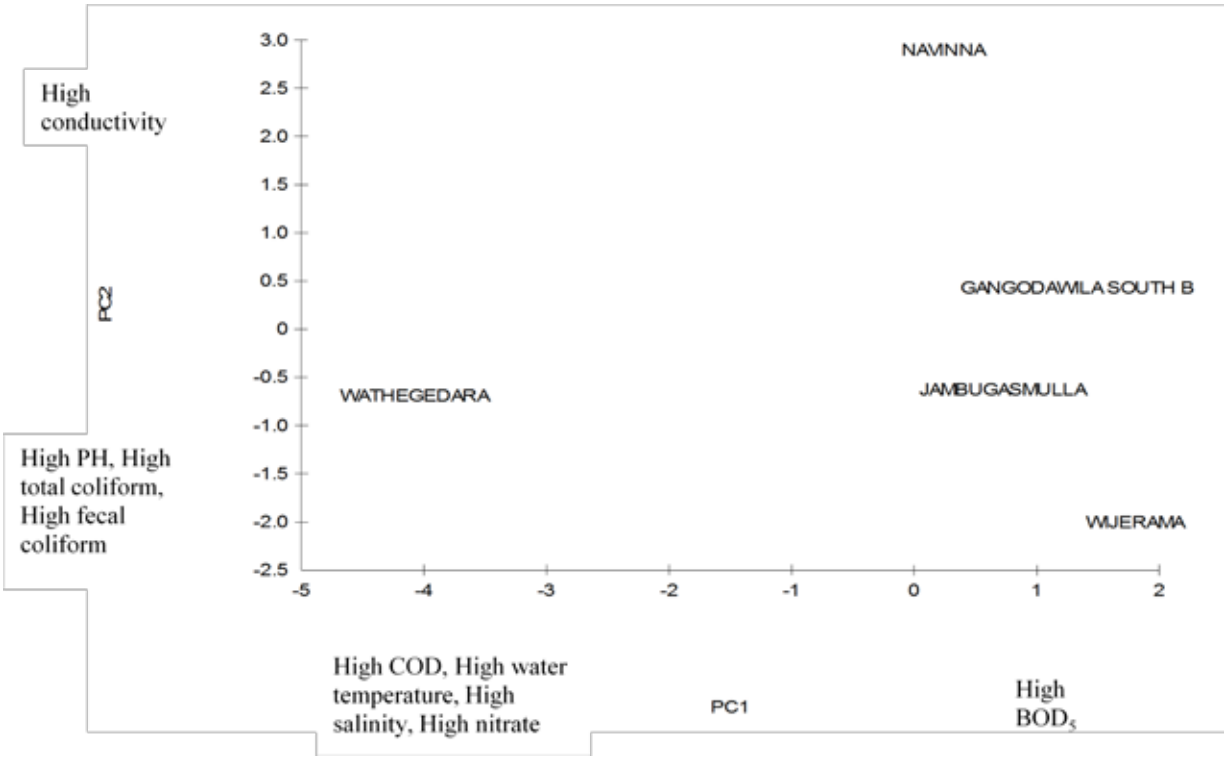

Figure 1. General Situation of the study area (With Comparison of Five GN divisions in Maharagama) using Principal Component Analysis (PCA)

The results of the study showed that overall water quality of the area is deteriorated and all parameters tested were far above the standard given for drinking water quality by SLS. PCA analysis showed that the pollution status of the Jambugasmulla and Wijerama area is more or less similar where Navinna area which has a solid waste dumping site had highest conductivity, nitrate, phosphate and microbial density which far exceeded the drinking water standards. As the study area has a very shallow water table it is very susceptible for pollution making the situation more dangerous. Although people in the area get the water supply from National Water Supply and Drainage Board, many people in this area still use their wells for water consumption. Therefore it is essential to take appropriate actions to safe guard the human population who consumes ground water to avoid water borne illnesses.

Keywords: Groundwater, physico-chemical parameters, PCA

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IONIC COMPOSITION OF BULK PRECIPITATION AT UNIVERSITY OF PERADENIYA

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The purpose of the present work was to investigate the chemical composition of bulk atmospheric precipitation at the University of Peradeniya premises. Thirty samples of bulk deposition, combination of both dry and wet depositions, collected at the Faculty of Science were analyzed during a four month period from May to September 2013. Parameters, such as pH, conductivity and inorganic ions (Na^+, Mg^{2+}, Ca^{2+}, K^+, NH_4^+, NO_3^- and SO_4^{2-}) were determined for each sample. The pH of each sample was measured using a digital pH meter (Orion Model 420A) and a conductivity meter (WPA CM35) was used to measure conductivity. The major ions such as NO_3^- and NH_4^+ were quantitatively determined using UV/Vis spectrophotometer (Shimadzu - 1800 UV), Ca^{2+}, Mg^{2+}, K^+ and Na^+ were analyzed using Atomic Absorption Spectrophotometer (Thermo Model 200A). Eutech Portable Turbidimeter (TN-100/T-100) was used to quantify the amount of SO_4^{2-} present in each sample.

The ionic abundance in precipitation shows in the order of $SO_4^{2-} > NO_3^-$ for anions and $NH_4^+ > Na^+ > Ca^{2+} > K^+ > Mg^{2+}$ for cations. Slight fluctuations were observed in some precipitation events may be due to the weather changes. The SO_4^{2-} ion gives the highest contribution of 42% of the total ionic mass which accounts for anthropogenic sources, such as vehicle exhausts. The contribution of NH_4^+ and Na^+ were 18% and 17%, respectively, and Ca^{2+} and NO_3^- show similar contribution to the total ionic mass, while $Mg^{2+}$and K^+ contribute at 3% and 4%, respectively. Among many parameters measured, conductivity is the key parameter to determine the ionic level in rainwater. The range of conductivity recorded during the study period was 6.1 µS cm^{-1} and 38.0 µS cm^{-1}, while the pH is averaged to 6.56 ± 0.52 with a normal distribution. Although pH is indicative of the absence of acid rain events during the measured period, high pH observed could be due to neutralization effects of Ca^{2+} and NH_4^+. Continuation of such measurements for a longer period will enable to design an atmospheric pollution model.

Keywords: Atmospheric precipitation, ionic abundance, anthropogenic sources

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EVALUATION OF ENVIRONMENTAL CONDITIONS FOR SELECTED FRESHWATER MICROALGAE SPECIES WITH THE POTENTIAL FOR THE PRODUCTION OF BIODIESEL

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The importance of using renewable green energies is being debated globally since harmful effects due to continuous combustion of fossil fuels have been realized. These concerns have increased the interest in the production of alternative energy sources such as biodiesel and bio ethanol. Production of biodiesel from microalgae is categorized under third generation biofuel which is considered to be a viable alternative energy resource. Sri Lanka is a tropical country with thousands of reservoirs having a variety of phytoplankton including several microalgae. This study focused on investigating growth kinetics of freshwater microalgae, cultivated in wastewater under laboratory conditions in order to identify the species with the highest potential for the production of biodiesel. Three freshwater microalgae species were isolated, from water samples collected from two reservoirs included Victoria reservoir in Central province (7˚ 14' N, 80˚ 47' E) and Ulhitiya reservoir in Uva province (7˚ 27' N, 81˚ 3' E), representing the Wet and Dry climatic Zones of Sri Lanka respectively. Algae species were cultivated in closed systems by using synthetic wastewater as the medium. Light intensity, aeration and temperature were varied as the growth parameters. The pH of the medium was maintained at 7.0. The light intensities were varied as 0.71 Klux, 1.77 Klux and 3.92 Klux, where the aeration rates were varied as 2 cm^3 min^{-1}, 4 cm^3 min^{-1} and 8 cm^3 min^{-1}. In addition, the temperature was varied as 30 $^{\circ}$C, 35 $^{\circ}$C and 40 $^{\circ}$C. According to the statistical analysis, *Chlorella* sp. showed the highest growth rate compared to *Monoraphidium* sp. and *Scenedesmus* sp. under all three conditions. Conversely in relation to the analysis, *Chlorella* sp. is more temperature sensitive where *Monoraphidium* sp. and *Scenedesmus* sp. are more sensitive to light intensity and pH respectively.

Keywords: Biodiesel, microalgae, growth kinetics, wastewater

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FLOOD RISK AMONG THE POSTWAR RESETTLED PEOPLE IN NORTHERN SRI LANKA

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During the last three decades the Northern Province of Sri Lanka had been affected by a civil war. After the end of war in May 2009, the Government of Sri Lanka took measures to immediately resettle the displaced people. The necessity to quickly accommodate the Internally Displaced People (IDP) in this Province resulted in unintentional resettlement of some families in flood prone areas. As a result, some IDP were severely affected by annual floods since 2010. This study aims to evaluate the level of risk of floods of selected resettled communities in the Vavuniya District. Flood hazard, vulnerability and risk assessment and analysis were done by a participatory Geographic Information System (GIS) and through the Statistical Package for the Social Sciences (SPSS). Hazards mapping identified flood distribution, depth and duration. Vulnerability and coping capacity analysis was carried out on the various social, economic, physical, developmental and environmental factors. Flood hazard assessment combined with the vulnerability assessment generated the flood risk assessment in the study area.

Data were collected through questionnaire based surveys, interviews with key local leaders and focus group discussions (FGDs). A total of 120 questionnaires were completed by males (60%) and females (40%). Overall, responses showed a sufficient level of understanding of both flood hazards and vulnerability. According to Cohen (1988) criteria, there is a positive correlation between resettlement and flood risk. The Kruskal-Wallis test revealed that respondents' ethnicity significantly affected the flood risk, $H(2) = 10.37$, $p < 0.01$. During the displaced period, IDP have produced their second generation. These new families were required to resettle in unsafe areas due to no land ownership. Maintenance of the tank cascade system and canals was very poor during the war period. IDP community was forced to live in low level agricultural land with poor land management techniques.

Regarding flooding, the availability and quality of basic services such as drinking water and sanitation became crucial in determining the level of disruption experienced by the household. The study indicated that, waterborne diseases are widespread in these communities (dengue and skin infections) which are strongly related to poor sanitation and unsafe water during rainy seasons. The vulnerability analysis showed that IDP are resettled in low-laying areas with threats of flooding. According to the risk evaluation on categories of income, housing and other aspects, resettled villages were identified as high risk areas. Resettled communities built their houses without proper knowledge of inundation depth and it resulted in flooding of their houses even at the beginning of rainy season. Increased poverty, marginalization, homelessness and a general decrease in well-being are some of the risks observed among the resettled communities. Most importantly, floods cause the contamination of drinking water which consequently has a drastic impaction on the health of people.

Keywords: Flood, displacement, drinking water quality, human well-being

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EVALUATION OF SURFACE INTERPOLATION METHODS FOR MAPPING SPATIAL VARIATION OF SHALLOW GROUNDWATER QUALITY IN MALWATHU OYA CASCADE - I

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Groundwater is a vital source in the dry zone due to the limited availability of surface water. However, presence of excessive salts and nutrients in groundwater is one of the major constraints for its use. Mapping of surface variation of shallow groundwater quality will provide an insight to the status of quality variation in an area. Surface interpolation techniques available in Geographic Information System (GIS) will help to map this spatial variation with the data collected at point locations. However, the outcome may vary with the interpolation technique used. This study was conducted to evaluate different surface interpolation methods for shallow groundwater quality mapping in Malwathu Oya cascade I. The total area of the cascade was divided into 1 km^2 grids and twenty agro-wells were purposely selected by identifying one well from each grid. Water samples were collected and analyzed for pH, Electrical Conductivity (EC) and nitrate nitrogen and the analyzed data were used for mapping using Arc GIS 10.2.1 software. The percentages of 75%, 70% and 50% from the total sample size were randomly selected and used for the interpolation and rest was used for the validation of results. Three interpolation methods namely; Inverse Distance Weighting (IDW) method, Spline and Kriging methods were used in the analysis. To evaluate the performance of each interpolation technique, Mean Absolute Error (MAE) was used. According to the results, Kriging produced the lowest MAE for all three sample sizes for pH. The Spline method produced the lowest MAE for EC and lowest MAE for nitrate nitrogen was given by IDW method. According to the results, sampling size does not have an influence on MAE. However, the suitability of interpolation technique varies with the quality parameters. Since the study was conducted with a small sample size, it is recommended to use a much larger sample size to see whether the analysis varies with the size of the sample.

Keywords: Groundwater quality, interpolation, Malwathu Oya cascade I

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CONSERVATION OF THE MINNERIYA RESERVOIR BY APPLYING A CONSERVATION FINANCE MECHANISM

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The Minneriya reservoir is a man-made, non-tidal water retention reservoir, having been built in the third century AD with a catchment area of 24,000 ha. Minneriya reservoir is being challenged to remain in its original condition due to degradation of its catchment. Main threats include the clearing of vegetation and Chena cultivation that lead to increase the soil erosion resulting in high sedimentation rate of the reservoir. Additionally, overfishing and poaching are also reported. Thus, there is a need to devise a mechanism to conserve the Minneriya reservoir which gives enormous benefits to people and wildlife. The objective of this study is to propose a suitable conservation finance mechanism to conserve Minneriya reservoir.

Literature review was the main source of information in this study. In addition Geographic Information System (GIS) analysis (using Google images) was also used for the identification of changes that have taken place over time in the reservoir area. The data of the reservoir area collected from 2000 to 2014 period was also obtained from secondary sources and analyzed using GIS.

Accordingly, fish and wild-life populations in Minneriya reservoir catchment area are under pressure due to various human activities. Unmanaged grazing by livestock, soil erosion, misuse of pesticides and lack of fisheries management are among the main threats. Fourteen year period data analyzed by GIS and comparison of land use maps indicate that there was a reduction of the surface area of the reservoir from 22.89 km^2 in year 2000 to 22.37 km^2 in 2014.

The results signify that the catchment of Minneriya reservoir should be managed through the controlling of grazing by livestock and proper fishery management. In addition, conservation finance mechanism such as payment for watershed services can also be introduced to the watershed area of the reservoir.

Keywords: Minneiya reservoir, catchment, conservation finance mechanism

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IDENTIFICATION OF GROUNDWATER POTENTIAL ZONES USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM (GIS) IN CHINTAPALLY MANDAL, NALGONDA DISTRICT, ANDHRA PRADESH, INDIA

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A systematic planning of groundwater exploitation using modern techniques is essential for the proper utilization and management of precious shrinking natural resource. With the advantage of contemporary techniques like Remote Sensing (RS) and Geographic Information System (GIS), it will be easy to identify and protect the groundwater potential zones. In the present study, an attempt has been made to delineate and classify possible groundwater potential zones in Chinthapally Mandal, Nalgonda district, Andhra Pradesh, India using Indian Remote Sensing (IRS-1D) satellite imagery and integrated remote sensing and GIS techniques. The thematic layers like water bodies, lineaments, landuse/landcover, hydrogeomorphology and soil map, drainage pattern and annual rainfall maps were prepared using the IRS-1D satellite imagery and analyzed. Groundwater potential zones were identified based on weighted and ranking scores assigned to each thematic layer and integrated all the layers using Spatial Analysis tool from GIS environment. The favourable areas for groundwater potential were categorized into 'Very Good', 'Good', 'Moderate to Good', 'Moderate', 'Poor to Moderate' and 'Poor' for recharge in the study area.

Keywords: Groundwater potential zones, remote sensing, geographical information system

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ASSESSING POTENTIAL GENOTOXICITY OF INDUSTRIAL EFFLUENTS DISCHARGED FROM SELECTED TEXTILE INDUSTRIES AND INDUSTRIAL ZONES, USING FISH ERYTHROCYTE BASED COMET ASSAY

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Industrial effluents are mostly being discharged into inland water bodies with or without treatments and some of these surface waters are used for public water supplies. Industrial effluents are considered as extremely complex mixtures with inorganic and organic constituents. The effluents may induce genotoxic effects posing health risks to the native biota in the receiving waters and the general public who consume the contaminated surface waters. Comet assay, which detects DNA damages in the exposed nucleated cells, is considered as a standard tool for genotoxicity testing of environmental samples. The present study was undertaken to evaluate the potential genotoxicity of four industrial effluents discharged into the Kelani river basin from two selected textile industries and two industrial zones using fish erythrocyte based Comet assay.

The four selected industrial effluents were collected from the discharging points directly or from close proximity to the point of discharge on three occasions during the years, 2012 - 2014, which covered dry and wet periods. The effluents were tested for a range of physico-chemical parameters including selected heavy metals using standard analytical methods. The bioassay was conducted by exposing the fish, Nile tilapia (*Oreochromis niloticus*) to the effluents (undiluted and 1:8 dilution) in the laboratory under static renewal conditions. Aged tap water was used as the dilution/control media. Comet assay was conducted using fish erythrocytes following standard procedures after five days of continuous exposure and erythrocyte DNA integrity was tested using total comet scores and genetic damage indices of the exposed fish in comparison to the controls.

Most of the tested physico-chemical parameters in the effluents were within the respective national tolerance limits for the discharge of industrial effluents into inland surface waters. However, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels in the textile industry effluents and COD and colour measurements in the industrial zone effluents occasionally exceeded the national tolerance limits. The erythrocytes of the fish exposed to both textile industry effluents collected during three sampling occasions showed significantly induced total comet scores (3 - 6 fold) and genetic damage indices (2 - 13 fold) in comparison with the controls both under undiluted and diluted conditions ($p < 0.05$). Industrial zone effluents under undiluted condition significantly induced total comet scores (2 - 4 fold) and genetic damage indices (2 - 7 fold) of erythrocytes of the exposed fish in comparison to those of the controls during three sampling occasions ($p < 0.05$) whereas the diluted effluent exposures caused significant increase in the scores ($p < 0.05$) on two sampling occasions in the dry period. The study revealed that the textile and industrial zone effluents have a potential to generate genotoxic impacts on the exposed biota. Furthermore, 1:8 dilution of the effluents might not be sufficient to reduce the genotoxic impacts on the biota in the receiving surface waters as genotoxicity was frequently detected in the expected diluted conditions. This study presents scientific evidence to emphasize the importance of incorporating genotoxicity bioassays as an integral part of management of industrial effluent discharge into inland surface waters considering human health and receiving ecosystems.

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Keywords: Industrial effluents, genotoxicity, Comet Assay, Kelani River

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LETHAL AND SUB-LETHAL EFFECTS OF PROFENOFOS, DIAZINON AND CARBOSULFAN EXPOSURE TO COMMON HOURGLASS TREE FROG, *Polypedates cruciger*

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Over 90% of sprayed biocides reach a destination other than their target species because they are sprayed across the entire agricultural field. The runoff carries pesticides into aquatic ecosystems affecting many non-target organisms including humans. The present study examined the acute and chronic toxicity of three agricultural insecticides commonly used for fruits and vegetables: Profenofos, Diazinon and Carbosulfan on the common hourglass tree frog, *Polypedates cruciger* as a non-target organism. First, acute exposure to high concentrations was carried out to determine the LC_{50} of each pesticide by exposing five days post-hatch tadpoles (Gosner stage 25) for 48 hrs. The highest LC_{50} value was reported for Carbosulfan in all three stages (15.3 mg L^{-1}) where as the lowest was reported for Profenofos (0.634 mg L^{-1}), which shows that Profenofos at high concentrations is more toxic to *P. cruciger* than the other two chemicals. Then, a chronic exposure to ecologically relevant doses of the three pesticides to tadpoles at Gosner stage 25 was carried out under laboratory condition. Survival, growth and development of malformations in the tadpoles and metamorphs were recorded. Survival decreased with increasing concentrations of all three pesticides. However, a significant relationship was observed only in tadpoles exposed to Carbosulfan (Pearson Correlation = - 0.969, $p < 0.05$). Individual comparisons with the controls showed a significant reduction in survival of tadpoles exposed to 3.0 µg L^{-1} Diazinon (Chi square test; $p = 0.015$) and 2.5 µg L^{-1} Carbosulfan (Chi square test; $p = 0.044$) which were the highest concentration in the exposure series. Length and the weight measurements showed that the tadpoles exposed to Profenofos and Diazinon were larger compared to those in the controls while the tadpoles exposed to Carbosulfan were significantly smaller compared to the controls (one way ANOVA, $p < 0.05$). Growth period was measured as TE_{50} (Time taken for 50% of the tadpoles to develop hind limbs). The average TE_{50} value was 54 days in the control, while in the exposed groups it exceeded 110 days with Diazinon recording the highest (154 days). This elongation of the development period was highly significant in all the exposures compared to the control (one way ANOVA, $p < 0.01$). None of the tadpoles or metamorphs developed any malformations. Profenophos and Diazinon are organophosphates and are well known as ChE inhibitors which can cause reduced growth and increased mortality. Tadpoles of *P. cruciger* exposed to Diazinon and Carbosulfan at ecologically relevant doses experienced lethal and non-lethal effects while those exposed to Profenofos experienced only non-lethal growth effects although its acute exposure was highly lethal.

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Keywords: Amphibians; non-target organisms; Pesticides; Sri Lanka

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STATUS OF AQUATIC HERBS IN MAHAWELI FLOODPLAINS: A CASE STUDY IN FOUR SELECTED *VILLUS*

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The riverine marshes (locally known as '*villus'*) of Mahaweli floodplains are important natural ecosystems with high biodiversity. The '*villus'* are more or less persistently filled with water. Four '*villus'* were selected from the Manampitiya area in the Polonnaruwa district to study the impacts of river flow regulation as a result of the Mahaweli Diversion Scheme (MDS) initiated in late 1970s. As there were no previous vegetation records available to compare the present status with that of the situation prior to the establishment of the MDS, two types of *villus* were selected as less-influenced (LI) (Karapola and Gengala) and another two as highly-influenced (HI) (Handapana and Bendiya). The categorization was made on the basis of their locations along the Mahaweli river before and after the 'Amban' ganga meets the river Mahaweli. In each site, the aquatic vegetation was sampled in three perpendicular belt transects (10 m × 40 m) starting from marginal flood plains towards the dry land. Transects were divided into 10 m × 10 m sub-quadrats and the percentage cover values of the all species of aquatic herbs were recorded. The most dominant aquatic herb species in all four study sites was *Eichhornia crassipes* (Mart.) Solms which is a well known aquatic invasive plant in Sri Lanka. The statistical analysis revealed that the aquatic herb cover in HI *villus* were higher than that of LI *villus* (at $p \leq 0.06$). Less-influenced Gengala showed the least aquatic herb cover (15.8%) compared to other study sites (Handapana: 54.2 %, Bendiya: 42.8% and Karapola: 32.9%). In all studied '*villus'*, exotic species showed the highest relative abundance over native species. *Ipomoea aquatica* Forssk was the most abundant native aquatic species in study sites while *Eichhornia crassipes* and *Salvinia molesta* were the dominant exotic invasive species. The high prevalence of *Eichhornia crassipes indicates* low water quality in HI '*villus'*. According to a study done in 1994, 26 aquatic herb species were recorded in Handapana and *Bendiya* '*villus*. However, in the present study only 10 aquatic species (38%) were recorded in these two '*villus*. Although *Aponogeton crispus*, *Nelumbo nucifera* and *Nymphae stellata* were the most abundant aquatic herbs in 1994, none of them were recorded in the present study. The results suggest that over the past 10 years, the aquatic plant richness has reduced in highly-influenced Handapana and Bendiya '*villus',* possibly as a result of the spread of aquatic invasive herbs and/or the altered micro-habitat conditions due to river regulation. Therefore, it is of critical importance to take necessary measures to control the spread of invasive aquatic plant species in '*villus'* and to introduce useful native or endemic aquatic herbs to restore these vulnerable ecosystems back to their original status.

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Keywords: *Villus*, river regulation, invasive aquatic herbs

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SEPARATION OF TOXIC MALACHITE GREEN FROM AQUEOUS SOLUTION USING WATER LETTUCE, *Pistia stratiotes*

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Water lettuce (WL), a common aquatic plant, shows strong potential as an adsorbent for the removal of toxic Malachite green (MG) in a batch adsorption system. In this study, batch adsorption studies were carried out to investigate the effects of adsorbent dosage, pH, ionic strength and dye concentration. Adsorption isotherm, thermodynamics and kinetics studies and regeneration experiments were also carried out. Elemental analysis of the adsorbent was determined by X-ray fluorescence; while the functional groups were characterized by Fourier transform infrared spectrophotometer. Experiments involving the effects of pH and ionic strength indicated that hydrophobic-hydrophobic interactions might be the dominant force of attraction for the MG-WL adsorption system. Extent of removal-equilibrium concentration relationships investigated within a wide concentration range indicates that the Langmuir isothermal model best represents the adsorption systems with a high regression coefficient leading to the maximum adsorption capacity (q_m) of 99.0 mg g^{-1} at 25 ^oC. Biosorption data did not comply with the Weber-Morris model suggesting that intra-particle diffusion is not the rate-limiting step, while the Boyd model suggested that film diffusion be the rate-limiting step. Gibbs free energy and enthalpy of biosorption of MG determined by monitoring the extent of dye removal at different solution temperatures indicated spontaneity and endothermic reaction, while the Arrhenius model indicated a physical adsorption dominant process with low activation energy of 12.6 kJ mol^{-1}. Spent adsorbent was regenerated with 0.1 mol dm^{-3} NaOH and was effective at removing MG even after five cycles. Therefore, it can be concluded that WL has the potential to be used as a low-cost adsorbent for the removal of MG in real life water treatment application.

Keywords: Malachite green (MG), water lettuce (WL), biosorption, kinetics studies, thermodynamics

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AVIFAUNAL DIVERSITY OF THONDAIMANARU LAGOON AND ADJACENT AREAS, JAFFNA, SRI LANKA AS AN INDICATOR OF WATER QUALITY

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Avifaunal diversity is an excellent indicator of ecosystem stability as birds respond quickly to changes in their environments. Therefore, the concept of using birds as environmental indicators to identify ecosystems health has now gained a wide global acceptance. Thondaimanaru and adjacent areas in Jaffna, Sri Lanka are notable for their bird diversity and they represent a major mangrove ecosystem in the Jaffna peninsula. Given the fact that the bird diversity of these areas has not been evaluated in the past due to the three-decade long civil war, the objective of the present study was to measure the avifaunal diversity which can easily used to understand the overall health of this ecosystem. Bird censusing was carried out from September 2014 to June 2015, when migratory species were also present in the area. Point transects were used to count birds. For observing birds, 8 × 40 standard birding binoculars and a 25 × 50 spotting scope were used. Peak counting hours were between 0630 and 0830 h each day, and counts were taken weekly. A minimum of three sampling points each from Thondaimanaru and adjacent areas (Vallai, Mulli, Nagarkovil, Mamunai) were selected. A minimum distance of approximately 250 m was kept between any two points to avoid double counting. Birds were counted for 20 minutes at each point.

A total of 71 species of birds were recorded from the area during the study period. Vallai was home to 21 migrant bird species and Thondaimanaru had 16 migrant species. Mulli and Mamunai were home to 5 migrant species and Nagarkovil had 8 migrant species. The Gull-billed Tern (*Gelochelidon nilotica*) (total abundance 1456), Greater Flamingo (*Phoenicopterus roseus*) (1260), and Northern Pintail (*Anas acuta*) (3010) had the highest abundance of any species of bird in the area. The significant rare species were the Whimbrel (*Numenius phaeopus*) (3), Eurasian Curlew (*Numenius arquata*) (1), Greater Sand Plover (*Charadrius leschenaultii*) (24), and Green Sandpiper (*Tringa ochropus*) (138). Among the other notable species were resident aquatic birds such as the Painted Stork (*Mycteria leucocephala*) (230), Black-headed Ibis (*Threskiornis melanocephalus*) (79), Eurasian Spoonbill (*Platalea leucorodia*) (89), Black-winged Stilt (*Himantopus himantopus*) (170), and Spotted-billed Pelican (*Pelecanus philippensis*) (589). Of the total 21 species of true mangrove plants in Sri Lanka, four species (i.e. *Avicennia marina*, *Rhizophora mucronata*, *Excoecaria agallocha* and *Lumnitzera littorea*) were identified as the most common in the area. In conclusion, it can be said that, compared to relatively disturbed areas such as Mulli and Mamunai, the very high species richness in the relatively undisturbed areas (Thondaimanaru, Vallai, and Nagarkovil) is indicative of the overall good health condition of these ecosystems.

Keywords: Jaffna peninsula, water quality, Avifaunal diversity, Lagoon, migratory birds

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BATTICALOA LAGOON NEEDS TO BE IN THE ICU

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Health of an organism is a good indicator to understand the quality of the environment it lives in. Batticaloa Lagoon is the second largest lagoon in Sri Lanka covering 11,500 hectares of surface area. History of Batticaloa and the life of Batticaloa has centered on the lagoon especially for the available resources. However, during the recent history the area is known to experience encroachments, pollution, siltation and dumping of solid waste.

Although few studies were carried out to understand prevailing environmental conditions of the lagoon, the effect of recent environmental pollutants especially agrochemicals and fertilizers on the water quality is not yet assessed. In addition, concerns are being developed to understand the effect of recently introduced paint with high concentrations of heavy metals. Several events of mass fish kills have been recorded in the recent history with unknown reasons. Appearance of periodic algal blooms also are now of human health concern because of the contamination of water with algal toxins. As bioaccumulation and biomagnification of algal toxins along the food webs could challenge the health of human through the consumption of fish and other sea foods, contamination of heavy metals in lagoon water can be identified as the root cause for recent local epidemics of the country. Among the diseases that suspect to have environmental origin includes Chronic Kidney Disease of unknown etiology (CKDu) prevalent in the Dry Zone of Sri Lanka. As the real cause is not yet confirmed, a cure of the disease is also not known. Further global climate change also likely to have an effect and therefore needs attention in these areas. Especially intense rain and prevailing drought that cause periodic floods and increase of salinity in water could directly affect the biological environment. Loss of river bank vegetation, lagoon shore destruction and the increase of motor boats in the lagoon are also identified as threats to the health of the lagoon. In addition, the lack of proper sewage disposal systems and accumulation of municipal solid waste of the area lead the lagoon to move towards eutrophication which directly affect the maintenance of the biodiversity. Therefore, it is with utmost importance to conserve the lagoon to safeguard the health of the ecosystem and the human community.

Keywords: Water, lagoon, health, pollution

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DEGRADATION OF MANGROVE FOREST IN THONDAMANARU LAGOON ECOSYSTEM, JAFFNA, SRI LANKA

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Thondamanaru lagoon is one of the major inland water resources in the Jaffna peninsula. It functions as an outlet for surplus rain water and as the only lifeline for the survival of the largest mangrove forest in this flat land where no rivers and streams exist. Construction of roads across the lagoons often destroys the natural habitats of biodiversity. Four main road causeways, two sub roads and a barrage have been constructed across the lagoon without adopting appropriate designs. The construction of barrage at 0.8 km from the narrow sea mouth of the lagoon in order to block the entry of sea water has influenced on the pattern of the vegetation which has been already damaged due to road construction and over exploitation by the local public. Since the construction of barrage in early 1950s, a considerable amount of sea water leaks into the lagoon due to the poor maintenance of the gates. Nearly 50% of the lagoon area has been reduced by silting.

A one year fortnight field survey was performed from June 2014 with the objective as to compare the type and distribution of mangrove vegetation with the last available data of 1969. The current distribution pattern of mangroves and mangrove associates up to 14 km from the barrage is highly reduced with increasing patches of *Clerodendron inerme*, *Lawsonia inermis*, *Vitex negundo*, *Calophyllum inophyllum*, *Cassia bicasularis*, *Pandanus tectorius*, *Phoenix pusilla*, *Calotropis gigantea* and two invasive plants *Prosobis juliflorea* and *Lantana camara.* As a result of the only receipt of rain and runoff water, coupled with prolonged droughts the original mangrove area at the western part of the lagoon, at 11 - 12 km from the sea mouth, now remain with isolated trees of *Lumnitzera racemosa* and *Excoecaria agallocha*.

Now, it is being planned to repair and close the barrage completely, to effectively block the entry of all sea water and to fill the lagoon with freshwater from successive monsoonal rain. It is anticipated that this brackish water body will be converted into fresh water lake in due course. The prevailing conditions will further worsen when the barrage is closed completely as planned. The proposed development programs of rehabilitating the Thondamanaru lagoon should consider the availability of inundation water periodically for nourishing the vegetation of the lagoon.

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Keywords: Mangrove, Thondamanaru lagoon, *Excoecaria agallocha*

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Ti/IrO_2-Sb_2O_3 ANODE MATERIAL OPTIMISATION FOR ELECTROCHEMICAL WATER TREATMENT

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The assurance of the water quality has become an important issue due to intense water pollution. Industrial activities are known to add organic pollutants as well as other pollutants to aquatic systems. In order to remove organic pollutants, a physiochemical wastewater treatment method such as electrochemical oxidation has become more attractive, as it is less expensive. Further mixed metal-oxide anodes provide better performance in electrochemical water treatment processes. In this study, Ti/IrO_2-Sb_2O_3 novel mixed metal anode was developed and optimised to oxidize phenol in wastewater. As high energy consumption is the main drawback of electrochemical technology, the optimized anode material will provide solution by reducing the energy consumption. Central Composite Design (CCD) with Response Surface Method (RSM) was implemented to optimise the Ir and Sb contents of the anode. Anodic charge, open circuit potential and Chemical Oxygen Demand (COD) values were the response factors determining the performance of the anode. In order to optimise the Ir and Sb contents, above response factors were monitored. RSM and CCD tools were successfully used in material optimisation. Statistical model validation was conducted with ANOVA analysis. The resulted probabilities of *p* values in the regression were 0.002 and 0.000 for anodic charge and OCP models, respectively. Very low *p* values in ANOVA results indicate that those models were the well fitted. Proposed statistical models were validated with experimental results. Optimised anode achieved 83% COD reduction at 80 mg L^{-1} of Ir and 920 mg L^{-1} of Sb compositions. At these optimised conditions, the model predicted optimum anodic charge as 0.362 mC and OCP as -0.08 mV for the Ti/IrO_2-Sb_2O_3 anode. An anode with 1.0 mg cm^{-2} coating load consumed 0.6 Wh energy for electrolysis process, when voltage and current are 5.0 V and 20 mA respectively. Therefore, the energy consumption for treatment of 1.0 m^3 of water is about 12 kWh. At the current electricity and material prices, the operational cost for treatment of 1.0 m^3 of phenol contaminated water using this optimized anode is about Rs. 82 m^{-3}. Therefore the low operational cost can make Ti/IrO_2-Sb_2O_3 anode material optimisation as an economically viable solution for treating waste water.

Keywords: Response surface method, anode optimisation, Ti/IrO_2-Sb_2O_3 anode, electrochemical water treatment

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REMOVAL OF CYANOBACTERIAL CELLS AND MICROCYSTIN IN WATER USING EXTRACTS OF *Moringa oleifera* SEEDS

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Cyanotoxins released by cyanobacteria are considered as an emerging global health issue. Microcystin is one of the most frequently occurring classes of cyanotoxins in freshwater reservoirs. The mass occurrence of toxigenic cyanobacteria in reservoir water renders the need to develop a treatment method for the removal of cyanobacterial cells and their toxins. Conventional water treatment methods are expensive and can cause environmental issues. Therefore a natural coagulant could be a better alternative for this purpose. Previous studies have shown that seeds of *Moringa oleifera* (MO) are being used for clarifying of drinking water and it could remove algae present in water.

The present study was conducted to determine the efficiency of the coagulation/ flocculation/ sedimentation (C/F/S) processes with *M. oleifera* seed extract as a natural coagulant, in the removal of turbidity, cyanobacterial cells and their toxin microcystin in water. Beira Lake water samples containing *Microcystis aeruginosa* with a turbidity of 55.9 NTU and *M. aeruginosa* laboratory cultures with turbidity values of 13.5 NTU and 41.1 NTU as standards were used for the C/F/S experimental analysis. MO seed extracts were prepared with 1M KCl and coagulant solutions (MO-KCl) with the concentrations of 150 mg L^{-1} and 250 mg L^{-1} were used for the experiment. Also a control was used with 1M KCl solution (without any seed extract). After 12 hrs and 24 hrs of C/F/S processes, turbidity was measured using a turbidity meter and cell counts were obtained using a Sedgewick-Rafter cell counter. Microcystin concentrations were determined using MicroCystest kit.

A significant reduction in turbidity was observed for the standard cyanobacterial cultures and Beira Lake water sample treated with MO seed extract. Treatment of turbid water samples with 1M KCl solution alone did not show a significant turbidity removal after 24 hrs. Cyanobacterial cell counts were comparable to the results obtained with the turbidity test. Dried and ripened seed extracts displayed promising cyanobacterial cells and turbidity removal from the tested Beira Lake sample which had an initial turbidity of 55.9 NTU. The highest cyanobacterial cell removal efficiencies in Beira Lake sample with the dried and ripened seed extracts were 75.50% and 74.89% respectively. Similarly, the highest turbidity removal efficiencies in Beira Lake sample with the dried and ripened seed extracts were 90.86% and 88.19% respectively. Coagulant solution from the dried seed extract did not show significant difference in turbidity removal in relation to the concentration of the coagulant solution. With the ripened seed extracts a significant initial turbidity removal was observed at the concentration of 250 mg L^{-1}. In laboratory cultures, both dried and ripened seed extracts showed significant turbidity removal at the concentration of 150 mg L^{-1} of coagulant solution for the initial turbidity of 41.1 NTU. Although ripe seed extracts at the concentration of 250 mg L^{-1} showed a trend of toxin reduction in 24 hrs, the results can only be considered as tentative. The results of the study demonstrated the potential of MO seed extracts in the removal of *M. aeruginosa* cells from water samples but further experiments are needed to confirm their interaction with microcystin.

Keywords: Microcystin. *Moringa oleifera*, natural coagulant

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BIOSORPTION OF Pb(II) USING *Trigonospora obtusiloba*

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Removal of Pb(II) from aquatic environments is important due to its chronic effects on the nervous system, liver, brain and kidney of humans. Contamination of Pb(II) occurs due to waste discharge from industries such as acid battery manufacturing, metal plating, Pb mining and coal combustion. Conventional methods to remove lead such as precipitation, electrochemical methods, coagulation, ion exchange and membrane filtration are associated with limitations. Therefore, it has become necessary to find a cost effective and environmentally friendly method to remove Pb(II) from water. In this study the fern *Trigonospora obtusiloba* was used as the biosorbent in the form of biochar and dried leaves to study the mechanism of biosorption of Pb(II).

The fern leaves were washed thoroughly and oven dried at 60 ºC for two days and ground to obtain particle sizes between 250 – 350 µm. Biochar was prepared by pyrolyzing the fern leaves at 300 ºC with a heating rate of 7 ºC min^{-1} for three hours. Then it was sieved to obtain particles less than 1 mm. Synthetic stock solution of Pb(II) was used for all the experiments and residual Pb(II) concentrations were determined using an Atomic Absorption Spectrophotometer.

The kinetic study was conducted with the biosorbent dosage of 2.0 g L^{-1} and 100 mL of 4.0 mg L^{-1} Pb(II) solution at pH 5.0 and 27 ºC. The experiments were conducted for both native biosorbent and biochar. The variation of the adsorption process for the native biosorbent was further studied with the different initial pH values (i.e. pH 1 – pH 8) and different series of initial Pb(II) concentrations (i.e. 1 mg L^{-1}, 2 mg L^{-1}, 8 mg L^{-1}, 10 mg L^{-1}, 15 mg L^{-1}, 25 mg L^{-1}). For the above experiments the equilibriation time was 75 minutes. The maximum Pb(II) adsorption of 100% was observed for biochar at 90 minutes. For the dried biosorbent, maximum adsorption of 97% was observed at 75 minutes. Both adsorption processes followed pseudo 2nd order kinetic model and the rate constants were 0.29 g mg^{-1} min^{-1} and 0.216 g mg^{-1} min^{-1}, respectively. Optimum pH for the adsorption process was pH 4 - 6. Isotherm data agreed with the Freundlich isotherm model and the heterogeneity was 1.23. This study indicates that dried biomass and biochar of *T. obtusiloba* could be used as a cost effective and environmentally friendly biosorbent to remove Pb(II) from contaminated aqueous environments.

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Keywords: Biochar, Biosorption, Kinetics, Pb(II), *Trigonospora obtusiloba*

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INVESTIGATION OF REDUCTION OF CALCIUM HARDNESS IN DRINKING WATER USING PLANT PARTS OF PALMYRAH AND BANANA

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Hardness makes water undesirable for consumption and causes many adverse effects. Therefore, cheap, environment and user friendly methods of minimizing water hardness are important. Palmyrah (*Borassus flabellifer*) plant parts and fruit peel of banana (*Musa accuminata*) variety *Ambul* are common in Sri Lanka but not properly utilized. The objective of this research was to investigate the Ca hardness reduction ability of above plant parts in both boiled and un-boiled water and optimize the application conditions.

Plant parts used were dried seed gel (1 cm × 1 cm), husk (1 cm × 1 cm), root powder (< 512 µm), leaf (1 cm × 1 cm) of palmyrah and banana fruit peel (1 cm × 1 cm). Hard water, both un-boiled (UBHW) ($[Ca^{2+}]$ = 475 mg L^{-1}, $[Mg^{2+}]$ = 375 mg L^{-1}) and boiled (BHW) ($[Ca^{2+}]$ = 240 mg L^{-1}, $[Mg^{2+}]$ = 360 mg L^{-1}) having highest hardness levels in Sri Lanka were prepared by dissolving $CaCO_3$ and $MgCO_3$ in HCl (pH = 8). In all the experiments, 200.0 mL of hard water was equilibrated at 100 rpm and $[Ca^{2+}]$ of the filtrates were determined using flame photometry. Hardness removal was calculated by the difference in the $[Ca^{2+}]$ before and after equilibration.

In the preliminary experiments, hardness removal was more than 5% by root powder and banana peel in UBHW and BHW but seed gel only in UBHW thus were selected for optimization. In optimization, different weights (0.5 - 19 g) of plant material were equilibrated for different times (2 - 360 min.). The findings were applied to well water of Anuradhapura (AW) and Jaffna (JW) and Jaffna tube well water (JT) both un-boiled and boiled (after removing the precipitate). To remove the colour in the filtrates of root powder samples, activated charcoal (1 g/100 mL) was added and kept without agitation. The effect of shaking was studied by analyzing samples without shaking.

In UBHW, optimized weight and time for highest Ca^{2+} removal by root powder (91%), seed gel (41%) and banana peel (40%) were 19.0 g for 10 min, 7.0 g for 5 hrs. and 1 g for 10 min, respectively. In BHW, it was 5 g for 10 min by root powder (60%) and 5 g for 30 min by banana peel (60%). Root powder showed highest Ca^{2+} reduction in UBHW with 83% in AW, 78% in JW and 64% in JT and in BHW with 59% in AW and 69% in JT. For all the others it was less than 22%. Lower Ca^{2+} reduction in natural hard water than synthetic hard water indicated the interference by the other ions on hardness removal. Different results in BHW and UBHW indicated the effect of the initial level of Ca^{2+} on hardness. There was no effect on agitation. The colour of root powder sample filtrates was disappeared upon adding activated charcoal.

It can be concluded that Palmyrah root powder shows a high Ca^{2+} removal irrespective of the Ca^{2+} level. For a wider application, the removal mechanism has to be studied.

Keywords: Water hardness, palmyra, banana peel, removal of calcium, bio sorbents

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EFFICIENT TREATMENT PROCESS WITH MINIMUM OPERATION AND MAINTENANCE COST FOR THE REMOVAL OF DISSOLVE IRON (Fe) IN POTABLE WATER

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Iron (Fe) is an element present in natural waters and is an essential nutrient that helps maintain a good health. However excessive Fe in potable water is a global concern due to aesthetic impairment of water by brownish colour, turbidity, suspended particles and stains on light colour surfaces. Ferrous (Fe^{2+}) is a form of Fe present in ground water. Under the condition of low dissolved oxygen in water, Fe^{2+} is highly soluble in water as a colorless substance. At low pH of water, solubility of Fe^{2+} increases. Such Fe^{2+} reacts with dissolved O_2 which is rich at the surface and forms colored oxidized ferric (Fe^{3+}), and impair the quality of water. Further, Fe^{3+} combines with carbonates of calcium and magnesium in water to form brown gelatinous material which could deposit inside pipe lines and surfaces. According to the guideline of Sri Lanka Standard (SLS 614:2013) the maximum permissible level of total Fe in drinking water is 0.3 mg L^{-1}. Some ground water sources report high Fe concentration as 40 mg L^{-1}. Therefore removing of Fe in water used for drinking, domestic and irrigation purposes have become an urgent need. As all existing Fe removing methods are with limitations, it has become essential to introduce a process with–no special operation practice, specific chemicals or materials and also without sophisticated and/or expensive mechanical or electrical equipments.

The proposed treatment process consists of an upward flow filter with a defined diameter as needed by the water recipient. The filter material is insoluble in water and essentially the specific gravity should be greater than that of water. The flow velocity of the system is maintained so that the system works continuously and delivers Fe free water. The process of treatment is mainly supported by a well-defined biological community introduced at the bottom of the filter and free from additional care after introduction. During the operation, Fe specific microbial community consumes Fe^{2+} in water and subsequently converts into insoluble Fe^{3+}. Thus, Fe^{3+} and water associated clay and sludge particles are trapped and deposited within the filter media in small quantities. Such a system of 2.5 m in height and a cylinder with diameter of 1.2 m was achieved Fe removal efficiency of 90% at the initial Fe concentration of 0.87 mg L^{-1}. Importantly, if the plant is functioned at optimum conditions, the removal efficiency of as high as 99% of total Iron (Fe^{2+} and Fe^{3+}) can be accomplished. On regular operation, depending on the levels of Fe in the feed water, the wash out can be opened either weekly or monthly in order to clean and remove excessive iron deposits. The proposed system is versatile to treat water with not only slight excess in Fe but also extremely rich in Fe, while it caters small scale (domestic) to community based requirements of water with minimum operation and maintenance cost.

Keywords: Operation and maintenance, Fe removing methods, microbial community, SLS 614:2013

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ISOLATION OF BACTERIOPHAGES FROM SEWAGE EFFLUENT AND DETERMINATION OF THEIR HOST SPECIFICITY

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Bacteriophages (B), viruses that infect prokaryotic microorganisms play a distinct and a significant role in ecosystems. They are thus abundant in most natural and manmade ecosystems. Many applications with bacteriophages including phage therapy are found in medical, agriculture and food sectors as they are considered one of the most harmless antibacterial approaches available. Thus, a study was carried out to isolate bacteriophages from sewage effluents and to study their host ranges. For the isolation and screening of host susceptibility, plaque assay was used and sewage effluents were collected from two sewage treatment plants, Pannarama Hostel (P) and Kelaniya University premises (K), in Sri Lanka. Sewage effluent was enriched with nutrient broth to increase the initial population of bacteriophages. *Escherichia coli* was used as a host. Subsequently the phages were isolated by filtration. Five strains of *E. coli* isolated from each location were screened for the susceptibility against the corresponding phage isolates obtained from the similar location. Results revealed that three *E. coli* strains P1, P2, P6, and two *E. coli* strains K4 and K5, were susceptible to the bacteriophages isolated from similar locations P and K, while the ability of plaque formation differed from one host to another.

Three isolated bacteriophages, BP1, BP2, and BK4, were screened for the infectivity against a broad range of microorganisms including Gram-negative and Gram-positive species. Two of them BP2 and BK4, showed a narrow range of host infectivity having the ability of infecting merely to their common host, *E. coli*. However, the other type of bacteriophage, BP1, had a broad range of host specificity with trans-subdomain infectivity between Gram-positive and Gram-negative hosts. This bacteriophage showed the ability in infecting and plaque production with a *Bacillus subtilis* strain apart from its original host *E. coli*.

Results of the study reveal the feasibility of phage mediated horizontal gene transfer among a wide range of bacterial hosts than what is generally estimated. This suggests a model to explain the wide expansion of antibiotic resistant varieties in ecosystems which can occur due to the exchange of genetic material among enteric bacteria and non-related species mediated by these broad ranged bacteriophages. Results also indicate a high frequency of occurrence of broad host ranged bacteriophages in sewage treatment systems compared to other ecosystems. It may be due to the ability of such bacteriophages being able to survive in a condition where population and composition of bacterial species and strains are rapidly changing as occurring in the sewage treatments. Therefore such bacteriophages may play a crucial role in regulating bio-dynamic properties in sewage treatment systems than their counterpart bacteriophages having a narrow host range.

Keywords: Bacteriophages, host specificity of phages, horizontal gene transfer

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REMOVAL OF MICROCYSTIN-LR FROM DRINKING WATER USING NATURAL RUTILE SAND

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Presence of cyanotoxins in water bodies, which are utilized for human consumption, is a major constraint in providing safe potable water in Sri Lanka. Present study was carried out to evaluate the potential use of natural rutile sand as a photocatalytic agent to remove Microcystin-LR (MC-LR) toxin from drinking water. Though several studies have been published on the photocatalytic effects of rutile and titanium dioxide on removal of organic molecules, this is the first report on the usage of natural rutile sand for removal of Microcystin-LR in Sri Lanka. Rutile sand was collected from the mineral sand deposit of Pulmoddai, Eastern Province and MC-LR toxin was extracted from the water samples collected from Beira lake, Colombo.

The photocatalytic activity of natural rutile sand was induced by providing Ultra Violet (UV) illumination (12 W, 365 nm). In vitro laboratory experiments were carried out to assess the photocatalytic ability of natural rutile sand on MC-LR. Water samples which were injected with known concentrations of MC-LR, were exposed to the photocatalytic process of natural rutile sand for a determined time and then were subjected to HPLC analysis to detect possible reduction in concentration. The results revealed the potential photocatalytic degradation of MC-LR by natural rutile sand. The MC-LR removal efficiency of natural rutile sand was compared with pure Titanium dioxide (TiO_2). The results showed that degradation rates of MC-LR by natural rutile was 50%, whereas pure granular and powder TiO_2 showed 63% and 78% degradation of MC-LR respectively. When MC-LR was exposed to only UV light treatment, 22% of reduction was detected. Based on the results obtained, a filter model was designed using natural rutile sand to evaluate the potential use of natural rutile sand to remove MC-LR. The constructed filter model showed 24%, 38%, 49% and 53% removal of MC-LR after 60, 120, 180 and 240 minutes, at a water circulation rate of 500 L h^{-1}.

The study showed that there is a potential of utilizing natural rutile sand to remove hazardous MC-LR from water and the research will help to improve drinking water treatment facilities in Sri Lanka.

Funding provided by the University of Sri Jayewardenepura is acknowledged.

Keywords: MC-LR, TiO_2, photo catalyst, natural rutile

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DEGRADATION OF MICROCYSTIN-LR BY NATIVE BACTERIA

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Cyanobacteria are a major component in most of eutrophic lakes. Bloom forming cyanobacteria may produce toxins such as hepatotoxic peptides, neurotoxic alkaloids and dermatotoxic phenolic compounds, in addition to lipopolysaccharides. These substances are natural endotoxins released into the water in high concentrations when cell lysis takes place. Microcystins are a group of cyclic heptapeptide hepatotoxins, which are chemically stable over a wide range of temperatures and pH due to their cyclic structure. Microcystin removal by conventional water treatment is beyond the scope of usual treatment methods due to their stability. Microbial degradation of microcystins is one of the major solutions for this situation since it is relatively low in cost. In the present study *Enterobacter sp*. (KM455978) *Enterobacter ludwigii* (KM504128) and *Bacillus cereus* (KM504128) strains which were previously reported as crude oil degraders were used to study their degradation capability of microcystin.

Microcystin-LR (MC-LR) was extracted from water samples taken from Beire Lake. The ability of the isolated bacteria to utilize MC-LR was determined by inoculating 0.5 mL of an overnight starved bacterial suspension (equalized to A590 = 0.35) into separate universal bottles containing 9 mL of filtered sterilized lake water and 0.5 mL of 200 μg mL^{-1} concentration of MC-LR was added to make up the final volume to 10 mL. Triplicate samples were prepared for each bacterial strain and incubated at 25 °C ± 1 °C with constant shaking at 100 rpm. Control samples were prepared without bacterial strains under similar conditions. One milliliter of the sample was taken at 2 day intervals for 14 days. MC-LR concentrations in each sub-sample were measured using High Performance Liquid Chromatography (HPLC).

After 2 days of incubation, significant degradation of microcystin-LR was recorded by *E. ludwigii* and *B.cereus*. In contrast, *Enterobacter* sp. maintained a gradual decrease of MC-LR by day 8 and then started rapid degradation, which ended up achieving 98% degradation after 14 days of incubation. *B. cereus* showed 82% degradation while *E. ludwigii* showed 96% degradation after 14 days. *E. ludwigii* showed the highest degradation rates at second day of incubation (0.77 d^{-1}) whereas the other strains showed lower degradation rates. The degradation rates of *Enterobacter sp*. was more or less constant up to day 10 and thereafter increased significantly up to 0.23 d^{-1} at 14 days of incubation. *B. cereus* showed high degradation rates at the beginning and a pronounced gradual decrease was observed afterwards. *E. ludwigii* showed the highest degradation rate at the beginning and decreased gradually up to day 6 and thereafter remained at a more or less constant rate until day 14 of the incubation. Half life time of MC-LR degradation by each bacterial strain was calculated and the lowest half life time was found for *E. ludwigii* (1.3 days) whereas *Enterobacter* sp. and *B. cereus*, showed 10.5 days and 1.8 days respectively.

The results of the present study revealed that the native bacteria remove a considerable amount of MC-LR by bioremediation which can be used to clean MC-LR contaminations as an environmentally friendly, green and low cost method.

The study was funded by the University of Sri Jayewardenepura.

Keywords: MC-LR, degradation, *E. ludwigii*, *B. cereus*, *Enterobacter* sp.

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ISOLATION OF HYDROCARBON DEGRADING BACTERIA FROM GROUNDWATER CONTAMINATED WITH CRUDE OIL IN JAFFNA, SRI LANKA

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Crude oil is one of the most significant pollutants in the environment as it is capable of causing serious damages to human and the ecosystem. Prolonged exposure and high oil concentration especially in drinking water may damage biological organs such as liver, kidney, bone marrow and increase the risk of cancer. Thus, the WHO recommendation is 1 mg L^{-1} as maximum permissible level for oil in drinking water. In this study, crude oil degrading bacteria were isolated from crude oil contaminated ground water in Chunnakam area in Jaffna, where unauthorized crude oil discharge has been taken place. Due to the absence of perennial rivers or major water supply schemes in Jaffna peninsula, groundwater is the predominant water resource supplying water for domestic, industrial and agricultural needs. Triplicate samples were collected from each selected locations at Chunnakam area in Jaffna. The residual hydrocarbon present in the collected groundwater samples were extracted using n-hexane and analyzed using a spectrophotometer (2UVD10053, Labomed, inc. U.S.A) at the wave length of 400 nm. Quantification of crude oil was done using a calibration curve. Ten bacterial strains were isolated by enrichment culture method using standard pour plate. Crude oil degradation kinetics were studied by introducing 0.5 mL of overnight starved bacterial suspensions into sterile groundwater samples in triplicate at final concentration of 0.01 mg L^{-1} and 0.1 mg L^{-1} respectively. The samples were incubated at 28 $^{\circ}$C, shaking at 100 rpm and 0.5 mL sub sample aliquots were removed at 2 days interval for a period of 14 days. Analyses of residual hydrocarbon were performed by the spectrophotometer (400 nm). The results revealed that crude oil contamination levels range from 0 to 1.021 mg L^{-1}. Based on the morphological and biochemical tests, bacterial isolates were identified as *Bacillus* spp. (B1, B2, B3, B4, B5), *Pseudomonas* spp. (PS1, PS2, PS3) and *Micrococcus* spp. (M1, M2) respectively. The highest degradation percentage of crude oil was detected at 14 days incubation by the bacterium *Bacillus* sp. (B2) (0.01ppm; 89%, 0.1ppm; 86%) whilst degradation potential of remaining strains were recorded as; *Bacillus* sp. (0.01 mg L^{-1}; 65%- 82%, 0.1 mg L^{-1}; 55% - 77%), *Pseudomonas* sp. (0.01 mg L^{-1}; 58% - 77%, 0.1 mg L^{-1}; 53% - 72%) and *Micrococcus* sp. (0.01 mg L^{-1}; 51%- 54%, 0.1 mg L^{-1}; 39% - 47%). The contamination of the Jaffna ground water may be a severe problem as the aquifer is the main source of water for the Chunnakam area in Jaffna. Therefore, these bacterial strains could be used as a useful bioremediation tool in the removal of crude oil from the aquatic environment.

Keywords: Aquifers, *Bacillus* sp., crude oil, *Pseudomonas* sp., *Micrococcus* sp., microbial degradation

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OPTIMIZATION OF MICROCYSTIN-LR DEGRADATION RATES OF ISOLATED FRESHWATER BACTERIAL STRAINS

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Microcystin-LR (MC-LR) is the dominant type of cyanotoxin present in Sri Lankan freshwater bodies. The present study optimizes the MC-LR degradation rates of *Bacillus cereus*, *Rahnella aquatilis* and *Stenotrophomonas maltophilia* previously isolated by authors as degraders of MC-LR. Optimization was done for different temperatures, nitrate and phosphate concentrations. 0.5 µL of overnight grown, starved and suspension equalized (A 590 nm = 0.35) bacterial cultures were introduced into filter sterile lake water containing MC-LR at a final concentration of 5 mg L^{-1}. The flasks were incubated at 18 $^{\circ}$C, 28 $^{\circ}$C and 32 $^{\circ}$C for 14 days at 100 rpm. Sample aliquots of 0.5 mL were removed every two days, freeze dried and analyzed using High Performance Liquid Chromatography (HPLC). The same procedure was followed to study the effect of nitrate (0.01 mg L^{-1}) and phosphate concentrations (0.005 mg L^{-1}) on degradation. Nitrate levels varied from 0.1 - 2.5mg L^{-1} and phosphate levels varied between 0.005 to 0.05 mg L^{-1}. Each experimental and control samples were carried out in triplicate.

Maximum MC-LR degradation by all three bacterial strains were exhibited at 32 $^{\circ}$C (*B. cereus*- 2.65 ± 0.03 µg day^{-1}, *R. aquatilis* - 2.38 ± 0.19 µg day^{-1}, *S. maltophilia* - 2.77 ± 0.04 µg day^{-1}) whereas MC-LR degradation of all three strains were inhibited at 18 $^{\circ}$C. MC-LR degradation rate of *B. cereus* and *R. aquatilis* increased from 0.43 ± 0.05 µg day^{-1} to 0.94 ± 0.15 µg day^{-1} and from 0.38 ± 0.01 µg day^{-1} to 0.56 ± 0.17 µg day^{-1}, respectively when phosphate levels were increased from 0.005 to 0.01 mg L^{-1} while phosphate concentrations higher than 0.01 mg L^{-1} resulted in a decrease in MC-LR degradation of both strains. *S. maltophilia* showed the highest MC-LR degradation rate of 0.34 ± 0.01 µg day^{-1} at 0.02 mg L^{-1} of total phosphate and total phosphate concentrations higher than 0.02 mg L^{-1} showed a decrease in MC-LR degradation. Moreover, a rapid degradation of MC-LR was recorded by all three strains, with the increase of nitrate concentration in the medium from 0.1 mg L^{-1} to 0.4 mg L^{-1}. Maximum degradation rates of 3.98 ± 0.15 µg day^{-1} and 3.68 ± 0.18 µg day^{-1} were showed by *B. cereus* and *S. maltophilia* at 0.4 mg L^{-1} of nitrates, whereas *R. aquatilis* showed a maximum rate of 3.31±0.05 µg day^{-1} at 0.5 mg L^{-1} of nitrate. Therefore, all three bacterial strains could be employed as a biofilm to remove MC-LR at 32 $^{\circ}$C, 0.01 mg L^{-1} of total phosphate and at 0.4 mg L^{-1} of nitrates.

Keywords: Optimization, *Bacillus cereus*, *Rahnella aquatilis*, *Stenotrophomonas maltophilia*, temperature, nitrate, phosphate

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SIMPLE ANALYTICAL METHODS FOR FLUORIDE DETECTION IN SRI LANKA

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Contamination of F^- in drinking water has been one of the serious problems in Sri Lanka because F^- pollution causes health problems such as mottled teeth. Therefore, it is important to develop techniques for F^- analysis. In this report, we propose the following two types of simple fluoride analysis.

La-ALC reacts with F^- and the reaction shows a colour change from red purple to blue purple gradationally. By adding Al^{3+} to the colour reaction, the discoloring in this reaction is interfered. Moreover, F^- concentration required for a colour change can be adjusted by the Al^{3+} concentration. Therefore, we have found that the color reaction of La-ALC could be controlled by the use of Al^{3+}. By the use of a controlled discoloring reaction (ON/OFF colour reaction), visual analysis of fluoride ion by counting the number of discoloring could be established. Furthermore, we have developed a test paper analysis of F^- by examination of ON/OFF color reaction on cellulose paper. Several concentrations of Al^{3+} (0.1 mL) were added to cellulose paper. After drying, these papers were added to 2 mL of sample solution containing La-ALC reagents. As a result, same discolor reaction was observed in the case of a cellulose paper. Moreover, F^- could be visibly determined by the number of discoloring using the cellulose paper with ON/OFF colour reaction.

Smart devices such as smart phone and tablet devices have been spreading rapidly around the world. Therefore, we have attempted to develop a method for fluoride analysis using a smart device as an analytical instrument. To achieve this objective, development of original attachment device and application software has been examined. Sample solution of 2 mL was added to plastic cell, and 0.1 mL of fluorescence analysis reagent of fluoride with zirconium/flavonol/EDTA complex was added. After 15 minutes, cell was set to the attachment mounted on camera which is part of the smart device. UV (256 nm) was used to irradiate the sample solution and the RGB value was measured by the smart device and F^- concentration could be determined by the intensity of the B value with original application software. As a result, F^- concentration could be automaticity determined by the proposed method.

Keywords: Fluoride, visual analysis, smart device

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PRECURSOR-INDUCED DICALCIUM PHOSPHATE FOR TREATMENT OF FLUORIDE IN THE WATER

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Fluoride present in the aquatic environment is one of the serious environmental problems that lead to affect the health of human. The dental and skeletal fluorosis is caused mainly by fluoride in drinking water. World Health Organization (WHO) reports that 25 countries including Sri Lanka face human health problems due to presence of fluoride at high concentrations especially in drinking water.

In an aqueous solution, dicalcium phosphate dihydrate [(DCPD) ($CaHPO_4 \cdot 2H_2O$)] reacts with small amounts of fluoride, and forms stable fluorapatite (FAp, $Ca_{10}(PO_4)_6F_2$). DCPD does not react with fluoride directly but forms a nano-scaled precursor particle on the surface of the DCPD particle. After the formation of the precursor, fluoride level decreased quickly. For the formation of the precursor, a few hours of retention time ("Lag Time") is required before the reaction with fluoride ion. The lag time is one of the problems for applying DCPD for the treatment of fluoride in aquatic systems. To reduce the lag time, steps were taken to induct the precursor particle on DCPD particle. The precursor can be easily induced by mixing DCPD with water or calcium phosphate solution.

Then the effect of hydroxyapatite (HA,$Ca_{10}(PO_4)_6(OH)_2$) in the reaction of DCPD with fluoride ion was investigated. DCPD containing various amounts of HA mixed with fluoride (concentration: 20 mg L^{-1}) and change in concentration of fluoride ion was measured by ion selective electrode continuity. It was found that the presence of HA was effective for the improvement of reactivity of the DCPD with fluoride ion. The lag time can be shortened by only mixing with 30 wt% of HA in the DCPD. In case of usage the pure DCPD, obtained FAp particle have similar morphology of the DCPD. However, addition of the HA resulted FAp particle having different morphology with the DCPD.

For coating of the HA, the Simulated Body Fluid (SBF) having same concentration of inorganic ions with human blood plasma was used. By immersion of the DCPD into the SBF, a thin HA layer was coated on the surface of the DCPD particle. It was found that the resulted DCPD reacted with fluoride ion without the lag-time, and morphology of the resulted FAp was same as the DCPD particle. Optimum amount of the HA was 3 wt%, and smaller than the mix of the HA powder. Coating of HA on the DCPD particle seems to be useful for water treatment because shape of the obtained FAp is controllable by controlling shape of the DCPD.

The results indicate that induction of HA as a precursor on the DCPD particle is applicable to treat fluoride present in aquatic systems.

Keywords: Fluoride, calcium phosphate, no-Hybrid

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BIOREMEDIATION OF CADMIUM FROM AQUEOUS SOLUTION USING *Ceratophyllum demersum*

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Pollution of waterways is becoming a serious environmental problem faced by the world today. Water pollution in Sri Lanka is caused mainly by discharge of agricultural runoff, untreated domestic wastewater, and industrial effluents. The aquatic environment is polluted by a variety of heavy metals due to anthropogenic activities. In Sri Lanka, most of the industries do not have water treatment plants. Even if they have treatment plants, these do not function effectively due to inappropriate design, inadequate maintenance, inefficient operations etc. Beira lake and Kandy lake are two of the most polluted water bodies in Sri Lanka.

Heavy metals are toxic, both chemically and biologically non-degradable, persist for a long time, and hence pose a potential threat to the environment. Cd is a toxic element that causes severe damage to both animals and plants. Thus, the removal and recovery of heavy metals from the polluted environments are essential. Traditional methods to remove heavy metals from wastewater are often inefficient, expensive and not eco-friendly. Biosorption, which is a process that utilizes biomass to sequester heavy metals, is currently gaining considerable importance as an alternative low cost and eco-friendly technology to remove heavy metals from aquatic media.

In this study, three aquatic plants namely *Eichhornia crassipes*, *Ceratophyllum demersum* and *Salvinia mollesta* were collected and thoroughly cleaned and dry powder was prepared with 500 µm pore size. Screening experiment was carried out for Cd biosorption. Then each biomass was digested by dry ashing method and analyzed for Cd using Atomic Absorption Spectrometer (Varian – AA 280FS). All three plants were promising and showed significant Cd adsorption (more than 100 mg g^{-1}). *Ceratophyllum demersum* was selected to carry out batch experiments at pH 5 and room temperature to further examine the ambient conditions such as biosorbent dosage (0.05 – 2.0 g), contact time (0 - 120 minutes) and initial concentration of metal ions (5 - 120 mg L^{-1}) in order to optimize the biosorption process. Equilibrium adsorption data were fitted to Langmuir and Freundlich isotherm models. Desorption experiments were also carried out to find out the possibility of recovering Cd from the cadmium- loaded biomass.

This study showed that 95% of cadmium was rapidly adsorbed by 0.5 g of non- living biomass of *Ceratophyllum demersum* from 100 ml of 5 mg L^{-1} solution at pH 5 and such adsorption reached equilibrium within 20 minutes. Adsorption of Cd increased with increasing concentration of Cd ions in the aqueous solution. The adsorption isotherm followed Freundlich model which indicates a multilayer adsorption. Desorption experiments indicated that 0.1 M EDTA, 0.1 M HCl and 0.1 M HNO_3 were efficient desorbents for recovery of Cd (II) from Cd-loaded biomass. This study revealed that *Ceratophyllum demersum* could be used as a potential low cost biosorbent to treat water polluted by Cd.

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Keywords: Biosorption, cadmium, *Ceratophyllum demersum*

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BIOSORPTION POTENTIAL OF THE PEEL OF *Artocarpus nobilis* FRUITS ON Cu(II) FROM SYNTHETIC WASTE WATER SOLUTIONS

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Commercial sorption materials used for the removal of heavy metals and their compounds from wastewater are expensive. These sorbents can be replaced with biosorbents, most commonly dead or live plant materials, such as shoots, barks foliage, seeds and fruits. Some compounds present in these materials have the ability to bind to pollutants present in wastewater, thereby removing them in an efficient way, and consequently, chemical and surface characteristics of a biosorbent play a key role in the biosorption process. Evaluation of the biosorption potential of *Artocarpus nobilis*, a plant species native to Sri Lanka and restricted to lowland rain forests, toward the removal of Cu(II) from aqueous synthetic solutions is the main goal of this research.

Optimization experiments conducted with dried peel of *Artocarpus nobilis* fruits of particle size in the range of 710 -1000 μm at 150 rpm shaking rate by varying one parameter at a time while others being kept unchanged lead to the optimum shaking and settling times of 210 min and 15 min, respectively. Under these optimum conditions, the maximum removal of 74% of Cu(II) was obtained at ambient solution pH of 3.8 and ambient solution temperature of 27 ± 1 ^{o}C. It was also found that the extent of removal of Cu(II) was not considerably varied with the processing temperature of fruit peel, and hence, unfired peel was used for further experiments. Adsorption isotherm studies, conducted within the initial concentration range of Cu(II) from 10 mg L^{-1} to 250 mg L^{-1}, lead to the validity of the linearized Langmuir model with a high regression coefficient of 0.921 favoring the monolayer adsorption coverage.

Keywords: *Artocarpus nobilis*, parameter optimization, isotherm, adsorption, Cu(II)

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IMPROVEMENT OF WATER QUALITY THROUGH METAL ION ADSORPTION BY HUMIC ACID EXTRACTED FROM MUTHURAJAWALA PEAT: A CASE STUDY OF Cu(II) ADSORPTION

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Readily available and easily reachable Muthurajawala peat deposit in Sri Lanka covers an area of approximately 600 ha. It is reported that Humic Acid (HA), a main component of peat, is responsible for the adsorption of metal ions from aqueous medium. Fourier Transform Infrared (FTIR) spectrum of HA, extracted using standard procedures, shows that the absorption patterns are identical to those of an authentic sample of HA within the wave number range of 200 – 4200 cm^{-1}, proving the high purity of the extracted sample. Further, the FTIR spectrum is indicative of functional groups of phenol, alcohol, carboxylic acid and ketone present in the extracted sample. The X-ray fluorescence spectrum and the energy dispersive X-ray images of extracted HA indicates the presence of a higher amount of Fe, and lower amounts of Ni, Ti, Cu and Zn. Additionally, HA extracted contains some amount of silica according to mass loss measurements on ignition, which indicates a significant loss of mass within the range of 300 – 400 °C as a result of combustion of organic substances as exothermic reactions. The purity of the extracted humic acid is determined to be 87% which is higher than that of the technical grade of HA of 66%. The point of zero charge is reached around pH of 3.5 – 4.0 and the charge of particles is always negative. Removal of Cu(II) ions by humic acid reaches the maximum of 17.4 g kg^{-1} at a pH of 5.0 within the concentration range of 60 - 90 mg L^{-1}, which does not change with increase in concentration. Nevertheless, neither the Langmuir nor the Fruendlich isotherm obeys the transfer of Cu(II) on HA according to low regression coefficients, suggesting that another mode of mass transfer, probably complexation, is possible.

Keywords: Humic acid, adsorption, Muthurajawala peat, copper

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PRELIMINARY STUDY OF INTERFERENCE EFFECTS ON Cu(II) REMOVAL FROM AQUEOUS SOLUTION WITH FIRED PEAT

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Investigation of the effect of cationic and anionic interferents present in industrial effluents on the extent of removal of chemical species is important in designing treatment procedures for industrial effluents. In this context, effect of Cd(II), Al(III), chloride, sulfate, phosphate and nitrate, which are commonly found in industrial effluents, on the extent of interaction of Cu(II) with peat fired at 200 °C, an effective adsorbent, was investigated in this research using 10 mg L^{-1} Cu(II) solutions at 1:10 (W/V) composition for 2.5 h shaking time and 1.0 h settling time. The extent of removal of Cu(II) by peat fired at 200 °C (d < 1 mm) from solutions at different concentrations of $Al_2(SO_4)_3$ in the range of 0.001 mol dm^{-3} to 0.1 mol dm^{-3} shows a slight decrease as the concentration of Al(III) increases. This is probably due to surface changes of peat which arise in the presence of $Al_2(SO_4)_3$. However, the presence of Cd^{2+}, Na^+, NO_3^- and PO_4^{3-} over a wide concentration range typically present in industrial effluents show the relative independence of the removal of Cu(II), indicating that the metal ion removal is not due to an ion exchange mechanism. Complexation of Cu(II) with compounds present in peat having strong chelating ability would be the probable mode of interaction of Cu(II) with peat. Low affinity of removal of Cd(II), despite being a d-block element, would not interfere the mode of interaction between Cu(II) and peat. More experiments are under way to arrive at a generalized conclusion.

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Keywords: Peat, interference, copper, aluminum, cadmium

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BREADFRUIT PEEL AS AN ADSORBENT FOR THE REMOVAL OF LEAD IONS FROM AQUEOUS SOLUTION

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This study focuses on the use of breadfruit skin (BS) as a low-cost adsorbent for the removal of Pb(II) ions from simulated aqueous solutions having 1:500 (w/v) composition of BS:Pb(II) solution. The optimum shaking and settling time periods for BS to remove Pb(II) are 1.5 hr and 1.0 hr, respectively. Effect of ionic strength of the medium on the extent of biosorption investigated in aqueous KNO_3 solutions of different concentrations indicate that, as the concentration of KNO_3 is increased from 0.01 M to 1.0 M, the removal of Pb(II) is decreased from 92% to 78%. Adsorption data, fitted to six isotherm models, namely the Langmuir, Freundlich, Temkin, Dubinin-Radushkevich, Redlich-Peterson and Sips, indicate that both the Langmuir and Sips models give good R^2 values. Based on the error functions, the lowest error values are associated with the Sips isotherm model with the maximum adsorption capacity (q_{max}) values of 78.5 mg g^{-1} and 85.4 mg g^{-1} for the Sips and Langmuir isotherm models, respectively. Thermodynamics studies show that the adsorption of Pb(II) on BS is feasible and spontaneous, and that the Gibbs free energy $\Delta G°$, decreases with increase in temperature. The negative value for standard enthalpy change ($\Delta H°$) indicates that the biosorption is exothermic in nature and the positive value of $\Delta S°$ suggests an increased randomness of solid – solution interface. Adsorption kinetics of Pb(II) on BS, investigated using three models, pseudo first order, pseudo second order and Weber Morris intra-particle diffusion, show that the experimental (0.227 mmol g^{-1}) and calculated (0.222 mmol g^{-1}) q_e values are in good correlation for the pseudo second order model with a rate constant of 0.504 g mg^{-1} min^{-1}, whose validity is further supported by having a high R^2 value of 0.995.

Keywords: Breadfruit peel, adsorption, lead, thermodynamics, kinetics

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PADDY STRAW DERIVED ACTIVATED CARBON AS AN ADSORBENT MATERIAL FOR FLUORIDE REMOVAL OF DRINKING WATER IN SRI LANKA - A REVIEW

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A high concentration of fluoride in groundwater was reported from the areas of North Central and Eastern provinces of Sri Lanka. Excessive levels of fluoride in drinking water have adverse health impacts, such as dental and skeletal fluorosis and chronic kidney diseases. Fixed bed adsorption method is an effective technique to remove excess fluoride in drinking water, especially for developing countries due to its technical feasibility and low operating cost. Activated carbon is becoming a promising adsorbent for fluoride ions, with low cost of preparation. In this study, severity of excessive fluoride issue in Sri Lanka, available de-fluoridation methods and suitability of rice straw derived activated carbon for fluoride adsorption are discussed.

Rice straw is one of the high volume and abandoned agricultural waste, produced in Sri Lanka. Therefore the surface area (S_{BET}) variations of paddy-straw derived activated carbon, with the activation method (one stage and two stage thermal activations) and surface modification (by $KMnO_4$, HNO_3 and KOH) are reviewed. According to the physical properties and fluoride removal efficiency, one step steam pyrolysis at 650 °C and modified with $KMnO_4$ can be considered as an effective method of adsorbent preparation. According to the experimental results of fluoride adsorption on activated rice straw, it is reported as a pseudo second-order adsorption, in which the rate limiting step is assumed to be chemisorption. Also the satisfactorily fitted isotherm is concluded as Langmuir isotherm. From the study, it is identified that paddy straw derived activated carbon is suitable for the reported levels of fluoride in Sri Lanka.

Keywords: Activated carbon, chemisorptions, fluoride

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PROCESS OPTIMIZATION FOR LIME SODA WATER SOFTENING METHOD FOR REDUCING HARDNESS IN WELL WATER

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Well water in the northern parts in Sri Lanka is encountering the problem of water hardness. According to the Sri Lanka Standards for potable water (SLS 614), the highest desirable level of total hardness is 250 mg L^{-1}. According to previous investigations, it was found that the well water located around northern parts in Sri Lanka exceed the maximum permissible level of water hardness. Therefore, as a solution, the lime soda water softening method is tested for reducing the hardness of well water. From the process optimization of the lime soda water softening method, the total hardness was brought down below 250 mg L^{-1}. Variations of total hardness in lime soda softening method were examined by improving the existing process with additional chemical processes. It was observed that lime soda water softening method can be applied to reduce the hardness to desirable levels. The main issue of lime soda water treatment process is the addition of an unnecessary excess amount of sodium ions into the water and increase of pH value due to the excess carbonate ions. In order to avoid these issues, the lime soda water softening method was further improved by adding hydrochloric acid and alum. In the basic lime soda treatment process, the results were below 50 mg L^{-1}. By the addition of hydrochloric acid after the lime soda treatment, the results were up to a desirable level below 50 mg L^{-1} but from the addition of alum, the results were above 250 mg L^{-1}. The people in the northern parts in Sri Lanka commonly use well water for their day today activities. However, because of the excessive water hardness, they face a severe issue in fulfilling their daily requirement of drinking water. In that case, the lime soda water softening method and its integrations can be applied as a solution to reduce the water hardness.

Keywords: Hardness of water, water softening, water purification

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REMOVAL OF MANGANESE FROM DRINKING WATER USING ACTIVATED CARBON DERIVED FROM AGRICULTURAL WASTE

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Toxic trace elements have been excessively released into the environment due to anthropogenic activities and have become a major global concern. According to the communication and findings, contamination of groundwater aquifers and food with toxic trace elements could be the key factors for one of the national health problem, Chronic Kidney Disease of unknown etiology in North Central Province (NCP) of Sri Lanka. Therefore, the objective of this study was to explore the possibility of purifying drinking water sources using activated carbon derived from carbonaceous agricultural waste to remove Mn^{2+} from contaminated water.

The activated carbon (AC), were prepared from: coconut shells (CAC), peanut shells (PAC), mango peels (MPAC) and teak saw dust (TSAC) by chemical activation using 14.8 M ortho-phosphoric acid at temperatures of 450 ^{o}C for coconut shells and 850 ^{o}C for other raw materials. Concentration of Mn^{2+} in water samples was measured using Atomic Absorption Spectrophotometer. Freundlich and Langmuir adsorption isotherms were used to model the equilibrium adsorption data obtained for adsorption of methylene blue (MB) at 27 °C on all the ACs produced. The adsorption capacity for MB (methylene blue number, MBN) and iodine (iodine number, IN) of each AC was determined according to the American Society for Testing Materials (ASTM) specifications in order to characterize them. Since, PAC exhibited best characteristics among the other ACs investigated, adsorption isotherms of PAC were obtained at 50, 60 and 80 °C.

It was found that all the isotherms obey Freundlich and Langmuir behaviors with high correlation coefficients ($r > 0.9$) and the type of adsorption of MB on PAC is activated chemisorption. MBN of AC samples; CAC, MPAC, PAC and TSAC were 57.02, 54.20, 51.40 and 48.95 respectively. Higher iodine adsorption capacities were obtained for PAC (355.33) and TSAC (291.88) compared to MPAC (286.80) and CAC (241.11) giving evidence for the presence of most heterogeneous carbonaceous structures developed due to the formation of the micro pores during the activation process of peanut shell and teak saw dusts. The ability of removing Mn^{2+} of the investigated ACs is in the order of PAC > TSAC > MPAC > CAC and the same order has been followed by the IN indicating the availability of number of adsorption sites for Mn^{2+} especially in micropores.

According to the results of this study, it was established that PAC possesses the most heterogeneous carbonaceous structure compared to CAC, TSAC and MPAC that was evident from its highest IN. Peanut shells and teak saw dust were found to be possible raw materials for the preparation of activated carbon since they have the best ability to remove manganese from contaminated water among other ACs investigated.

Keywords: Activated carbon, agricultural waste, iodine number, manganese

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REMOVAL OF Cd(II) AND Pb(II) FROM DRINKING WATER USING COST EFFECTIVE ENVIRONMENTALLY FRIENDLY CHITOSAN BEADS

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Chitosan is a biopolymer derived by deacetylation of chitin. Even though chitosan has been used to remove heavy metals mainly from industrial wastewater, little attempt has been made to study the ability of chitosan to uptake heavy metals in drinking water contaminated with trace amounts (μg L^{-1}) of heavy metals. Since chitosan was reported previously by our group to be effective as a drinking water purification agent, the current study focused on modification of commercially available chitosan to increase the surface area and the porosity of the polymer and thereby to increase the heavy metal adsorption capacity of chitosan. In this research physically modified chitosan; chitosan beads were prepared and characterized. Then the metal adsorption capacity of chitosan beads for selected metal ions; Cd(II) and Pb(II) was determined under selected experimental conditions and investigated the potential use of chitosan beads to remove heavy metals from drinking water.

Chitosan beads were prepared by adding prepared chitosan slurry (made by dissolving chitosan flakes in 1% v/v acetic acid) into a NaOH bath (0.5 M) by using a micropipette. Then the beads were characterized using a Scanning Electron Microscope (SEM). According to the SEM images chitosan beads had higher porosity than that of commercially available unmodified chitosan flakes. The effect of chitosan bead dosage, initial metal ion concentration and water hardness (Mg^{2+} and Ca^{2+} concentration) for metal adsorption capacity of chitosan beads for Pb(II) and Cd(II) were examined at room temperature (29 ± 0.5 ºC), at pH = 7 with a two hour agitation period. The amount of metal removed under the selected conditions was determined using Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS). Optimal performance for Cd(II) was observed when the initial metal concentration was 50.00 μg L^{-1} while that for Pb(II) was observed at 70.00 μg L^{-1} initial metal concentration. The maximum adsorption capacity of chitosan beads for both metals was observed when chitosan bead dosage was 0.050 g. Hence the research revealed that under the optimized conditions, chitosan beads have adsorption capacities of 124.17 μg g^{-1} for Pb(II), and 197.98 μg g^{-1} for Cd(II) which were clearly higher than the corresponding metal adsorption capacities of unmodified chitosan flakes. This indicates that the higher porosity in chitosan beads leading to enhanced metal adsorption capacity of chitosan beads. Under the experimental conditions; Pb(II) and Cd(II) adsorption capacities of chitosan beads were not significantly affected by the presence of Ca^{2+} or Mg^{2+} in the solution indicating that chitosan have less affinity towards alkaline earth metal binding.

Some water samples collected from common drinking water sources (well water, tap water, etc.) in North Central Province and Western Province had Cd(II) levels within the permissible limits defined by World Health Organization (WHO). Water samples collected from Killinochchchi and Vavuniya have exceeded Pb permissible level and which were successfully reduced into the permissible range defined by WHO by treating with chitosan beads. Therefore this study indicates that physically modified chitosan beads could be used as an efficient bioadsorbent to remove Cd(II) and Pb(II) from polluted drinking water.

Keywords: Chitosan beads, adsorption capacity, cadmium, lead

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PRODUCTION OF CHITOSAN FROM BLACK TIGER SHRIMP *(Penaeus monodon*) WASTE AND REMOVAL OF Cd(II) FROM AQUEOUS SOLUTIONS USING CHITOSAN FILMS BY ADSORPTION AND AN ELECTROCHEMICALLY-ASSISTED METHOD

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Heavy metals in drinking water can be removed using different methods such as adsorption using adsorbents, membrane filtration, electrodialysis, photocatalysis etc. As some of these conventional strategies have some drawbacks; numerous new approaches have been studied for the development of cheaper, effective and more efficient technologies to remove heavy metals in drinking water. In recent years, the search for efficient, readily available and more affordable adsorbents that have metal-binding capacities has intensified and therefore; the current study focused on use of physically modified chitosan; chitosan films (deacetylated product of chitin) as a cost-effective heavy metal removal agent for drinking water purification by adsorption and electrochemically-assisted method. The main objectives of this study were to prepare chitosan film/membrane from chitosan flakes to enhance the surface area and evaluate its Cd(II) removal ability by adsorption and an electrochemically assisted method.

Initially chitosan was extracted from shrimp (*Penaeus monodon*) shells using five different pretreatment methods. The chitosan with highest degree of deacetylation (deacetylation percentage 52.92%), was observed when shrimp shells were pretreated with acetic acid (0.008 M) followed by deacetylation with NaOH (12.5 M) for 20 hours. Then chitosan films were prepared *by* pouring the 1% w/w chitosan solution (made by dissolving chitosan in 2% v/v acetic acid**)** into a petri dish and allowing the solvent to evaporate at room temperature. Cd(II) adsorption capacity of chitosan films was evaluated, at room temperature (29 ± 1 °C) and at pH = 7 under different initial Cd(II) ion concentrations and different adsorbent dosages using Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS). Finally an electrochemically assisted method was carried out to test the permeability of the chitosan film for Cd(II) under an electric potential.

The highest Cd adsorption capacity for a chitosan film was observed when initial Cd(II) concentration was 50 μg $L^{-1}$and the initial adsorbent dosage was 0.025 g. Unsurprisingly chitosan film had higher Cd(II) adsorption capacity of 194.45 (± 0.19) μg g^{-1} compared to that of unmodified chitosan which had a Cd(II) adsorption capacity of 73.86 (± 0.24) μg g^{-1}. These results clearly indicate that the enhanced surface area in chitosan film leads to enhanced Cd(II) adsorption capacity in the physically modified bioadsorbent. Further, the results of electrochemically assisted method revealed that the chitosan membrane had allowed Cd(II) ions (40 μg L^{-1} and 100 μg L^{-1}) to migrate towards the cathode when an electric current was applied. However, the collected Cd(II) at the cathodic compartment did not significantly migrate back to the anodic compartment through the chitosan membrane when the current was switched off indicating that the chitosan membrane permeability for Cd(II) is significantly higher under an electric potential. This study indicates that chitosan films could be used to remove Cd(II) from drinking water and the electrochemically assisted method could be further studied to develop it as a new method to purify drinking water**.**

Keywords: Chitosan film, adsorption capacity, cadmium, electrochemically assisted method

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PRESENCE OF POTENTIAL TOXIN PRODUCING CYANOBACTERIA IN WELL WATERS OF THE GIRANDURUKOTTE, CHRONIC KIDNEY DISEASE OF UNKNOWN ETIOLOGY (CKDu) ENDEMIC AREA IN SRI LANKA

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Safe drinking water is one of the key important aspects of human health. Among drinking water sources, well waters are the most common in rural areas of Sri Lanka. The quality of drinking water in relation to CKDu is of increasing interest to both the scientific community and to the general public since shallow and deep wells are the main sources of potable water in the affected regions and both chemical and biological contaminants are of common concern. Among biological contaminants, cyanotoxins have a high potential of exposure that could have an adverse affect on the human body and thereby can have various health impacts. This study aimed CKDu and Chronic Kidney Disease (CKD) patients in Girandurukotte and their well water sources and control samples from other parts of Sri Lanka analyzing in terms of cyanobacteria and their toxins. A questionnaire analysis was carried out with 330 subjects (CKD n = 33, CKDu n = 244, and healthy individuals n = 53). Eleven factors showed significant differences ($p < 0.05$) that could be related to CKDu. Among them, the well water source for drinking was ($p = 0.00$) notable.

Potential microcystin (MC) and cylindrospermopsin (CYN) producing cyanobacteria were morphologically identified from 110 (CKD n = 11, CKDu n = 74 and healthy individuals, n = 25) water samples. Out of 74 CKDu well water samples, 10 samples did not have any cyanobacterial growth. Among 64 samples, species belonging to 13 genera were found as MC producers and three genera as CYN producers. Out of 11 well water samples from CKD patients, seven genera were found as MC producers in most of the samples while in two samples *Anabaena* sp. and *Lyngbya* sp. were found as CYN producers. Compared to Girandurukotte patients' well water samples, cyanobacterial diversity was found to be less in healthy individuals' well waters. Overall, out of 25 well water samples, one sample did not have any cyanobacterial growth. Among other 24 samples, species belonging to seven genera were MC producers while *Lyngbya* sp. were found as the only CYN producer in one sample. Among potential toxin producers, presence of *Phormidium* spp. in CKDu patients' well waters were found to be significant ($P = 0.004$) compared to other two populations. Presence of cyanobacteria in these water samples were also confirmed by molecular analysis. Further, 50 CKDu and 15 CKD + healthy individuals' well water samples were assayed for partial *myc*E gene, CYN specific NRPS and PK genes and partial nodularin synthetase (*nda)* gene. Among these, presence of CYN producers ($p = 0.049$) and nodularin (NOD) producing *Nodularia* sp. ($p = 0.0029$) were found to be significant.

In conclusion, well waters in Girandurukotte, Sri Lanka contain a vast cyanobacterial diversity with potential MC, CYN and NOD producing species. As such, presence of cyanobacteria with toxin generating ability in well water source could be an indication regarding the numerous health impacts faced by the people living in the dry zone of Sri Lanka. Consequently, more epidemiological studies are required to explore the relationship existing between CKDu and cyanotoxins in water.

Keywords: Cyanobacteria, Chronic Kidney Disease, toxins, well water

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EPIDEMIOLOGICAL RELATIONSHIPS OF DRINKING WATER QUALITY FOR THE PREVALENCE OF CHRONIC KIDNEY DISEASE OF UNCERTAIN ETIOLOGY (CKDu)

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An alarming increase of CKDu has been observed during the last three decades. However, up to date no certain cause(s) of the disease has been identified. But, it is suspected as a toxin-mediated renal failure and several risk factors are hypothesized; unrecognized environmental toxins and occupational exposures, chronic exposure to heavy metals, presence of high level of fluoride, cyanobacterial toxins in water, genetics and social factors. Water is one of the most efficient avenues of toxin invasions to the human body. As drinking is the main pathway of water intake by humans, it is important to study the chemical composition of drinking water with reference to CKDu. Thus, the objective of this study was to elucidate any epidemiological relationships of water quality with the prevalence/non-prevalence of CKDu.

North Central province is well known as a high-risk zone for CKDu and it was noted that within this macro-region, small pockets of CKDu non-prevalence zones do exist and notably, the residents in those pockets consume spring water. Therefore, the drinking water quality of four areas, namely high-CKDu-prevalence areas, low-CKDu-prevalence areas, CKDu-free isolated pockets and control areas were examined for F, Al, Cd, As, and hardness. Water samples were collected from; high CKDu prevalent regions [Padaviya (A), Medawachchiya (B), Kebithigollewa (C) and Rambewa (D)], low prevalence regions [Anuradhapura town (E), Pulmoddai (F), Vauniya (G), Sigiriya (H)], isolated spring areas and control areas [Gampaha (I), Kandy (J), Nuwara Eliya (K)] (a total of 612 samples). Statistical analyses of data were performed by using Vegan package in R software to identify whether there is any significant evidence of the concentrations of chemicals among the given areas.

According to elemental analysis results of water samples, it is not possible to demarcate a single causative factor for the etiology of CKDu. (Among F, Al, Cd, As, hardness). In all cases, the total As concentration in drinking water was lower than 2 µg L^{-1} (well below the World Health Organization (WHO) level of 10 µg L^{-1} for As). Thus, the multi-faceted nature of possible causative factors is assumed. This was examined by a multivariate scatter plot (Figure 1). The control areas are distinctly separated from other areas showing contrasting differences in water quality. It is also interesting to note the behavior of Al where the effect of Al is weak in all considered areas, while it is high in the area E (which is a low-prevalence area) due to treated water (higher dose of Alum addition).

The overall results presented a clear correlation in high prevalence areas; the occurrence of CKDu is highly correlated to F, and hardness (and to a lesser extent with Cd). However, the effect of Cd in high prevalence areas is considerable even though the effect of Cd is not that marked as of F and hardness. Thus, suggesting a possibility of synergy existing among hardness, F and Cd with the etiology of CKDu. To further

elucidate the contribution from each element for the significant factor, correlation (loading) values were estimated. When comparing the loadings of each element, it follows the order F > Cd > hardness; where F has the highest effect on CKDu. Moreover, there is a strong possibility of formation of toxic substances such as CaF_2 and CdF_2 in nature, which can damage liver and kidney. Thus, the major finding of this study shows clear correlation of toxic synergic effect of F, Cd and hardness for the prevalence of CKDu. Importantly, the synergic effect proposed by this model was confirmed by our recent animal study.

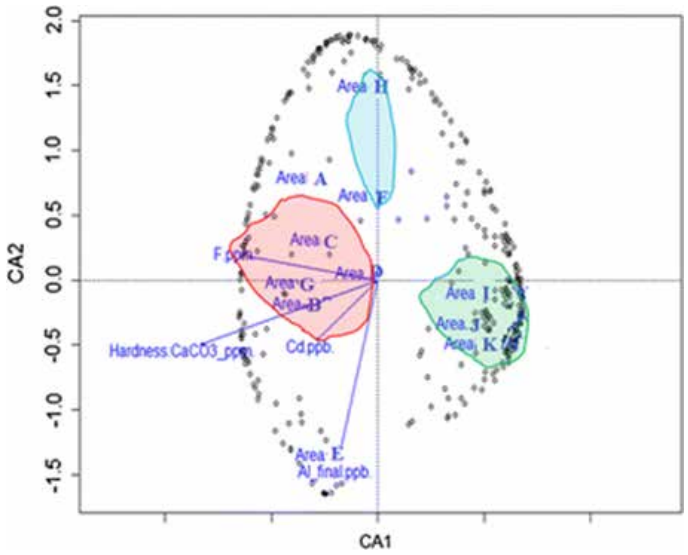

Fig.1. Multivariate scatter plot of water quality parameters in prevalence/non prevalence areas; (High CKDu Prevalence areas - A,B,C,D), (Low CKDu prevalence areas-E,F,G,H), - (CKD non prevalence areas/Control areas-I.J.K)

Keywords: CKDu, epidemiological relationships, synergic effect, prevalence areas, multivariate scatter-plots

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A STUDY OF THE EFFECT OF ENVIRONMENTAL, GEOGRAPHICAL AND PERSONAL HEALTH ISSUES ON SOME AGE RELATED DISEASES: A MULTIVARIATE MULTILEVEL STUDY

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Studies on worldwide health care systems strictly consider the mortality rates of various diseases along with the corresponding risk factors. However, among the risk factors, the environmental factors play an important role and 'Water' and 'Sanitation' play a major part of it. This research examines the role of personal health issues, environmental and geographical factors to the contribution of the worldwide health care system. For that, some age related diseases such as Cardiovascular Disease, Diabetes (CDD) and Chronic Respiratory Conditions (CRC) were taken as response variables and several risk factors such as 'Water', 'Sanitation', 'Solid Fuels', 'Blood Glucose', 'Blood Pressure', 'Smoking', 'Alcohol Consumption' and 'Obesity' were taken as explanatory variables. Data were collected from the work "*World Health Statistics 2013*". It consists of worldwide mortality rates of adults for the above mentioned diseases in 195 countries. These countries are clustered within the continents geographically and hence it shows the importance of considering the continent effect which is a geographical effect. This led to the use of the multilevel concept. Furthermore, the two diseases were highly related to each other and consequently the multivariate idea was decided upon. Accordingly, a multivariate multilevel model was fitted to the dataset.

The data were primarily subjected to a graphical phase, which was based on bar charts and mosaic plots. It was then followed by a univariate test to obtain individual relationships. The preliminary analysis was further followed by an advanced analysis, which adopted multilevel binary logistic models which were used to suggest variables for the multivariate stage which resulted in the fitting of the multivariate multilevel probit regression model.

The univariate phase results showed that both the 'Water' and 'Sanitation' are significant for CDD and CRC together as well as separately. In the advanced modeling phase, the variables 'Water' and 'Sanitation' showed some hidden essential relationships for both diseases after adjusting for the other explanatory variables specified. It was established that, when the usage of improved drinking water sources decreases, the probability of getting the two diseases increases. Furthermore, it showed that North America and Europe contributed to a lower risk of having CDD and CRC while Asia and Oceania contributed to a higher risk of having CDD and CRC. Therefore, the results reveal that the environmental factors such as 'Water' and 'Sanitation' play important roles for this macro geography variation of CDD and CRC. Finally, the model adequacy techniques showed that the fitted models were adequate.

Keywords: Water, sanitation, age-related diseases, continents, multivariate-multilevel models

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WATER QUALITY ANALYSIS IN CHRONIC KIDNEY DISEASE OF UNKNOWN ETIOLOGY (CKDu) EMERGING LOCATIONS (WARUNAGAMA AND RAHATHANGAMA) IN MONERAGALA DISTRICT, UVA PROVINCE, SRI LANKA

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A distinct form of Chronic Kidney Disease independent of hypertension, diabetes or other known etiologies has been emerging slowly but progressively in farming communities those predominantly living in North Central region of Sri Lanka. However, kidney disease emerging in villages such as Pelwatta and Buttala are some of the CKDu confined locations in the Moneragala District in the Uva Province. Most importantly, sugar cane farming is predominant in these CKDu confined locations. Due to similar farming practices, it is predictable that people living in these locations are likely to be experiencing kidney diseases similar to CKDu affected population living in the North Central region of Sri Lanka. For detailed investigation into causative agents and sources developing CKDu in Uva Province, we assessed drinking water as it is the major and the commonest source for introducing causative agents into the human body. Drinking water quality parameters such as nitrate (NO_3^-), phosphate (PO_4^{3-}), fluoride (F^-), hardness, conductivity, total dissolved solids (TDS), dissolved oxygen (DO), pH and salinity were determined in Warunagama (n = 14) and Rahathangama (n = 31) G.S. divisions surrounding sugar cane plantations. Water samples (groundwater and tap water) were collected during the dry season (February to March, 2015). pH of water samples were measured by a pH meter. DO, salinity and conductivity were measured using a water quality meter (YSI 85) and TDS was analyzed using a TDS measuring meter (HANNA HI9835). In addition, NO_3^-, PO_4^{3-} and F^- were analyzed using a spectrophotometer (HACH DR 4000U) and hardness was measured using a titrimetric method with EDTA. Water quality parameters were compared with drinking water standards of Sri Lanka and World Health Organization (WHO). Nitrate, phosphate, DO, pH, TDS and salinity were within the permissible limits in Warunagama and Rahathangama locations. Fluoride in Rahathangama site 1 (0.50 mg L^{-1}) and site 2 (0.59 mg L^{-1}) were very close to exceeding drinking water standards of WHO. Furthermore, conductivity (in Rahathangama but not in Warunagama) and total hardness (in both Warunagama and Rahathangama except site 3) exceed SLS 614 maximum desirable levels. Further studies analyzing heavy metals and pesticide residues in drinking water need to be performed to highlight exact causative agents responsible for CKDu emergence in current study locations.

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Keywords: Chronic kidney disease, heavy metals, pesticides

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MITIGATION OF THE WATER POLLUTION DUE TO MUNICIPAL SOLID WASTES VIA PRODUCTION OF COMPOST

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There are broad spectrum ways, for instances, as small as domestic level to mass scale industrial generation, at present, in the country that directly contribute to generate wastes. The waste in solid nature has become a major threat on the environment and its livelihood. About three decades back, most of the solid waste generated in Sri Lanka were organic in nature and thereby naturally balanced in the environment. With time, the composition of the solid wastes shifted to more non-degradable matter especially due to the industrial and urban contributions. Most local authorities collect solid waste in haphazard ways and openly dump them in low lying areas without any treatment. The leachate formed during the digestion of the solid waste is rich in potentially toxic elements and other pollutants. Thus, direct victims of such chaotic dumping are the surface and ground water resources, especially during the rainy season. Production of compost from waste implicates a dual way forward by lowering the burden on water resources while adding a monetary value to the waste. In this direction, four such projects have been in operation in the Kegalle district under the 'Pilisaru Project' of the Central Environmental Authority. To strengthen the acceptability of the compost along this direction, Sri Lanka Standards Institution has introduced the SLS 1246:2003 standard for the compost. In this study, quality of compost from two local authorities of the Kegalle district was ascertained against the standard. pH values of the compost comply with the standard (6.5 - 8.5) except one instance reported at the Rambukkana site as 9.1. As expected, conductivity of the composts always deviated from the standard and positive deviations are more in the urban site of Kegalle compared to the Pradeshiya Sabha site of Rambukkana. Moisture levels in Rambukkana recorded lower values while those at Kegalle was associated with slightly higher values than the standard (20 - 30 %). Variations of storing conditions greatly affect these results and can be easily managed. Chemical characteristics of the compost including nutrients, total nitrogen, total phosphorus as P_2O_5 and potassium marginally comply with the SLS standard. Deviation of the results of a particular parameter from one sample to another at the same site indicates non-homogenized nature of the composts. Importantly, levels of organic carbon in both sites show a good agreement with the standard (20 - 25 %) being 24% at Rambukkana and a higher value of 29% at Kegalle UC. However, a common characteristic of the compost from both sites is the remarkably higher sand content than the standard (< 10 %). The findings show the need of careful management of the quality of compost. Further, results of physico-chemical parameters associated with the composts should be enhanced to comply with the national guidelines in order to make the product acceptable, and thereby mitigate the impact of solid waste.

Keywords: Composts, pollution characteristics, solid waste, toxic elements, water pollution

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SORPTION STUDIES OF TEXTILE DYES USING NATURALLY AVAILABLE SUBSTANCES

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Textile industry releases several types of dyes to the environment. The contamination from these substances may adversely affect any ecosystem. Over the past few decades, many treatment techniques were introduced to remove dyes from industrial effluents. The current study is mainly based on the removal of dyes present in effluent samples using naturally available substances. Textile dyes, namely Sumifix Blue Exf (Dye 1), Sumifix Rubine Exf (Dye 2) and Sumifix Yellow Exf (Dye 3), obtained from a textile industry show their λ_{max} values at 605 nm, 545 nm and 415 nm, respectively. Among different adsorbents (e.g. brick clay, rice husk, coir dust, saw dust, feldspar and dolomite), investigated for the removal of dyes from aqueous solutions, using 50 mg L^{-1} individual dye solutions under batch mode, brick clay shows the highest efficiency. The optimum values of various parameters, such as adsorbent firing temperature, adsorbent dosage, shaking time, settling time, solution initial pH, for brick clay were 200 °C, 4.0 g, 15.0 min, 15.0 min and pH < 10, respectively. Adsorption data obtained at ambient temperature modeled using Langmuir, Freundlich, Temkin, Dubinin-Reduskevich isotherm relationships, results in the validity of the Langmuir adsorption isotherm with high regression coefficients close to 1.0. The kinetics of dye adsorption on brick clay can be best described by the pseudo second order model having a high regression coefficient of 0.999 for all three types of dyes. These results indicate that fired brick clay could be used as an effective option for removal of dye present in industrial effluents.

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Keywords: Textile industry, dye effluents, burnt brick clay, isotherm studies, kinetics

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