2016

CHALLENGES AHEAD

WATER QUALITY AND HUMAN HEALTH

International Symposium
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All begins with water

05th & 06th August 2016

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

PROCEEDINGS

5th International Symposium on

WATER QUALITY AND HUMAN HEALTH: CHALLENGES AHEAD

5-6 August 2015

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Table of Contents

I am pleased to issue this message to mark the "5th International Symposium on Water Quality and Human Health: Challenges Ahead" to be held on the 05th and 06th of August 2016 at the Postgraduate Institute of Science (PGIS).

On the global scale, the „Water Sector" is probably the most important sector among others, owing to the necessity of the wide consumption of water, pure enough for the intended application. Unfortunately, water is the most abused natural resource on the earth. Consequently, water-related health problems have been on the rise, and further, irreparable damage to the entire ecosystem has resulted in due to water pollution problems. Scientists have thus stimulated themselves in conducting research on identifying the root cause of problems and to propose remedial measures. The public is also keeping attention on issues related to water expecting viable solutions. I believe that it is the duty of water scientists to disseminate their knowledge through appropriate mode of action. In this respect, this symposium would provide a platform for water scientists to share their knowledge on water pollution issues and possible remedial actions.

The Organizing Committee of this symposium has taken a keen interest to conduct this timely and globally important event at international level. I am glad to report that about fifty abstracts covering a broad spectrum under the theme of Water Quality and Human Health will be presented. Water scientists from many national and foreign universities, research institutions and government/private sector organizations 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 6th Symposium on the same theme be conducted in the year 2017.

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

Prof. H.M.D. Namal Priyantha
Director
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FLUORIDE IN WATER ENVIRONMENTS: PROBLEMS AND REMEDIAL MEASURES

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Fluoride is widely used in various industries because of its specific chemical properties, such as high electronegativity and reactivity. However, fluoride in the water environments is one of the serious issues since it is a harmful element for human health. In this address, problems and remedial measures on fluoride in water environments are presented.

Groundwater is contaminated with fluoride when surrounding minerals contain fluoride. Long-term intake of fluoride-containing water causes adverse impact on hard tissues, such as teeth and bones, in human. Effect of fluoride on dental enamel tissues causes colored spots and/or lines called "dental fluorosis (or mottled teeth)". The reports from the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) have pointed out that more than twenty five (25) countries, including China, United States, Turkey, Japan and Sri Lanka, face problems due to the presence of fluoride in drinking water. In Japan, fluoride in drinking water had been an issue of public health during the period from the 1930s to 1980s. An investigation conducted in the United States indicates that the rate of dental fluorosis is directly related to the concentration of fluoride in drinking water, and further, it is recommended that fluoride in drinking water be regulated within the range of 1 and 2 mg L^{-1} worldwide.

Two methods are available as counter measures for fluoride problems associated with water environments. First one is to change in the water source from groundwater to either another well with less fluoride, or surface water. Removal of fluoride from drinking water is the second one. Since access to clean surface water has become a problem in many countries, the latter method would invariably be a better choice.

Removal of fluoride is carried out by many techniques, such as precipitation, adsorption and membrane separation. Precipitation method is widely used because of its simple operation and low cost. Although the aluminum coagulation method (so-called Nalgonda method) is a major choice for precipitation, generation of huge amounts of sludge would be one of the problems. Adsorption method by bone char is a better choice for removal of fluoride from water. Toyama Prefectural University, Japan, and National Water Supply and Drainage Board, Sri Lanka, have jointly addressed this problem at household and community levels.

Our research group has developed a novel social system on fluoride treatment in Tunisia in Northern Africa by focusing on the sediment in reservoirs. Tunisia also faces with the fluoride problem in aquatic environments, where a huge amount of suspended solid sediments in the reservoirs causes diminishing capacity of water. Accordingly, dredging of the sediment in reservoirs is required to keep the water capacity at adequate levels. However, the high cost of the dredging is one of the serious problems. We confirmed that adsorption of fluoride is possible by the ceramics made of the sediment by calcination. During this project, a social system has been established in which the income by selling the ceramics as an adsorbent of fluoride is used for dredging of the sediments to produce ceramics.

CURRENT ISSUES IN WATER SECTOR RESEARCH

Pathmalal Manage

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Water is the most familiar and abundant liquid on earth and it is an essential nutrient, a vital component of every cell, tissue and organ in the body. On earth, 97% of water is found in seas and oceans, and 3% in freshwater. The Sri Lankan river system comprising 103 rivers flowing from the central highlands makes up a total collective length of about 4560 km covering a total area of 59,245 km^2. Groundwater extraction in the country has estimated at about 7,800 million m^3 per year, and 72% of the rural population and 22% of the urban population is dependent on groundwater for their daily requirement. It is a known fact that variety of quality concerns in water includes contamination by nitrate, phosphate, heavy metals, pathogenic microbes, antibiotics, chloro and fluoro chemicals and cyanotoxins. Recent research in the Centre for Water Quality and Algae Research has revealed that heavy metals related to toxic chemicals are derived from the industrial sector and agricultural lands. Further, it has been shown that insufficient sanitary conditions and poor management of waste disposal would elevate the occurrence of human pathogenic bacteria, antibiotic, fluoro and chloro chemicals in surface and ground water, sediment and fish. The results are alarming bioaccumulation potential of hazarders xenobiotics via food chain, drinking water along with pathogens. Thus, providing safe drinking water is a challenge and consequently, research on environmental and health issues related to water quality, and development of novel technologies for water purification should be priority areas to develop the country. Results of such studies were shared with the Central Environmental Authority, Ministry of Environment, Ministry of Health and United Nations Development Programme to prepare a strategic plan for the river basin in the country. Accumulation of nitrate in ground water due to heavy usage of fertilizers has become another burning health problem with "blue baby syndrome" in some part of the country and hence, a green approach using microbes are being studied to develop removal methods for nitrate by bioremediation through enzyme technology. Further, Chronic Kidney Disease of unknown etiology (CKDu) has become a major health issue over the past two decades in Sri Lanka and no exact source of course or causative agent has been identified. Among the prevailing hypothesis on CKDu, the USJP a research team of the University of Sri Jayewardenepura (USJP) has investigated the effect of cynotoxins and heavy metals on CKDu along with contamination status of microcystin in both ground and surface drinking water sources. As a result of collaborative research conducted by Japan International Cooperation Agency (JICA), National Water Supply and Drainage Board and USJP, microcystin-LR and cylindrospermopsin were included to the SLS drinking water quality standards in 2014. It is believed that this is high time to move environmental friendly green methods and technologies to find solution for water pollution. In this contest, application of bioremediation and phytoremediation technology in order to find solution for oil pollution, textile dye pollution, cyanotoxin and pesticide contamination, water odor and taste problem prevailing in different part of the country are being under investigation. Recent work at the Robert Gordon University and the MaCaulay Institute, UK have discovered far greater toxin and other xenobiotics degrading bacteria as world first record on microcystin degrading actinobacteria and recent studies in Sri Lanka the bacterium *Rahnella aquatilis* was recorded as world first report of microcystin-degrading bacteria which belong to class gamma-proteobacteria. Pivotal to this work the robust bacteria was incorporated as biofilm into lab-scale sand filters as a navel finding to treat microcystin contaminated water for water treatment solution.

STABLE ISOTOPE ANALYSIS: AN EMERGING TOOL FOR ENVIRONMENTAL FORENSICS - NON LEGAL APPLICATIONS

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Approximately 270 stable isotopes of different elements have been identified. Thus, most elements have different (two or more) isotopes in various proportions. This means that, for a given chemical compound, different combinations of isotopes for each component element are possible. This variability of compounds is mainly due to two main facts: the original isotopic variability of natural substances and the changes in isotopic composition of the compound once released in the environment. Subsequently, the original isotopic composition may either change or alter due to fractionation processes, specific for different transformations to which the contaminant is subjected to. This tremendous isotopic variability offers a strong forensic tool in comparing different samples of the same compound (contaminant) and assessing the source and age of contamination.

Stable isotopic analysis is being increasingly applied as a tool to investigate and monitor sources, transport and fates of contaminant compounds in the environment. Results of an increasing number of studies indicate that stable isotopic analysis is a promising tool in environmental chemistry. This presentation discusses reported results of successful environmental forensic applications of isotopic analyses including identification of the source of petroleum hydrocarbons, chlorinated solvents, polychlorinated biphenyls (PCBs), benzene, toluene, and *o,m*, and *p*-xylene (BTEX), methyl tertiary butyl ether (MTBE) and polycyclic aromatic hydrocarbons (PAHs) in groundwater. The ability of isotopic analysis to identify the occurrence of degradation makes it a potential tool for identifying and monitoring intrinsic bioremediation, or natural attenuation, of groundwater contaminants as well. Though this presentation is limited to a few examples of isotopic analysis of environmental contaminants, the principles discussed herein are relevant to all applications of isotopic analysis as an environmental forensic tool. Further, such applications in Sri Lankan context will also be discussed.

TOXICOLOGY OF CYANOBACTERIA

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Number of chemical contaminants in drinking water has been shown to cause adverse health effects in humans after prolonged exposure. Cyanobacteria are one of the most potent remarkably widespread, highly adaptable and successful group of photosynthetic prokaryotes, colonizing in diverse ecosystems. One key component of cyanobacterial success in the aquatic environment is the production of potent toxins as secondary metabolites, which have been responsible for numerous adverse health impacts in humans. Among cyanotoxins, microcystins (MCs), cylindrospermopsins (CYNs) and nodularins (NODs) are the most common and persuasive cyanotoxins in fresh waters that cause acute and chronic illnesses. Groundwater is heavily used all over the world, to provide primary sources of domestic drinking water supplies, and contaminated groundwater enhances risk to public health. Cyanotoxins have been detected in urban drinking water supplies in both industrialized and developing countries but regular testing of purified drinking water for algal toxins is generally not practiced in most of these countries including Sri Lanka.

Based on the mode of action on mammals, cyanotoxins are categorized as hepatotoxins, neurotoxins, dermatotoxins, etc. Two classes of hepatotoxic compounds produced by cyanobacteria are the cyclic peptides MCs and NODs, which are highly selective liver protein phosphatase inhibitors. CYN, is a cyclic guanidine alkaloid toxin. These toxins mainly damage the hepatocytes of the liver. They are potent inhibitors of serine/threonine protein phosphatases type 1 and 2A (PP1 and PP2A), which leads to hyperphosphorylation of proteins associated with the cytoskeleton of hepatocytes, leading to cytoskeletal disorganization. Further, MCs are tumor-promoting substances and are known to induce hepatocarcinoma and colorectal cancers. Chemically, NODs differ from MCs by the absence of two core amino acids and it is also a potent hepatotoxin and a carcinogen. The toxin CYN is zwitterionic in nature and stable under varying heat, light, and pH conditions. Therefore, the toxin can persist for long periods in turbid and unmoving water and cannot be removed by boiling.

It is not known why cyanobacteria produce cyanotoxins and a limited literature about why their production varies. Furthermore only certain cyanobacterial species produce cyanotoxins. Even toxigenic cyanobacterial species do not always produce toxins and the production of certain cyanotoxins is both species and strain specific. Some cyanotoxins can be produced by more than one cyanobacterial species and likewise, the same species is able to produce more than one cyanotoxin.

Being a tropical country, Sri Lanka has a wide range of topographic and climatic variations which grants excellent ecological niches providing exceptional growth conditions for varied cyanobacteria. The occurrence of toxic cyanobacterial blooms have also been reported from different aquatic systems of the country. Among them, toxic cyanobacteria in dry zone water sources drew extensive attention due to the epidemic of Chronic Kidney Disease of unknown etiology (CKDu) prevailing in dry zone of Sri Lanka.

The presentation would discuss about harmful cyanobacteria and their toxicology with special references to microcystin, nodularin and cylindrospermopsin.

Water pollution and Human Health

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According to the World Health Organization (WHO), access to quality drinking water is a right of every person living on Earth. Quality of drinking water is a powerful determinant of health of human beings. There are three main parameters which determine the quality of water: physical parameters, chemical parameters and biological parameters. Today, the world"s water resources are polluted heavily in several ways. Untreated industrial effluents, domestic waste, health care waste, heavy metals, grease and oil, industrial organic chemicals, pathogenic organisms, cyantoobacterial toxins, radiation are to name a few.

As a result of the polluted water, the health of the human population has been affected adversely. Millions of babies die every year due to water-borne diseases, such as typhoid fever, dysentery, and cholera. Cholera mainly found in Asia although some prevalence is reported in South America and rare occurrence in the western world. Screening of drinking water for algal toxins has become essential for many parts of the world as these toxins can be very acute hepatotoxins, neurotoxins and nephrotoxins. The nature of the water related diseases has taken a different turn with the industrial revolution. When Japan acquired a drastic industrial and economic development, Japanese people had to pay the price by becoming victims of diseases like Minamata disease which occurred due to industrial waste containing mercury, and Itai Itai which is due to industrial waste containing Cadmium.

Water pollution can be of natural origin too, such as high levels of fluoride (F^-) and arsenic (As), and there are many health problems associated with them. Bolken endemic nephrophathy reported in 1956 is a unique familial, chronic renal disease with a high-prevalence rate in Serbia, Bulgaria, Romania, Croatia, Bosnia and Herzegovina. Although strong evidence is available as the etiology of this disease, it is more likely to be explained as multi factorial. Similar disease was reported in Sri Lanka recently, Chronic Kidney Disease of unknown etiology (CKDu) which has a high prevalence in the North Central Province (NCP) among farmers with male preponderance. Although many causative factors are proposed, exact etiology of the disease is still unknown.

REAL-TIME *IN-SITU* MEASUREMENTS OF SELECTED WATER QUALITY PARAMETERS USING AN AUTOMATED COLORIMETER

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Time and money are important even in water quality testing, specifically when water quality relates to health, it becomes a crucial challenge. Chronic Kidney Disease of Unknown etiology (CKDu) among the rural community of the North Central Province of Sri Lanka has become the most attended non communicable disease in the country during the past decade. Though there is no exact reason given for the cause, it is suspected that higher concentrations of fluoride and hardness could be important causes. Expensive laboratory based water quality tests are unaffordable by rural community and also additional charges for sample collection and transportation to the testing laboratories have aggravated the situation. Therefore, the need of a real-time *in-situ* measurement of important water quality parameters through an automated colorimeter was investigated and an *in-situ* measuring device was designed and fabricated. This research was carried out in two phases. During the first phase, a questionnaire survey was carried out in the selected CKDu prevalent areas to understand the requirement of a portable measuring instrument to check the drinking water quality. In the second phase, an *in-situ* measuring device was designed and fabricated. Prototype design consists of a detector unit, sample preparation unit and a controller unit, peristaltic pumps, solenoid valves used to control the water flow and the accurate volumes for sample mixing. Algorithms were developed based on the Beer–Lambert law of absorbance principle. SPADNS reagent was used for fluoride detection while complexometric titration was automated for the detection of hardness. Using the invented system, the ground water samples of the CKDu prevalent areas were tested.

The results of the questionnaire survey showed that 63% of the people do not use an instrument or laboratory tests to check the quality of their drinking water. Ninety four percent of the community is willing to use a method which gives results within a short period of time and 90% prefers to have an economical real time *in-situ* method which guides them whether to consume their well water for drinking. Further the results showed that the reasons for not testing their drinking water are mainly associated with the poor transportation facilities and poor knowledge of the severity of the problem they face. Therefore, the need of a real-time *in-situ* measurement of selected water quality parameters through automated colorimeter was investigated and *in-situ* measuring device was designed and fabricated to measure fluoride and hardness of well water. Simultaneously conducted laboratory tests revealed that the measurements of water quality parameters are accurate. The test results showed that 70% of the samples exceed 180 mg L^{-1} limits of hardness and 10% samples were above the fluoride concentration of 1.0 mg L^{-1} stipulated by SLS 614: 2013. However, 70% of samples show that the fluoride concentrations are in the range of 0.5 mg L^{-1} and 1.0 mg L^{-1}. Thus portable system invented eliminates the handling of expensive chemicals based on flow analysis while it consumes less volumes of water samples and reagents than those of the APHA laboratory testing method. However, the critical challenge is to educate the authorities about the need of equipping rural communities with techniques to check their well water quality periodically at a reasonable cost.

Keywords: Real time *in-situ*, automated colorimeter, CKDu, fluoride, hardness

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IMPACT OF AGRICULTURAL PRACTICES ON WATER QUALITY IN BADULU OYA CATCHMENT AREA IN SRI LANKA

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Impacts of agricultural practices on surface water quality is currently given special attention since the safe and ample supply of freshwater is a fundamental right of humans and a need for the sustainability of functioning of ecosystems. With the complexity associated with such influence, holistic approaches incorporating physical, chemical and biological parameters into account are more appropriate when determining stream health, rather than the conventional water quality monitoring programmes. Badulu Oya, a sub-catchment of Upper Mahaweli Catchment area, is one of the highly affected watersheds by intensive agricultural practices. However, empirical evidence of catchment influenced on stream health is lacking for Badulu Oya catchment. Therefore, the present study was aimed at evaluating the impact of the use of agricultural lands on physical habitat quality, water quality and macroinvertebrate indices of streams in the catchment.

Ten second and third order tributaries of Badulu Oya which drain through microcatchments with varying degrees of agricultural land cover were selected for the study. Percentages of agricultural land cover within micro-catchments were estimated using supervised classification of Landsat^{TM} Satellite images. Analysis of physico-chemical water quality parameters, such as temperature, pH, electrical conductivity, TS, total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD), alkalinity, nitrate-N, nitrite-N, ammonia-N, PO_4^{3-}, SO_4^{2-}, stream embeddedness and benthic invertebrate was done for samples collected at each sampling location from August 2014 to July 2015. Channel Quality Index (CQI) and Riparian Quality Index (RQI) were calculated to determine the stream physical habitat quality. Standard multiple regression analysis was conducted to determine the relationship among catchment scale percentage of agricultural lands, water quality and macroinvertebrate indices. The results indicated that stream physical habitat quality, water quality parameters and macroinvetebrate indices are significantly ($p < 0.05$) affected by catchment scale percentage of agricultural land cover. Among the water quality variables tested, NO_2^--N, NH_3-N, and PO_4^{3-} levels in sites with higher percentage of agricultural land cover exceeded the Sri Lankan standards for drinking water quality and PO_4^{3-} level in those sites exceeded the proposed ambient water quality standards for inland waters in Sri Lanka for aquatic life and for irrigation purposes. Macroinvertebrate family richness and total abundance were prominently influenced by the extent of catchment scale percentage of agricultural lands. Hence, they could be considered as better predictors for short term impacts triggered by land disturbances in the given catchment. Findings of the present study suggest that catchment scale interventions are crucial for the management of Badulu Oya watershed, and for the improvement of water quality and sustainable agricultural production.

Keywords: Badulu Oya, water quality, macroinvertebrate indices, intensive agricultural practices

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ASSESSMENT OF NATURAL RADIOACTIVITY IN MARINE SURFACE SEDIMENTS OF NEGOMBO LAGOON

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Study of natural and anthropogenic radio nuclides in the marine and coastal ecosystems of Sri Lanka is significantly important for tracking and assessing the associated radiological risk as well as any pollution inventory in the environment. Both natural and artificial radioactive materials present in the sediment of the Negombo Lagoon were determined using Germanium gamma spectrometry. Twenty seven (27) samples from the upper 5 - 10 cm sediment layer were collected at 1.0 km intervals along the lagoon bank in March 2015. The hydrographic parameters of lagoon water which lead to the association and transport of radio nuclides in the adjacent environment were also measured. The water temperature, pH, TDS, conductivity and salinity were determined at 5-10 cm below the depth of air-water interface. The conductivity of the water varied from 13.6 mS cm^{-1} to 55.4 mS cm^{-1} and the salinity varied from 7.2×10^{-6} µ L^{-1} to 32.1×10^{-6} µ L^{-1}. The average temperature and average pH of the water were 28.7 °C and 7.6, respectively. The grain size analysis showed that the sediment samples containing 61% sand (0.25 mm – 2.0 mm particle size), 31% fine sand (0.25 - 0.063 mm particle size) and 1% fine slit + clay (< 0.063 mm particle size). The mean radioactivity concentrations were found to be 24 (± 4), 67 (± 9), 181(± 10), 59 (± 8), 3.5 (± 0.4) and 0.47 (± 0.08) Bq kg^{-1} for ^{238}U, ^{232}Th, ^{40}K, ^{210}Pb, ^{235}U and ^{137}Cs, respectively. The mean absorbed dose rate in air, radium equivalent activity, external hazard index, annual gonadal dose equivalent and annual effective dose equivalent were 60.8 nGy h^{-1}, 137.3 Bq kg^{-1}, 0.4 Bq kg^{-1}, 425.3 µSv year^{-1} and 74.6 µSv year^{-1}, respectively. The outdoor air absorbed dose rates due to terrestrial gamma rays for sediment have been calculated because of the nearby fishing, agricultural and domestic areas. The radium equivalent activity, external hazard index and annual gonadal dose equivalent were calculated to assess the radiological hazard of sand mixed with sediment since sand is used as construction materials in this region. The annual effective dose equivalent was slightly higher than that of the world average, 70 µSv year^{-1}. Therefore, it is apparent that the health effects due to natural radiation from the sediment of the Negombo lagoon are low, and thus, health hazards are insignificant. This study can be used as a baseline for future investigation, and the data obtained in this study may be of used for natural radioactivity mapping.

Keywords: Radioactivity, sediments, gamma spectrometry

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PRELIMINARY FIELD DATA OF DISSOLVED OXYGEN PROFILES IN PADAVIYA RESERVOIR, SRI LANKA

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Dissolved oxygen (DO) concentration is one of the most important physicochemical parameters in aquatic systems that could significantly influence the overall quality of water. Dissolved oxygen profiles describe the variation of DO concentration along the gradient of the water column. Understanding the variation of DO in aquatic systems is important as it relates to other chemical characteristics of the system. Although DO profiles of lentic systems in other countries have been extensively studied, similar studies of reservoirs of Sri Lanka are limited. Therefore, the present study focused on the DO distribution in the Padaviya reservoir in the North Central Province of Sri Lanka. A preliminary study was carried out on 23rd January 2016, at 25 locations covering the entire reservoir using a field portable DO meter equipped with a probe having a 20 m cable. The probe was deployed to water body and data were collected at two feet depth intervals. According to field data, the average DO value at the surface of the reservoir was 8.1 ($\pm$ 1.0) mg L^{-1} and varies in the range of 9.2 to 4.6 mg L^{-1}. The maximum surface DO concentration was observed at the middle section of the reservoir which has an average depth about 8.84 m and the minimum surface DO concentration was observed at the two water inlets of the reservoir which were shallow. The results suggest that the system contains a clinograde type DO profile with steep decline of DO after 4.57 m in Padaviya reservoir. The epilimnion, the upper most water column of the reservoir, had a DO value of $\sim$ 8.1 mg L^{-1} and the hypolimnion, the bottom stratum of the water column, exhibits anoxic condition. The most important observation was the abrupt DO depletion between approximately 4.57 to 5.18 m. At this depth, DO values decreased from $\sim$ 6.5 to $\sim$ 0.4 mg L^{-1} within 0.61 to 0.91 m. This phenomenon could not be satisfactorily explained with the current data. It could be assumed that DO is consumed by the aerobic microbial mediated oxidation of organic matter and by the oxidation of chemical species such as Fe^{+2}, Mn^{2+} and NO_2^-. Further studies are underway with more data to explain these oxygen profiles in the Padaviya reservoir.

Keywords: Dissolved oxygen, Padaviya reservoir, clinograde

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EXPOSURE ASSESSMENT AND GROUNDWATER QUALITY IN PADALANGALA DIVISION, SRI LANKA

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The present study was conducted to assess both *in-situ* and laboratory analysis of pH, salinity, conductivity, total dissolved solids (TDS), hardness and nitrate (NO_3^-) in an Agricultural area in Padalangala, which is located in the Embilipitya administrative division Sri Lanka. Water samples ($n = 20$) were collected from common groundwater sources which were used for drinking water and for other purposes. Sampling was carried out during the dry season of July 2015. Water pH and conductivity were measured on site using water quality meter (YSI 85), and TDS was measured using TDS meter (HANNA HI9835). Water hardness, salinity and NO_3^- were measured by the EDTA titrimetric method, $AgNO_3$ titration method and spectrophotometric method, respectively. A questionnaire based field survey was conducted to collect data for the risk assessment model, to evaluate Total Hazard Quotient (HQ) and Odd Ratio from 20 families. Salinity level [500 ($\pm$ 200) mg L^{-1}] in 19 wells out of 20 exceeded the highest desirable level of 200 mg L^{-1} given by BOI drinking water quality standards. In all the wells, conductivity of 347.9 ($\pm$ 145.5) $\mu S\ cm^{-1}$ and total dissolved solid of 174.1 ($\pm$ 72.9) mg L^{-1} were recorded, which were lower than the highest desirable levels. Hardness of one dug well located near the paddy field (404 mg L^{-1}) exceeded the highest desirable level of 200 mg L^{-1}. It was recorded that 19 families use dug wells, and one family uses a tube well. Non-carcinogenic effects, such as high blood pressure, diabetes and asthma, were observed in six persons from six families are still on the survey. Odd ratio value for non-carcinogenic effects for males and females did not exceed the limit of 1 and the values were 0.52 and 0.47, respectively. Even though NO_3^- concentration 0.50 ($\pm$ 0.19) mg L^{-1} did not exceed the highest desirable level of BOI, it was observed that the quotient values of non-carcinogenic effects exceeded the unity criteria of the risk 1×10^{-6} for males (1.3×10^{-1}), females (1.4×10^{-1}) and children (2.2×10^{-1}), respectively.

Keywords: Groundwater, nitrate, hazard quotient, odd ratio

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JUSTICE FOR THIRST: WILL THE WORLD'S NEXT WAR BE FOUGHT OVER WATER?

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Two world wars and a large number of major revolutions, along with significant social, political and economic upheavals have made changes of great importance in a historical and military sense among all the countries of the world. Most wars are fought over issues, such as territory/boarder disputes, political dignity, glory, power and for resources such as petroleum. Over the years, armies have been mobilized and blood has been shed over everything due to tragic misunderstandings. However, an outstanding feature among all these wars was that the issues did not affect every individual around the world. But a new issue has now emerged which has an equal influence on all humans. That is water shortage or water crisis. Since water is central to all human activities, including survival, no state can allow its water resources to be compromised. Therefore, in a world of squeezed water supply, a rhetoric question arises as to whether states would go for war to protect their access to water. On that backdrop, the objectives of this study were to understand the root causes for the water crisis, how it could lead to a water war, to analyze and suggest refinements to several water policy themes and issues and to outline the role of states to bring back justice for all water users. This research followed a legal research methodology based on secondary sources (mainly the Internet). Furthermore, this study intends to seek out water laws, human rights implications and water management tools used by different countries over the world to overcome this crisis.

This study revealed that, throughout history, there had been conflicts over water from time to time across national boundaries in order to expand power and glory rather than due to scarcity of water. However, the main reason why the world faces a water crisis today is primarily due to mismanagement of water resources. Unlike petroleum, a majority of the countries had access to water resources and no state attempted to protect them. This paradigm has changed, and now, water is increasingly in short supply because of growing demands from agriculture, population increase and energy production. In addition, climate change and pollution have reduced the availability of potable water and created an imbalance between demand and supply. Thus Middle East, North Africa and South Asia are in a vulnerable stage to experience water shortages over the coming years because of decades of bad management and overuse. Immediate steps have to be taken before the situation gets worse and states should start to protect the remaining water resources. This study recommends that states should prioritize new water management systems to meet the ongoing issues and adopt new strategies and promulgate laws and punishments to ensure strict adherence to minimize misuse and abuse of water.

Keywords: Conflict, legislations, water crisis, water rights, water management

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EFFECT OF SOIL MOISTURE ALTERATION BY ANTHROPOGENIC ACTIVITIES ON MAJOR SOIL PROPERTIES OF MUTHURAJAWELA MARSH

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The Muthurajawela marsh is a marine wetland system identified in the Directory of Asian Wetlands as one with an international importance. The marsh floor is mainly comprised of partially decomposed organic matter, peat. The soil in the periphery of the marsh therefore contains high amounts of soil organic matter (SOM). High soil organic matter contents attribute the wetland with a high water holding capacity and a high cation exchange capacity (CEC). The high water holding capacity serves in flood attenuation during the rainy season and helps to reduce the damage to the hinterland. The high CEC makes the marsh a potential waste dumping site that can hold heavy metals, cations and acids in industrial effluents. The CEC also enables the marsh to act as a buffer that retains the excess acidity within the soil, thereby preserving the ground water pH.

The present study was done to investigate the effect of soil moisture content on SOM degradation in the peripheral regions of the marsh. The study was conducted in two phases. For both phases, sampling was conducted around Pamunugama area closer to Muthurajawela Sanctuary in April 2015. In the first phase selected soil properties (soil moisture content, soil organic matter content, and soil pH; both active and exchangeable pH) were directly characterized. In the second phase, the soil moisture contents were controlled at specific values (25%, 50% and 65%) and soil samples were characterized for 12 weeks to study the influence of soil moisture levels on soil properties. The results from the first phase showed a marked variation of soil properties over the study area. The results observed included a moisture content of 12.61% to 164.56% (by dry weight) and 20.89% to 92.10% (by wet weight), an organic matter content of 5.06% to 59.78% (by dry weight), a total CEC of 44.00 to 696.00 meq per 100 g of soil, an active soil pH of 2.10 to 7.91 and an exchangeable soil pH of 2.08 to 7.26. The model study showed that the SOM degradation increases with decreasing soil moisture levels through time. It was also observed that the decrease in SOM was associated with a decrease in CEC. Furthermore, it could be observed that the soil pH increased with decreasing soil moisture contents and soil organic matter contents.

The wide variation seen in the results of first phase is indicative of the extent of anthropogenic influence on the wetland soil. The model study evidently indicated that the moisture content has a significant influence on the organic matter content of the soil. This clearly affects the soil properties that link to the organic matter content, such as CEC, soil pH, which in turn influence leaching of contaminants into water sources in the hinterland. This, in the long run, will compromise the ability of the marsh soil to buffer the ground water that aids in preserving the ground water pH. Hence, the end effect would be pollution of the natural water sources around and this would lead to health issues in inhabitants consuming them.

Keywords: Muthurajawela marsh, organic matter, moisture content, cation exchange capacity, CEC

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VOLATILE ORGANIC COMPOUNDS AND LEACHATE QUALITY FROM DIFFERENT LANDFILLS IN SRI LANKA

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Landfill leachate contains many pollutants which may create potential environmental and health impacts related to groundwater and surface water contamination. Among many different pollutants such as heavy metals, nutrients, biological oxygen demand (BOD) and chemical oxygen demand (COD), volatile organic compounds (VOCs) are toxic, carcinogenic, mutagenic and/or teratogenic and found in municipal solid waste dump sites. Although there are hundreds of open dump sites in Sri Lanka, no study has focused on the fate of VOCs.

This study aimed to understand the characteristics of leachate focusing mainly VOCs in Dambulla, Kurunegala and Gohagoda dump sites located in different climatic zones. The static headspace gas chromatography coupled mass-spectrometry (GCMS) was enabled with respect to EPA 524 method for VOCs in leachate analysis. In addition, samples collected were subjected to general water quality parameters, such as pH, electric conductivity (EC), dissolved oxygen (DO), and suspended solid, biological oxygen demand (BOD_5), chemical oxygen demand (COD), anions (NO_3^-, NO_2^-, PO_4^{3-}, etc.), and heavy metals (Mn^{2+}, Fe^{2+}, Pb^{2+}, etc.). The pH, EC, DO and BOD_5 were measured by electrochemical techniques while COD and anions were measured by colorimetric determination. In addition, heavy metals were analyzed by atomic absorption spectrometer.

The GCMS quantitative results showed that the number of VOCs detected at higher levels in the wet zone (Gohagoda) dump site, moderate and low in the dry (Dambulla) and intermediate zones (Kurunegala), respectively. The concentrations of total VOCs, for the site of Dambulla (290.0 µg L^{-1}) were higher than those of the others. Toluene was the most frequent VOC in dump sites except intermediate zone and the highest toluene concentration of 586.5 µg L^{-1} was recorded in the dry zone dump site whereas wet zone depicted an average value of 9.0 µg L^{-1}. Among the VOCs quantified in the wet zone, 4-isopropyltoluene had the highest average concentration of 83.5 µg L^{-1} during the sampling period. General leachate quality results exhibited that most of the pollutants exceeded the maximum tolerance limits of the Central Environmental Authority (CEA) standards. In addition, all three sites exceeded the COD and BOD_5 effluent standards. Gohagoda dump site showed the highest COD value of 11460 mg L^{-1} whereas the dry zone dump showed the lowest value of 340 mg L^{-1}. Recorded PO_4^{3-} level of the intermediate zone dump was high (38 mg L^{-1}) and the sequence of dry and wet were extremely low (7.78, 2.67 mg L^{-1}). Reported concentrations for metals were higher in the wet zone and the highest recorded value for Mn^{2+} was 3.95 mg L^{-1} at Gohagoda dump site. The physicochemical characteristics denote the importance of site-specific leachate pollution control techniques to minimize environmental damage.

Keywords: Volatile, landfills, leachate, organic

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COMPARATIVE STUDY OF WELL WATER AROUND AND WITHIN VENIGROS RUBBER GLOVE FACTORY AT RATHUPASWALA, GAMPAHA DISTRICT, SRI LANKA

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Well water is the main drinking water source although municipal water supply is available in some urban areas of Sri Lanka. It is a well-known fact that some areas of Gampaha district are having a low pH in ground water. The Venigros Rubber Glove Factory in Rathupaswala was started in 1998 and closed at the end of 2013, mainly due to the water quality issues of the area. The present study aims to find out the effects of this latex factory on the quality of well water in Rathupaswala area.

The present study started in 2013 and is an ongoing program as of July 2016. Samples were collected from 7 wells within the premises of the glove factory and 10 wells around the glove factory including 2 reference wells located 4 km away from the factory. The following water quality parameters were tested in order to find out the effects of treated wastewater discharged to the natural environment from the latex factory; electrical conductivity (EC) (Electrometric APHA, 2510B method), pH (Electrometric APHA, 4500-H^+B method), temperature (Thermometric APHA 2550 B method), Chloride as Cl^- (Titrimetry APHA 4500 Cl B method), Phosphate as PO_4^{3-} (spectrophotometry APHA 4500 PE method), Nitrate as NO_3^- (spectrophotometry APHA 418 D), Sulphate as SO_4^{2-} (Turbidimetry APHA 4500 SO_4^- E method), Zinc as Zn^{2+} (APHA 3111 B method) and Copper as Cu^{2+} (APHA 3111 B method). According to results obtained up to 2015, the majority of the parameters measured were within the guideline values for drinking water issued by the Sri Lanka Standards Institute (SLSI). However, the pH values of well water within the latex factory were between 5.2 to 6.8 and well water around the latex factory was between pH 3.6 to 5.9. Therefore, the study highlights the importance of continuation of the study in order to confirm the present results because people in this area still use well water as their main water source.

Keywords: Well water quality, pH, Gampaha district

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DETERMINATION OF CORRELATION BETWEEN APOPTOSIS AND TOXIN RELEASE IN THE CYANOBACTERIUM *Microcystis aeruginosa*

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Cyanobacteria are a diverse group of aquatic photosynthetic prokaryotes and under positive conditions they produce potent cyanotoxins which cause numerous livestock and human poisonings. Cell death can be accomplished by several mechanisms all of which have some characteristics of a regulated program. Apoptosis is a process of programmed cell death (PCD) which is mediated by the enzymes caspases which can be induced by physiological stresses like phosphorus and iron starvation, high irradiance and oxidative stress. Metacaspase (MCAs) has similar homology sequences to caspases and is identified in prokaryotes including cyanobacteria which play a major role in prokaryotic PCD. Understanding the cell death in cyanobacteria is important and as such the purpose of this study was to determine a relationship between apoptosis and toxin release in the cyanobacterium *Microcystis aeruginosa*.

Experiments were carried out with *Microcystis aeruginosa* culture; *Microcystis aeruginosa* bl (FU051239) was isolated from Beira Lake, Colombo, Sri Lanka. For molecular analysis, DNA was extracted with standard CTAB Method and DNA amplifications were carried out to confirm the presence of the peptidase C14 domain (meatacaspase gene) and microcystin producing gene (*Mcy E*) with universal primer pairs (UCA-F/UCA-R) and HEPF/HEPR respectively.To evaluate the relationship between oxidative stress and PCD, artificial induction of PCD was done by introducing 1.5×10^4 cells mL^{-1} into two different concentrations of hydrogen peroxide (H_2O_2) as1.5 M (A) and 0.5 M (B). Evaluation of the live and dead cells in H_2O_2 treated samples and controls in BG11 medium (C) were determined with the aid of fluorescence microscope and MTT assay. According to the microscopic observations, the number of dead cells gradually increased with the duration of incubation period and the concentration of H_2O_2. The numbers of dead cells after one hour were 115, 111 and 20 for A, B and C respectively. After six hours, the readings were A-5444, B-4333, C-333 and finally after 24 hours A-7556, B-5889, C-444 from an initial live cell concentration $\sim 1.5 \times 10^4$ cells mL^{-1}. According to the MTT assay, absorbance was determined at 560 nm. Initial readings were A-0.030, B-0.034, C-0.018, after six hours incubation A-0.012, B-0.037, C-0.021 and after 24 h incubation A-0.008, B-0.038, C-0.140. In toxin (microcystin) quantification, commercially available microcystin standards (0.25, 1.0, 2.5 ng mL^{-1}) were used to plot a standard curve by measuring absorbance at 230 nm. According to the standard curve, the amount of microcystin secreted by H_2O_2 treated samples at 230 nm was calculated. Microcystin concentrations (ng mL^{-1}) at the initial stage were A - 659.71, B - 656.17, C - 641.18, after six hours of incubation A - 986.32, B - 947.07, C - 632.04 and after 24 h of incubation the values were A - 991.39, B - 956.63, and C - 649.29, respectively. According to the results, artificial induction of PCD by H_2O_2 has shown a positive correlation with protein damaging activities in *Microcystis aeruginosa* bl as well as with the release of cyanotoxin, microcystin.

In conclusion, chemical stressors such as H_2O_2, induce oxidative stress on cyanobacteria which results in PCD and a concomitant release of cyanotoxin into the environment.

Keywords: Apoptosis, *Microcystis aeruginosa,* toxin

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AN ASSESSMENT OF WATER QUALITY AND SUITABILITY FOR VARIOUS USES OF BENTOTA ESTUARY IN SRI LANKA

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In an effort to develop a water quality management plan for Bentota estuary in Sri Lanka, eight water quality variables were measured at eight selected sites from upstream to downstream in the estuary over a period of six months. Water quality data collected were evaluated using a Water Quality Index (WQI) technique to indicate its quality in terms of index number for easy understanding (0 – poorest, 100 – excellent). WQI converts the analytical data of eight parameters into five quality classes ranging from "poor to excellent" against the proposed ambient water quality standards for bathing and protection of aquatic life. During the study period, parameters tested were compared against the bathing category, and it was observed that the Fecal Coliform (FC) exceeded the standards at all times (100%, FC.) and other parameters occasionally exceeded the standards. The parameters that complied with the standards were NO_3^- and PO_4^{-3}. The calculated WQI values of 35 to 50 for Bentota indicates that the water quality of stream belongs to "very poor to poor" range for bathing. When the parameters tested were compared against the fishes and other aquatic life protection category, it was observed that the COD recorded the highest values and some parameters occasionally exceeded the standards. All other parameters complied with the standards. The calculated WQI values for Bentota estuary ranged from 76 to 92 indicating the estuary water quality within "good" for the protection of fish and other aquatic life. The most upstream parts of water body showed the best water quality rating with significant decreases towards the downstream and the poorest water quality rating recorded at station No 6. Water quality was significantly impacted by illegal construction activities, such as hotels and houses, storm water discharges, solid waste dumping and discharge of treated and untreated wastewater, mostly from the hotels and related activities. High COD and FC levels are of particular concern at the majority of the sites investigated.

Keywords: Water quality index, parameters, fecal coliform

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LITTLE EGRET FEATHERS AS A BIO MONITORING TOOL FOR MERCURY IN AQUATIC ECOSYSTEMS OF SRI LANKA

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The diet of Herons and Egrets (family Ardeidae) mainly consists of piscifauna and they represent top trophic levels of aquatic ecosystems. As a result, they can potentially accumulate heavy metals which are non-biodegradable and can be used as a bio-monitoring tool to investigate contaminant levels in aquatic ecosystems. By analyzing metal concentrations in different tropic levels and potential source of heavy metals, one can determine the metal accumulation pattern in an aquatic food chain.

Little Egrets (*Egretta garzetta*) were selected as a model organism in the present study, since they are widespread and occupy higher tropic levels in food chains. To assess the bioaccumulation patterns, mercury concentration was assessed in feathers, regurgitated materials of Little Egrets and water collected within the foraging areas at five heronries from three districts of Sri Lanka (Anuradhapura, Kandy and Gampaha) which are in three different climatic zones. The study was carried out from May to August 2015.

Mercury levels were reported with significant variations in water, regurgitated materials and feathers of Little Egrets ($p < 0.05$). Mercury concentration in water was significantly high in Kadugannawa heronry in Kandy district ($p < 0.05$), whereas it was significantly high in regurgitated materials that were sampled from heronry at Anuradhapura CTB depot ($p < 0.05$). Feathers sampled from Jaffna Junction site at Anuradhapura had the highest level of Hg concentrations (3.81 mg L^{-1}). By analyzing the accumulation pattern of Hg from water to feathers through their prey, it was observed that Hg concentration in feathers was significantly higher than that in water and regurgitated materials in all sites ($p < 0.05$). However there was no significant variation between the Hg concentration of water and regurgitated materials. According to the field observations, the nestlings spend 7-8 weeks at the nest and depend on food brought by their parents within 1-2 km radius from the heronry. These food chains that are formed during the breeding seasons of Egrets represent contaminant levels with spatial and temporal restrictions. Thus, Little Egret feathers can be used as a potential biomonitoring tool for Hg contamination and a clear pattern of bioaccumulation is also evident in this system.

Keywords: Little Egret, bioaccumulation, feathers, regurgitated materials

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DEVELOPMENT OF A COLOR ANALYTICAL DEVICE FOR FLUORIDE USING SMART DEVICE

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Fluoride pollution in drinking water has been one of the serious environmental problems in Sri Lanka. Hence, the need for developing a simple analysis for fluoride is desirable. Colorimetry is one of the effective on-site analyses, because it does not require analytical instruments for the determination of sample concentrations. However, this method causes individual differences of analytical results, because of the errors in judgment of concentration by color contrast. Recently, portable type analyzers have been developed. However, analytical cost increases with the introduction of analytical devices. In the present study, a simple color analyzer for fluoride using a smart device was developed. The proposed method consists of an original attachment and application software. Using the proposed method, the color data of a sample photo can be converted to sample concentrations. The reagent from a commercial pack test for fluorine colorimetric test based on Lanthanum Alizarin complexson is added to 2.0 mL of sample. After dissolving the reagent, the solution was added to a plastic cell. The cell was set to a dedicated cell folder mounted on the smart device. After 10 min, cell folder was capped with cover part, and the fluoride concentration was determined by measuring the v using original application software which automatically converts the discoloring of sample to concentration. As a result, 0.5 to 1.5 mg L^{-1} of fluoride could be determined in the proposed method. In addition, the same result was obtained under several irradiation conditions. Using the original attachment, the sample cell is fixed on the camera of the smart device and screen light of the smart device can act as the light source. Therefore, a photo of the sample is taken under the same conditions of position and irradiation using the original attachment. Furthermore, analytical data can be easily mapped in a wide range of field analysis in combination with application software of GPS and Map.

Keywords: Smart device, attachment, application software, screen light, mapping

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IMPROVED UNDERSTANDING OF WATER QUALITY PARAMETERS TO SUPPORT A MULTI-STAKEHOLDER WATER SAFETY APPROACH FOR THE MANAGEMENT AND CONSERVATION OF KELANI RIVER BASIN

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Kelani River Basin provides water to millions in Greater Colombo area which is the home for 25% Sri Lankans. It also provides water and environmental services for over 10,000 industries with about 2,000 industries registered with the Central Environmental Authority for pollution control. The river water quality is challenged by industrial, urban, agricultural and domestic pollution. Balancing the socio-economic development that involves employment opportunities and ensuring the safety of drinking water is a challenging proposition that require cooperation of agencies with different mandates and experts. In 2015, Central Environmental Authority (CEA), International Union for Conservation of Nature and Natural Resources (IUCN) and United Nations Children's Fund (UNICEF) joined hands with over 50 agencies to develop a medium to long-term initiative, named "Kelani River Basin Multi-Stakeholder Partnership (KRMP)".

To support the development of KRMP a number of studies on water quality were conducted using the CEA and National Water Supply and Drainage Board (NWSDB) collected water quality data during the period from 2009 to 2015. This paper covers the results related to biological oxygen demand (BOD), chemical oxygen demand (COD), turbidity, nitrate nitrogen (NO_3^- -N), phosphates and total coliform. Violations or exceedance of the concentrations of parameters compared to CEA standards were computed. Pollutant loads for turbidity, nitrate-N, phosphate and total coliforms at Hanwella and Seethawaka monitoring stations were determined. Water quality at Hanwella indicated a high level of pollution in terms of BOD and dissolved oxygen. COD related metal pollution issues have been identified at Seethawaka.

The five-year estimates of pollution loads, using the US-Army Corps of Engineers FLUX Model indicated that 66 metric tons of nitrate-N load per annum were obtained at the Hanwella Bridge monitoring station, with about 300 kg of nitrate-N loads in the months of June, October and November. Similarly, the average annual turbidity load that passed by Seethawaka and Hanwella monitoring stations were 1,604 and 2,329 metric tons, respectively. These water quality observations strengthened the KRMP planning and implementation design on land use management and water quality monitoring. The methods used in this study could be replicated in other river basins to minimize land degradation and pollution control.

Keywords: Water, pollution, turbidity, nitrogen, Kelani

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DEVELOPMENT OF WATER QUALITY MEASUREMENT APPLICATION

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Fluoride in ground water has become an environmental problem in many parts of the world. It has become important to understand the distribution of fluoride in ground water and to take necessary remedial measures to assure human health. As the extensive surveys and analyses are not cost effective, alternative methods such as Android application for detecting the fluoride in ground water could become a better solution. Therefore "Android device" was developed for easy measurement of fluoride in groundwater which can be done with the help of a smartphone or a tablet. In this application, fluoride present in water is obtained by measuring the density of water. This measure the density based on the change in color by a pack test. As for the pack test, the color changes by the density of fluoride. When the density is low, it is pink and when it is high, it is blue. Furthermore, when the fluoride level is measured using an Android device, the location also can be marked with the help of built in GPS. Thus fluoride distribution map can be obtained in all the areas. From these results, it is possible that this application may work enough in investigating a cause of the fluoride pollution of the well water.

Keywords: Fluoride, smartphone, tablet, GPS

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POTENTIAL ROLE OF CHLORIDE ION IN DRINKING WATER ON CHRONIC KIDNEY DISEASE OF UNKNOWN ETIOLOGY (CKDu) IN THE DRY ZONE OF SRI LANKA

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We compared the levels of some selected ions in deep drinking well water of chronic kidney disease of unknown etiology (CKDu) affected households compared to non-affected households in the same geographical area. Karagahawewa in Talawa, Anuradhapura District which has a high prevalence of CKDu was selected for sampling. Five houses with recognized CKDu patients and another 5 houses without any record of CKDu were selected. The inhabitants of both groups obtain drinking water from their own wells for over 10 years. Water samples from wells were collected monthly for 6 months from January to August (except in February and April). The content of fluoride (F^-), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), bicarbonate (HCO_3^-), chloride (Cl^-), sodium (Na^+) potassium (K^+), and calcium (Ca^{2+}) were analyzed. The mean monthly concentrations of ions were compared between the two groups and a *p*-value of less than 0.05 was considered statistically significant.

Except HCO_3^-, all other ions were high in the CKDu group than the non-CKDu group in each month for which the water samples were tested. However, the differences in the concentration of F^-, PO_4^{3-}, SO_4^{2-} and Ca^{2+} ions were not statistically significant in any month during the study period. During May, the concentration of K^+ ions was significantly high in CKDu (2.22 mg L^{-1}) samples compared to the control group (1.75 mg L^{-1}). The concentration of Na^+ ions in June, July and August in the CKDu group (105.80, 76.4, 72.2 mg L^{-1}) was significantly higher than in the control group (71, 30.2, 40.4 mg L^{-1}). The concentration of Cl^- ions was significantly high in CKDu samples except in August. The concentrations of Cl^- ions in January, March, May, June and July were 1292, 818, 806, 836, 639 mg L^{-1} in the CKDu group and 757.8, 552, 533, 607, 492 mg L^{-1} in the control group, respectively.

It appears that at least Cl^- could play a role in CKDu. The ionicity in drinking water in the area keeps changing during the study period that could have some relation with the water levels. It would be interesting to study tubular changes in immature kidneys when Cl^- rich water is regularly fed.

Keywords: Chronic Kidney Disease of unknown etiology, chloride ions, Sri Lanka

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GROUNDWATER DEVELOPMENT OF COASTAL LENS AQUIFER USING INFILTRATION GALLERIES AT POINT PEDRO AREA IN JAFFNA DISTRICT

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The development of Point Pedro Water Supply Scheme (WSS) has indicated the significant importance due to the complex hydrogeological setup and the water demand of 4000 m^3 day^{-1}. The main challenge was to cater high water demand under the complex hydrogeological setup including the various geochemical limitations in this region. In this background, special attention was made to apply the most appropriate technical method for groundwater extraction. It was decided to construct infiltration galleries rather than using individual boreholes to exploit groundwater using the sand dune aquifer system located on the narrow land strip in between the lagoon and the sea. The sand dune aquifer acts as lens aquifer which is highly vulnerable for saline water contamination.

Prior to the construction of infiltration galleries, a detailed hydrogeological investigation was carried out to identify the most suitable locations. Accordingly, investigations were performed focusing the key components of electrical conductivity (EC) variation, shallow water level distribution, aquifer thickness and its characteristics and potential. Accordingly four infiltration galleries were constructed at the hydrogeologically most appropriate locations. The design of one infiltration gallery was consisted of a 3.0 m depth of central collective section and a horizontally laid, 100 m long two lateral screen pipes of 225 mm diameter at a depth of 2.5 m below the ground level.

Infiltration galleries skim water off the surface of the lens (thin aquifer formation), thus distributing the pumping over a wide area. This distributed pumping avoids the problems of excessive drawdown and creates possible minimum stress to the aquifer and minimizes consequent up-coning of saline water caused by localized pumping from individual wells. The drawdown can be considered as the most crucial hydrogeological factor that is needed to control while extracting groundwater under such complex aquifer setup. Therefore, this kind of distributed pumping system can be applied to minimize such excessive drawdown that helps to control saltwater up coning and also lateral inflow by long term water usage. Considering all facts discussed, it should be a priority to consider the appropriate technical method that is applicable in to extracting groundwater from the shallow lens aquifer of this area. Application of the infiltration galleries under these conditions will lead to obtaining a large quantity of water by accessing the hydrogeologicaly sensitive aquifer system in safer manner.

Keywords: Groundwater, aquifer, hydrogeological, electrical conductivity

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MODELLING OF GROUNDWATER QUALITY IN THE AREA AROUND RATHUPASWALA, GAMPAHA DISTRICT, SRI LANKA

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Industrialization followed by poor water quality management often creates certain environmental and health issues, especially in developing countries. Methods to assess spatio-temporal trends in water quality are essential for guiding adaptive management strategies for water quality remediation. The major objectives of the study were to investigate the impact of water quality in lateral variation of different underlying geological formations and formulate the geochemical model to explain the high acidity of the water bodies of the Rathupaswala area, where many public protests were made during the recent past.

Groundwater samples were collected from 62 drinking ground water wells of three traverse lines along different geological formations (sandy soil, peaty soil at Muthurajawela, laterite and crystalline rocks) from the sea to the land area and water quality parameters were assessed. Results revealed that parameters related to water quality degradation such as pH, electrical conductivity (EC), sulphate and nitrate were the most important contributors to the water quality variation in the study area. Principal component analyses (PCA) and factor analysis (FA) were used to identify parameters that were important in assessing spatial variations in water quality. A greater than 7 of pH values were observed for all the water samples towards the sea side and nearly 7 was recorded in the crystalline rock terrains towards landside whereas low pH values up to 5 were reported in the wells located in between two formations, where lateritic soil is the main underlying geological formation. Sulphate, nitrate concentrations and electrical conductivity values did not exceed the maximum permissible value of SLS drinking water standards but comparatively high EC values and sulphate concentrations were found in areas that are closer to the coastal areas. Significantly, the depth of the water table was un-characteristically high in the middle part of the traverses, which is identified as the area of Rathupaswala.

R Mode Factor Analyses identified three factors with eigen values summing to 83.4% of the total variance in the water quality dataset. Factor 1, which accounted for 43.0% of the total variance, correlated primarily with pH, EC and sulphate, implying typical "sea side" infiltration to the landside. Factor 2 explained 26.2% of the total variance with positive loadings on nitrates and depth of water table. This factor suggests "nutrient" pollution, which could be caused by anthropogenic sources such as excessive industrial effluents and/or domestic sewage discharged directly into the watershed without treatment and over pumping in the area. Water quality predictive model prepared based on the chemical parameters, statistical methods and underlying geological formations integrated with depth of the water table and pumping groundwater at 60,000 L day^{-1} from the glove factory shows the formation of a cone of depression, which could be recharged only by the infiltration of groundwater from surrounding peaty soils which has characteristically low pH values. The infiltration of acidic water could result in the formation of a low pH area in the Rathupaswala village. The results of this study help in the ongoing water quality remediation efforts by documenting trends in water quality across various land use zones in Sri Lanka.

Keywords: Water quality, Rathupaswala, factor analysis, modeling

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VARIATION OF ADSORPTION CAPACITIES OF DIFFERENT METAL IONS ON SELECTED ADSORBENTS

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Heavy metals, due to their highly toxic nature, cause severe problems to the ecosystem. Consequently, their removal from wastewater systems is essential for protecting the health of living beings and the environment. Natural substances which show adsorption properties deserve attention in this regard. Potential of natural substances found in their waste forms, such as rice husk, brick clay, coir dust and saw dust, in their natural sizes is investigated in this research towards the removal of heavy metals from simulated industrial effluents. The optimum time to reach equilibrium is determined to vary within $10 - 60$ min for all metal ions investigated; Cd(II), Cr(III), Cu(II), Pb(II), Ni(II) and Zn(II). Furthermore, the extent of removal of heavy metal ions shows its maximum at neutral pH for all metal ions, for all adsorbents investigated. As expected, at the optimized conditions, maximum adsorption capacities were in different ranges for different adsorbents for individual metal ion solutions: $800 - 5,000$ mg kg^{-1} for rice husk, $200 - 12,500$ mg kg^{-1} for brick clay, $10,000 - 97,000$ mg kg^{-1} for coir dust and $3,000 - 18,000$ mg kg^{-1} for saw dust, all of which fulfill the requirements of the Langmuir adsorption isotherm model. Ion-exchange would contribute to the removal of heavy metals by brick clay, where Ca^{2+}, Mg^{2+}, Fe^{2+} and Al^{3+} are exchanged with heavy metal ions. However, other natural adsorbents which contain hemicellulose, cellulose and lignin would show a different mechanism of metal ion removal involving complex formation between hydroxyl, phenolic and carboxylic groups with heavy metal ions, and electrostatic attraction. Significantly higher binding capacity of coir dust would be due to the presence of a large amount of cellulosic materials towards metal ions. Salient adsorption characteristics of coir dust over other materials are also due to the increase in porosity via deterioration of lignocellulostic compounds and opening of bonds during its formation under semi-anaerobic conditions which would contribute to elevated removal ability of coir dust. Furthermore, Pb(II), having the lowest hydrated radius among that of other metal ions investigated, shows the highest removal among all adsorbents investigated. Results of this study would be useful in designing systems consisting of different types of adsorbents for treatment of industrial effluents containing several metal ions. Investigation of correlation between porosity and surface area of each adsorbent with heavy metal ion removal ability is currently underway.

Keywords: Sorption, heavy metal, isotherm studies, adsorption capacity, natural adsorbents

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APPLICATION OF DYNAMIC ADSORPTION MODELS FOR REMOVAL OF NI(II) FROM FIXED BED COLUMN BY DRIED PEEL OF *Artocarpus nobilis* FRUITS

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Removal of toxic heavy metals from contaminated environmental samples by physical, chemical and biological methods has been attempted to overcome environmental and health problems. Most of the chemical methods which are currently applied for the removal of heavy metals are proven to be much costlier and less efficient than biosorption. Biosorption ability of varieties of plant-based materials, such as orange peels and peanut shells, has been investigated, and attractive results have been obtained. The aim of this research is to predict dynamic adsorption characteristics of the peel of the fruit of *Artocarpus nobilis*, a native plant in Sri Lanka. Linearized dynamic models, namely, the Thomas model, Adam's-Bohart model and Yoon Nelson model were applied on the extent of removal of Ni(II). When Ni(II) solutions were passed through glass columns of internal diameter 1.0 cm packed up to 10.0 cm height with particles of diameter 710 – 1000 µm at flow rates of 4.8, 6.6, 8.4, 12.0 and 16.0 mL^3 min^{-1}, regression coefficients in the range of 0.807 – 0.974 were resulted in, indicating the validity of all three models. The Thomas rate constant changes between 0.971 - 1.552 mL mg^{-1} min^{-1}, and the equilibrium uptake per gram of the adsorbent fluctuates slightly, while the rate constant of the Adam's Bohart model decreases with increasing flow rate. However, the saturation concentration of the Adam's Bohart model increases from 70 mg L^{-1} to 1960 mg L^{-1} with increasing flow rate. On the other hand, the rate constant of the Yoon Nelson model slightly fluctuates and the time required for 50% adsorbate breakthrough (τ) decreases with increasing flow rate. Furthermore, τ values determined from the Yoon–Nelson model and experimentally determined values are in good agreement. Determination of equilibrium and kinetics characteristics through the application of dynamic models could be helpful to extend laboratory findings to real applications.

Keywords: *Artocarpus nobilis*, flow rate, Thomas model, Adam's -Bohart model, Yoon Nelson model

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REMOVAL OF HEAVY METALS FROM LABORATORY WASTE WATER USING CLAY SOIL AS A NATURAL ADSORBENT

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Clay is a natural adsorbent that plays an important role in the environment as a removing agent of environmental toxin. The properties, such as high cation exchange capacity, high surface area and high availability, make clay a potentially useful adsorbent. As there are no reports available for laboratory wastewater management in Sri Lankan universities for treatment of heavy metals, the aim of this research is to develop a cost effective wastewater management system to remove heavy metals from laboratory wastewater using natural clay soil. In this study, soil samples were collected from a clay mining site for brick making purpose at Malwana area and they were characterized using different chemical methods. The moisture content of samples collected ranged from 33.34 ($\pm$ 0.25)% - 42.97 ($\pm$ 1.01)% (w/w) by dry weight. The soil pH ranged from 5.35 ($\pm$ 0.07) - 5.60 ($\pm$ 0.10), while the organic matter content ranged from 11.71 ($\pm$ 0.17)% - 12.02 ($\pm$ 0.29)% by dry weight and the cation exchange capacity ranged from 30.38 ($\pm$ 1.57) - 37.89 ($\pm$ 0.98) meq per 100 g of soil. From those soil samples, the Na^+ homoionic clay soil (the adsorbent) was prepared using the highest cation exchange capacity contained soil.

Single element batch experiments were carried out to determine the cation adsorption capacities of the adsorbent prepared for selected heavy metal ions; Pb^{2+}, Cd^{2+}, Cr^{3+} and Cu^{2+} from aqueous solutions as a function of initial metal ion concentration, contact time and solution pH. The adsorbent governed the maximum Pb^{2+} adsorption capacity at 3000 mg L^{-1} of initial Pb^{2+} ion concentration, three days of contact time and at pH 11.00. The same results were obtained for Cd^{2+} and Cu^{2+}. The adsorbent governed the maximum Cr^{3+} adsorption capacity at 2700 mg L^{-1} of initial Cr^{3+} ion concentration, three days of contact time and at pH 11.00. Metal ion adsorption increased with the rise of the above three functions. The order of adsorption of the ions in single-element system was $Cr^{3+} > Pb^{2+} > Cu^{2+} > Cd^{2+}$. Multi element batch experiments, carried out using mixed metal ion solution containing Pb^{2+}, Cd^{2+}, Cr^{3+}, Cu^{2+}, Co^{2+}, Ni^{2+}, Mg^{2+} and Ca^{2+} ions, showed a severe suppression of metal ion adsorption due to the competitive effect. Flame atomic absorption spectrometer was used to analyse metal concentrations and instrument detection limits for Cr, Pb, Cu and Cd were 0.01, 0.21, 0.01 and 0.003 mg L^{-1} respectively.

Na^+ homoionic clay soil (15.00 g) packed columns were used for column studies and 150 mL each of 1.9, 3.8 and 9.5 mmol L^{-1} of the above mentioned mixed metal ion solutions were eluted on clay soil packed columns. Almost 100% Cr^{3+} and Pb^{2+} removal efficiencies were shown in the 1.9 and 3.8 mmol L^{-1} solutions. Breakthrough volumes of 40.0 mL and 60.0 mL were detected for Pb^{2+} and Cr^{3+}, respectively, in 9.50 mmol L^{-1} solutions. The above column was successfully used to totally remove Cr^{3+} and Pb^{2+} ions from 30.0 mL of inorganic laboratory wastewater which contained 28.4 mg L^{-1} of Pb^{2+}, 6.9 mg L^{-1} of Cr^{3+} and other inorganic ions. A NaCl solution of 0.5 mol dm^{-3} was used to regenerate the columns for repeated use. Thus clay soil packed bed columns can be successfully used as a cost effective method to remove heavy metals from laboratory wastewater.

Keywords: Adsorption, clay soil, heavy metals, laboratory wastewater

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USE OF CHITOSAN BEADS FOR THE REMOVAL OF Cd (II) FROM WASTE WATER

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With the industrial revolution, the amount of metals used for industrial processes has increased. This led to an increase in the amount of waste containing toxic heavy metal ions. Cadmium is such a highly toxic metal that is released into the aquatic medium. In recent years, chitosan, a naturally abundant low-cost bio-adsorbent, has been recognized as an excellent metal adsorbent to remove heavy metals from waste water. As the maximum Cd(II) uptake by chitosan was observed at pH = 7, in this project, batch experiments were carried out at this pH at a temperature of 30 ($\pm$ 2) ºC to study the efficiency of cadmium adsorption onto physically modified chitosan; chitosan beads under different conditions, such as contact time, initial metal ion concentration, bead dosage and bead size. Furthermore, visual examinations of chitosan beads were conducted using scanning electron microscope. Isotherm experiments and kinetic studies have been done to find out the maximum adsorption capacity and the order of the reaction respectively. Fixed bed column experiments were conducted to study the practical usability of the adsorbent.

Optimal performance of chitosan beads were observed when initial Cd(II) ion concentration of the sample was 50 mg L^{-1} with a chitosan bead diameter of 1.11($\pm$0.02) mm (the smallest bead diameter used in the experiment), contact time of 150 min and chitosan bead dosage of 0.40 mg. Isotherm data for a range of initial metal ion concentration from 20 to 100 mg L^{-1} satisfied the Langmuir model with a R^2 value of 0.993. The Langmuir constant, q_0 (the amount of adsorbate adsorbed per unit weight of adsorbent corresponding to complete coverage of available sites) value obtained for adsorption of Cd on chitosan beads was 62.5 mg g^{-1}, which is considerably higher as compared to q_0 values for adsorption of cadmium on various other biomass types reported in the literature. The kinetic data were fitted with the pseudo second order model with R^2 values of 0.992 and 0.988 for initial Cd(II) concentrations of 30 and 50 mg L^{-1}, respectively. According to the results obtained from fixed bed experiments, the breakthrough time, and LUB (Length of Unused Bed) for the elution rate of 10 mL min^{-1} were 10 min and 4.6 cm, respectively, but for the elution rate of 20 mL min^{-1} the above values were 3 min and 5.1 cm respectively. However, results obtained by the experiments reveal that chitosan beads are more efficient as compared to a number of alternative low-cost natural adsorbents reported in purifying water samples contaminated with Cd(II).

Keywords: Cadmium, chitosan beads, adsorption capacity, fixed bed column

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REMOVAL OF Cd(II) FROM DRINKING WATER USING ACTIVATED CARBON PREPARED FROM NATURAL WASTE MATERIALS

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Pollution of drinking water sources by heavy metals is a serious threat to terrestrial and aquatic organisms because some of these metals, such as cadmium, are potentially toxic, even at very low concentrations. Several methods including precipitation, reduction and ion-exchange have been developed to remove toxic metals from wastewater; but all are extremely expensive and not practicable in a developing country like Sri Lanka. In recent years, the search for efficient, readily available and more affordable adsorbents that have metal-binding capacities has intensified. Therefore, the objective of the present study was to test the ability of activated carbon derived from four types of natural waste materials (cassava peel, jack fruit peel, rice straw and rambutan peel) to remove Cd(II) from drinking water containing trace amounts (ppb levels) of Cd(II) using batch experimental studies under selected conditions.

In the preparation of activated carbon from selected four types of natural waste material, H_3PO_4 acid (85 wt%), was used as the activating agent. The microstructure of activated carbon was observed with Scanning Electron Microscopy (SEM) and the activated carbon samples were characterized by Fourier Transform Infrared Spectroscopy (FT-IR) and by determining physical properties, such as attrition and bulk density. Cadmium removal percentages for activated carbon derived from different raw materials were determined by adding activated carbon (1.00 g) to different concentrations of Cd(II) standards (30.00 μg L^{-1}, 50.00 μg L^{-1}, 70.00 μg L^{-1}, 90.00 μg L^{-1},110.00 μg L^{-1}) while the pH of the solution was adjusted to 7.0 as the pH of most raw water lies within the range of 6.5 – 8.5. The solutions were stirred for 2 h, filtered and the residual heavy metals were determined by Graphite Furnace Atomic Absorption Spectrophotometry (GFAAS).

The activated carbon samples derived from all four waste materials showed a maximum Cd(II) removal percentage varying between 98.00 % - 99.00%, when the initial Cd(II) concentration of the solution was 70.00 μg L^{-1}. Among the activated carbon samples prepared, activated carbon of rice straw had the highest attrition (67%) and the lowest bulk density (27%) indicating that it has higher porosity than other activated carbon products tested. According to the SEM images, activation process has produced extensive external surface with quite irregular cavities and pores in activated carbon samples which may lead to the efficient surface adsorption of Cd(II) ions. As the results clearly indicate, activated carbon derived from the above raw materials. Activated carbon has reduced the contaminant Cd(II) considerably from aqueous solutions and hence it would be an economical adsorbent for the removal of Cd(II) from drinking water.

Keywords: Activated carbon, removal percentage, cadmium

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EXPERIMENTAL METHOD TO REDUCE AMMONICAL NITROGEN IN A RUBBER PROCESSING INDUSTRY

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This study describes an experimental method to reduce ammonical nitrogen in the final effluent of a rubber processing industry. According to BOI norms, 50 mg L^{-1} is referred as the maximum level of ammonical nitrogen for the final discharge and this maximum level was exceeded in the experimented industry.

With the aim of reducing the levels of ammonical nitrogen in the final discharge, biological nitrogen removal method was introduced as the experimental method. The method consists of two processes; nitrification and denitrification. In nitrification, ammonium (NH_4^+) is first oxidized to nitrite (NO_2^-) by chemo-autotrophic bacteria in aerobic conditions (*Nitrosomonas*). Then, nitrite is oxidized to nitrate (NO_3^-) by chemo-autotrophic nitrite-oxidizing bacteria (*Nitrobacter*). In anaerobic denitrification, nitrate is reduced to nitrogen gas (N_2) by heterotrophic denitrifiers (*Pseudomonas, Bacillus*, *Spirillum, Hyphomicrobium, Agrobacterium, Rhizobium, Cornebacterium, Cytophata, Thiobacillus* and *Alcaligenes*) with the presence of a carbon source (e.g. methanol, acetic acid) as electron donor.

The main objective of this research was to use a biological method to decrease the ammonical nitrogen content to 50 mg L^{-1}. A specific nutrient medium for nitrifying bacteria was used and denitrification was made to determine the availability of bacteria in different stages of effluent treatment plant by the aid of spread plate method. Enumeration rate of ammonifying bacteria was measured using the colony counting method. Inoculated nitrifying bacteria and denitrifying bacterial suspensions were separately introduced with different environmental conditions to 180 L of final effluent with two trials and one control trial for two processes. Ethanol was used as the carbon source for denitrifying bacteria. Ammonical nitrogen and nitrate were measured using a colorimetric method. It was observed that at least five days were required to reach 50 mg L^{-1} of ammonical nitrogen.

It was found that this biological removal method is a sustainable method rather than using chemical removal methods to reduce ammonical nitrogen in industrial effluents, since chemicals used are a threat to the environment. However, there are some practical problems to carry out this biological removal method since the process takes five days per batch of processing, while the industry continuously releases effluents and could not store a capacity of effluents for five days. Thus, this method has to be further modified and improved to reduce the duration to obtain 50 mg L^{-1} of ammonical nitrogen in the final discharge.

Keywords: Ammonical nitrogen, biological, denitrification, nitrification, effluent

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REMOVAL OF AMOXICILLIN AND AMPICILLIN FROM AQUEOUS SOLUTION BY USING *Bacillus cereus* AND GRANULAR ACTIVATED CARBON (GAC)

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Antibiotics, such as ampicillin (AMP) and amoxicillin (AMX), are impossible to remove even by sewage treatment. Their continuous introduction to the environment poses serious ecological risks. In the present study, removal of AMP and AMX from antibiotic contaminated water was evaluated by using standard particle size (0.5 mm) of granular activated carbon (GAC) [bamboo (*Bambusa* sp.), coconut shells (*Cocos nucifera*)], along with introduction of the bacterium *Bacillus cereus* which was previously recorded as apotent degrader of AMP and AMX. Five grams of GAC (bamboo/ coconut) was added into 100 mL of deionized water which was spiked by the antibiotic at a final concentration of 100 µg mL^{-1}. The effect of bacteria on degradation of antibiotic was evaluated by adding 1.0 mL of overnight grown, starved, equalized (A_{590nm}= 0.35) bacterial suspension to GAC. Triplicate experimental and control setups were incubated at 28 ºC with shaking at 200 rpm until equilibrium was reached. One mL sub samples were removed at 24 h interval for a period of 8 days and subjected to centrifugation at 2500 rpm for 10 min followed by freeze drying. Antibiotics in samples were analyzed using high performance liquid chromatography (HPLC). The coconut based GAC removed 78% of AMP and reached the equilibrium after 4 days of incubation, whereas AMX removal percentage was 95% and reached equilibrium after 2 days. Bamboo GAC completely removed AMP and AMX at 3 days and 2 days, respectively. Addition of *B. cereus* to the GAC showed enhanced removal percentage of antibiotics. The complete removal of AMX (bamboo, 1 day; coconut, 5 days) and AMP (bamboo, 2 days; coconut, 7 days) were detected when the system was treated with *B. cereus*. Therefore, in the present study bamboo with bacterial inoculation was identified as the most efficient and a low cost solution for the removal of antibiotics in ß- lactam (AMX,AMP) group from wastewater.

Keywords: GAC bamboo, GAC coconut, ampicillin, amoxicillin, *B. cereus*

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ISOLATION OF TEXTILE DYE DECOLORIZING BACTERIA FROM ENVIRONMENTAL SAMPLES

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Textile dyes have highly stable structures, toxic properties and are resistant to the degradation processes in the environment. The ability of microorganisms to decolorize a wide variety of chemical compounds have been identified and exploited in various biotreatment processes. The present study was carried out to study decolorization of CI Direct Blue 201 textile dye by bacteria which were isolated from wastewater collected near textile factories at Avissawella and Pugoda, Sri Lanka. Wastewater samples were enriched under static conditions by spiking the dye at a final concentration of 50 mg L^{-1} for 14 days. Bacteria were isolated using the Standard Pour Plate Method. The decolorization ability of bacteria was determined by introducing overnight starved equalized bacteria suspensions into filter sterilized dye solutions at a final concentration of 75 mg L^{-1}. The flasks were incubated at (28 ± 1) ºC under static conditions. Sub sample aliquots each of 3 mL were removed at 2 day intervals for a period of 14 days. Standard spectrophotometric method was used to determine the decolorization percentage. Among 35 bacteria isolates, five strains showed remarkable decolorization of the dye. Bacteria were tentatively identified by biochemical tests and the strains belonged to genera *Pseudomonas*, *Bacillus*, and *Micrococcus.* Decolorization percentage were detected as 58.15 ($\pm$ 0.92)%, 55.02 ($\pm$ 0.70)%, 54.73 ($\pm$ 1.99)%, 51.86 ($\pm$ 0.49)%, and 51.55 ($\pm$ 0.74)% for *Pseudomonas* sp.2, *Bacillus* sp.2, *Pseudomonas* sp.1, *Micrococcus* sp., and *Bacillus* sp.1, respectively. The highest dye decolorization percentage (58.15%) was recorded when *Pseudomonas* sp. 2 cell density was increased from 8×10^3 CFU mL^{-1} to 2.8×10^4 CFU mL^{-1}. Other bacteria cell densities remained low and low decolorization percentages were detected. Photolysis experiments revealed that decolorization of CI Direct Blue 201 dye was not affected by sunlight. Thus, isolated bacteria can be used as better candidates for removal of CI Direct Blue 201 textile dye as a green remedial solution.

Keywords: Decolorization, CI Direct Blue 201, *Pseudomonas* sp., *Bacillus* sp., *Micrococcus* sp.

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EFFICIENCY OF USING DICALCIUM PHOSPHATE DIHYDRATE FOR THE REMOVAL OF FLUORIDE FROM WASTEWATER

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Fluoride-containing wastewater is discharged from various industrial sites. Recently, recovery of fluoride from wastewater from destruction of fluorocarbons and hydrofluorocarbons has been studied by Japanese companies. Fluoride in the wastewater can be recovered in the form of calcium fluoride. However, effluent from this recovery process still contains 20 - 30 mg L^{-1} of fluoride ions. Currently, aluminum precipitation process is generally applied for the treatment for fluoride of the effluent.

In this study, we applied the transform reaction of dicalcium phosphate dihydrate (DCPD: $CaHPO_4.2H_2O$) to treat the effluent containing 20-30 mg L^{-1} of fluoride ions. The DCPD used in this study is a by-product of the gelatin industry. The DCPD was mixed with warm water (about 40 °C) to improve the reactivity of DCPD toward fluoride ions. Wastewater used in this study was the effluents from the fluoride treatment unit for scrubber water with a fluoride concentration of around 30 mg L^{-1}. Water treatment was carried by mixing various amounts of DCPD into 50 mL of wastewater for 1.0 h. After treatment, sludge was separated by vacuum filtration. Fluoride concentration in the treated water was analyzed by an ion selective electrode (ISE) and the amount of sludge was determined using an electric balance. Precipitation method of aluminum sulfate was carried out for comparison. The specific removal amount of fluoride by DCPD was as high as 8 mg L^{-1}, even when the final fluoride concentration was less than 1 mg L^{-1} from the original value of 30 mg L^{-1}. This value was higher than conventional aluminum precipitation and adsorption using bone char. It is clear that the amount, settling ability and filterability of sludge were better than conventional methods. From these results, cost of water treatment by DCPD was 20% more cost-effective compared to conventional methods.

Keywords: Fluoride, water treatment, cost effective

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COPPER AND ZINC CONTENT OF *Lasia spinosa* (KOHILA) IN SELECTED AREAS OF THE WESTERN PROVINCE, SRI LANKA

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Lasia spinosa (Kohila) is a widely used vegetable plant, especially in Asian countries. It is grown or cultivated in marshlands of the wet zone of Sri Lanka. The plant has high moisture content. Previous studies have shown that *Lasia spinosa* is rich in mineral elements and that some may contain toxic levels of heavy metals. Nevertheless, the heavy metal content present in different parts of *Lasia spinosa* plant is not known at present. Among heavy metals, both copper (Cu) and zinc (Zn) have been identified as micronutrients required for healthy life. However, they are both toxic to the human body at elevated levels. Hence, this study was conducted to determine Cu and Zn content in different parts of *Lasia spinosa* plant.

Nine sites were selected within the Western Province: three from less populated non agricultural environments, three from agricultural environments in less populated areas, two in close proximity to highways in urbanized environments and one from a waste water canal in an urbanized environment. Several plants were selected from each site and a composite sampling was done. A composite sediment sample was also collected from each site. All plants were separated into different parts as immature leaves, matured leaves, petioles, and rhizomes for analysis and oven dried at 105 ^{o}C until a constant mass was obtained. The samples were then digested with acids followed by ashing at 450 ^{o}C. Sediment samples were subjected to a wet digestion. All the digested samples were analyzed by using flame atomic absorption spectroscopy.

Results showed that Zn is present at elevated levels in all the samples exceeding 99.4 mg kg^{-1} by dry mass, which is the maximum permissible level defined by WHO/FAO. Zinc concentrations of these samples ranged between 180.19 - 384.68, 116.00 - 404.12, 104.34 - 364.34 and 300.34 - 1319.02 mg kg^{-1} in immature leaves, matured leaves, petioles, and rhizomes on dry matter basis respectively. A significant higher accumulation of Zn was observed in rhizomes as compared to the other parts of the plant. Zn content in soil samples collected from each site ranged between 65.52 - 977.74 mg kg^{-1}. However, there was no significant correlation between the Zn content in plant parts and sediment samples in the sites analyzed. None of the samples exceeded the maximum permissible limit of 73.3 mg kg^{-1} for Cu. The Cu concentration ranged between 8.43 - 21.83, 5.31 - 1.73, 6.53 - 21.04 and 1.62 - 28.70 mg kg^{-1} in immature leaves, matured leaves, petioles, and rhizomes, respectively. The Cu content in soil samples collected from each site ranged between 4.72 and 28.70 mg kg^{-1}. With respect to the samples analyzed, *Lasia spinosa* showed a significant accumulation of Zn, especially in rhizomes and may possibly cause health effects if frequently consumed in large quantities.

Keywords: *Lasia spinosa*, Kohila, heavy metals

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COMPARISON OF HEXAVELANT CHROMIUM TOLERANCE AND REMOVAL CAPACITY OF TWO *Bacillus* SPECIES ISOLATED FROM TANNERY DISCHARGE

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Tannery activities create potentially toxic waste and large amounts of solid waste that contain hexavalent chromium [Cr(VI)]. Acute poisoning of Cr(VI) through the oral route causes severe health problems such as renal failure, intravascular hemolysis, circulatory collapse, liver damage, acute multisystem organ failure, coma, and even death, depending on the dose. The Kelani River, is the primary drinking water source for millions of people in the Western, Sabaragamuwa and Central Provinces, has been identified as the most polluted river in Sri Lanka. In the past, the Central Environmental Authority has identified various industries which discharge untreated effluent into Kelani River. This situation emphasizes the importance of an economical and ecofriendly technique for Cr(VI) remediation to remove or minimize the toxic chromium added to inland water ways. This involves bioremediation of Cr(VI) contaminated industrial effluent through indigenous bacterial isolates.

In the present study, two indigenous Gram positive bacteria were selected from the bacteria isolated from a tannery effluent. The isolates were initially identified up to genus level and were tested for Cr(VI) tolerance and removal in (modified) Tris minimal broth. Cr(VI) tolerance was determined using minimum inhibitory concentration (MIC) of Cr(VI) for each isolate. The potential of Cr(VI) removal was tested, in (modified) Tris minimal broth by the Diphenylcarbazide assay, after an incubation period of 96 h at room temperature under aerobic conditions. Antibiotic susceptibility was also tested for each isolate. The isolated bacteria belonged to genus *Bacillus*. The highest Cr(VI) removal was recorded by *Bacillus* TE 9 and *Bacillus* TE 5. *Bacillus* TE 9, showed removal percentages of 100.0%, 24.9%, 14.2% and 5.8% at 5, 20, 35 and 50 mg L^{-1} concentrations of Cr(VI) respectively, with MIC of 150 mg L^{-1} of Cr(VI). *Bacillus* TE 5 showed removal percentages of 94.2%, 35.8%, 13.7% and 12.0% at 5, 20, 35 and 50 mg L^{-1} concentrations of Cr(VI) respectively with MIC of 100 mg L^{-1} of Cr(VI). *Bacillus* TE 9 showed resistance for antibiotics Polymyxin B (300 mcg) and Penicillin (10 U), and was sensitive for Chloramphenicol (30 mcg), Kanamycin (30 mcg), and Gentamycin (10 mcg). *Bacillus* TE 5 was sensitive to Chloramphenicol (30 mcg), Kanamycin (30 mcg), Gentamycin (10 mcg), Polymyxin B (300 mcg) and Penicillin (10 U). *Bacillus* TE 9 and *Bacillus* TE 5 were found to exhibit a significant capacity to tolerate Cr(VI) and remove Cr(VI) in (modified) Tris Minimal broth at 5, 20, 35 and 50 mg L^{-1} of Cr(VI). With further studies, there is a possibility, for these isolates to be utilized for bioremediation applications for the removal of Cr(VI) from contaminated tannery discharge, to prevent the Cr(VI) contamination of inland water ways.

Keywords: *Bacillus*, hexavalent chromium, Tannery effluent

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ADSORPTION OF CADMIUM ION ON ACTIVATED CHARCOAL OBTAINED FROM BAEL FRUIT SHELL, PALMYRA PALM FRUIT SEED AND COCONUT SHELL

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Removal of heavy metal ions from water resources has received considerable attention due to the toxicological effects of these substances on ecosystems, humans and agriculture. The commonest heavy metal contaminants are As, Ba, Cd, Cr, Cu, Pb, Hg, Se and Ag. Among these metal ions, cadmium is one of the most toxic metals, affecting the environment. Several metal ion removal techniques, including chemical oxidation, coagulation, membrane separation, precipitation, biosorption and adsorption are commonly available. However, many of these approaches are either not cost effective or difficult to implement in developing countries. The low cost adsorbent, activated carbon which is produced from coconut shells is frequently used in the removal of the toxic heavy metals through adsorption processes. This study explores the effectiveness of adsorption of Cd by activated carbon obtained from Palmyra Palm fruit seeds and Bael fruit shell in comparison to charcoal obtained from the coconut shell.

Charcoal was prepared from different materials, such as palmyra palm fruit (*Borassus*) seeds, coconut (*Cocos nucifera*) shell and bael fruit (*Aegle marmelos*) shell. Charcoal Prepared was chemically activated by heating it with H_3PO_4 acid at 80 °C for three hours. It was neutralized with deionized water and was dried at 120 °C in an oven for 24 h. Charcoal and chemically activated charcoal obtained from the above materials was mixed with 10 mL of 100 µmol dm^{-3} Cd(II) ion solution and agitated for 30 min. It was kept for 6 h to attain equilibrium and then filtered. Five mL of filtrate was taken and diluted up to 100 mL with buffer solution (pH - 4.58). Then, the remaining Cd(II) concentrations were measured using an Autolab Adsorptive Stripping Voltammetry using a glassy carbon working electrode. The standard addition method was used to the blank solution to determine the linear range for determination of Cd(II) and unknown concentration of Cd(II) remaining in filtrates.

Normal charcoal of palmyra palm fruit seeds, coconut shell and bael fruit shell showed Cd(II) adsorption of 66%, 53% and 40%, respectively. Chemically activated charcoal showed Cadmium ion adsorption of 97%, 93% and 71% for coconut shell, palmyra palm fruit seeds and bael fruit shells, respectively.

Based on the results, normal charcoal obtained from palmyra palm fruit seeds have the best capability in removing of Cd(II) from aqueous solutions when compared to the other two types of charcoal. When considering chemically activated charcoal, charcoal obtained from coconut shell and palmyra palm fruit seeds show good capacity to remove cadmium ions from aqueous solutions. Due to the increasing demand for activated carbon and the high availability of palmyra palm fruit seeds in Sri Lanka (especially in Northern Province), palmyra can be used as an adsorbent to fulfill part of the demand for activated carbon.

Keywords: Adsorption, chemically activated charcoal, Cadmium(II), voltammetry

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REMOVAL OF Ca^{2+} AND Mg^{2+} USING CHEMICALLY MODIFIED RICE HUSK

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Water hardness due to dissolved Ca^{2+} and Mg^{2+} in ground water is a major problem, especially in the dry zone of Sri Lanka, including Jaffna. In this research, the capacity of chemically modified rice husk to remove Ca^{2+} and Mg^{2+} from water was investigated. Agricultural waste materials are suitable for the removal of contaminants from water as they are ecofriendly, renewable, economical and readily available. Previous work has indicated rice husks as a potential source for the removal of heavy metals from waste water.

In this research, the effectiveness of chemically modified rice husk on the removal of Ca^{2+} and Mg^{2+} from water was investigated using batch experiments. Cleaned and dried rice husk with particle size ranging between 1700 μm and 500 μm was chemically modified using 1.0 mol dm^{-3} NaOH solution. Several parameters, including particle size, shaking time, settling time, dose of rice husk were optimized. At optimized experimental conditions, 100 mL of different concentrations of Ca^{2+} (100, 200, 300, 400 and 500 mg L^{-1}) and Mg^{2+} (50, 100, 150, 200 and 250 mg L^{-1}) solutions were shaken with 10.00 g of rice husk for 10 min at 250 rpm using an orbital shaker in triplicate. The resulting solution was filtered and the amounts of Ca^{2+} and Mg^{2+} remaining were determined by complexometric titration with standard EDTA solution.

The results obtained from the present study shows that modified rice husk have the potential to remove Ca^{2+} and Mg^{2+} effectively from water. The average removal percentage of Mg^{2+} from 50 mg L^{-1} Mg^{2+} solution was 81%. The removal percentage decreases with increasing concentration of Mg^{2+} and it was 43% for 250 mg L^{-1} Mg^{2+} solution. The average removal percentage of Ca^{2+} from 100 mg L^{-1} Ca^{2+} solution was 92%. The removal percentage decreases with increasing concentration of Ca^{2+} and it was 69% for 500 mg L^{-1} Ca^{2+} solution. The mode of removal of both ions by chemically modified rice husk is to be established.

Keywords: Water hardness, rice husk, chemical modification

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DEGRADATION OF HYDROCARBONS BY BACTERIA ISOLATED FROM USED OIL CONTAMINATED WATER

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Several sources of water are polluted by natural geological sources, pesticides, industrial discharge from various processing industries and accidental oil discharges. Bioremediation has proven to be a relatively inexpensive and effective alternative to traditional waste management techniques. Microorganisms have naturally occurring microbial catabolic diversity capable of degrading a huge range of compounds including hydrocarbons.

The present study was carried out to explore the possibility of the use of indigenous bacteria isolated from the hydrocarbon contaminated sites and to degrade petroleum hydrocarbons that are found in used oil. Hydrocarbon degrading bacteria adapted to a tropical environment were isolated from used oil contaminated water from the service stations in Marudhanamadam and Kondavil in Jaffna. Among five bacterial cultures (WS_2-2, WS_2-3, WS_2-4, WS_2-5, and WS_2-6) isolated from oil-contaminated water samples, three bacterial isolates, WS_2-6, WS_2-4 and WS_2-2, were selected for the degradation study based on the efficiency of used oil utilization in terms of growth on mineral salt agar medium. The viable count of isolates WS_2-4 and WS_2-2 were 400×10^6 CFU mL^{-1} and 110×10^6 CFU mL^{-1} respectively after a 62 day incubation period. WS_2-6 was the spreading type bacteria. The growth of each culture was monitored through culture densities spectrophotometrically. Among WS_2-6, WS_2-4 and WS_2-2, isolate WS_2-4 showed the highest absorption on the 62nd day of the incubation period, while WS_2-6 gave the highest absorption on the 20th day. Efficiency of biodegradation was enhanced by shaking the culture flasks. The pH decreased from 6.7 during the bacterial degradation process but not less than pH 5.5.

An increase in the viable cell number and absorbance indicated that these bacterial isolates used oil for their growth as carbon and energy sources. The preliminary studies of the gas chromatograms of the used oil and oil samples degraded from WS_2-4 and WS_2-6 isolates show distinguishable variation at 22-35 min retention time. It was concluded that native bacteria could be used in the cleanup strategy for petroleum hydrocarbon remediation.

Keywords: Contaminated water, used oil, bacterial isolates, degradation

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IMPACT OF PARTICLE SIZES OF THE *Strychnos potatorum* STEM ON THE REMOVAL OF IRON FROM GROUND WATER

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Water is the most abundant and essential natural resource, and it is necessary for the sustainability of the ecosystems. Groundwater is one of the preferred sources for drinking purposes in many countries with minimal or no treatment. In addition, ground water contains a variety of chemicals which seep through soil, sediment and rock. Iron is one of the most troublesome elements found in ground water. According to the WHO standards, the tolerable level of iron in drinking water is 0.3 mg L^{-1}. *Strychnos potatorum* is a tropical plant, locally known as clearing-nut tree, belonging to the family Loganiaceae. Seeds of this tree have been used for purifying water and in traditional medicine, especially in India and Myanmar. However, the ground water in the Mesalai area in the Jaffna peninsula appears to be brownish yellow or yellow due to the presence of high concentrations (10 mg L^{-1}) of iron. In the past, *Strychnos potatorum* stem has been used to remove the iron from ground water in this area. However, the effectiveness of the removal of iron using *Strychnos potatorum* stem has not been studied and the present research work is mainly focused on the impact of the particle sizes of the *Strychnos potatorum* stem over the removal of iron.

In this study, different particle sizes of the *Strychnos potatorum* stem were obtained after drying the stem followed by cutting, grinding and sieving through the different sieves of less than 0.5, 0.5 – 2.0, 2 – 5 mm and greater than 5 mm, respectively. The test solution of ferric ion was prepared in the range from 0 mg L^{-1} to 25 mg L^{-1} in 5 mg L^{-1} intervals using the stock solution of 100 mg L^{-1} of $NH_4Fe(SO_4)_2.12\ H_2O$. In a typical sorption procedure, 0.50 g of *Strychnos potatorum* stem with different particle sizes were taken into stoppered bottles (100 mL) and series of ferric ion solutions were added into it. The suspensions were then thoroughly mixed in an orbital shaker at 4000 rpm for 2 h and the reaction mixtures were rested for 24 h. Then, the supernatants were filtered through Büchner funnel, and the filtrates collected were tested separately using UV-VIS spectrophotometer with addition of hydroxylamine hydrochloride and 1,10-phenanthroline monohydrate. The absorbance was recorded at the wavelength of 508.5 nm, which corresponds to the intense reddish orange color of ferrous complex (ferroin). An effective iron sorption was achieved with the particle size of 0.5 – 2.0 mm, whereas a lower removal was observed in the 0.5 mm particle size compared to other particle sizes. In addition, these results were found to be valid for all the concentration ranges studied. The study clearly indicates that the moderate particle size (0.5 – 2.0 mm) of *Strychnos potatorum* stem is effective in removing iron from iron contaminated water.

Keywords: Absorbance, ground water, ferric ion, particle size, sorption

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ADSORPTION OF CRYSTAL VIOLET DYE USING *Artocarpus odoratissimus* LEAVES MODIFIED WITH SODIUM DODECYL SULFATE (SDS)

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Chemical modification of leaves of *Artocarpus odoratissimus*, locally known as Tarap (TL), with sodium dodecyl sulfate (SDS) (a surfactant), changes surface features leading to significant changes in adsorption characteristics. The surface changes are indicated by observing the pH at the point of zero charge (pH$_{pzc}$) to decrease from 5.2 to 4.7 with SDS treatment. Scanning electron microscopic images and Fourier transform infrared spectroscopic characteristics provided further evidence for surface modification with SDS. A notable feature of this chemical modification is that the modified TL surface becomes resistant to changes in the medium pH and ionic strength toward adsorption of the Crystal Violet cationic dye, which shows antifungal and antimitotic properties, from aqueous solution. Under the optimized conditions, adsorption of the dye on SDS modified TL is best described by the Temkin adsorption with maximum adsorption capacity of 109 mg g^{-1} based on monolayer adsorption, and pseudo second order kinetics with a rate constant of 0.13 g mg^{-1} min^{-1}. Modification of TL by SDS enhances the adsorption capacity by 115%, conclusively demonstrating the superior ability of SDS modified TL for adsorption of Crystal Violet. Furthermore, the adsorption of the dye on TL is spontaneous and endothermic within the temperature range of 294 K and 343 K, suggesting that warmer temperatures be more efficient for the removal of Crystal Violet from contaminated industrial effluents.

Keywords: *Artocarpus* waste adsorbent, adsorption, crystal violet dye, chemical modification

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REMOVAL OF Cu(II) BY HUMIC ACID EXTRACTED FROM MUTHURAJAWELA PEAT

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Use of natural substances for removal of heavy metal ions from industrial effluents has become popular, because such substances are cost-effective and environmentally friendly. When a heavy metal ion is in contact with such substances, many mass transfer processes, such as adsorption, ion-exchange, complexation and inter-particle diffusion and intra-particle diffusion, would occur. The contribution of each mass transfer step to the overall removal process depends on many factors, including the type of the adsorbent, type of the adsorbate and experimental conditions employed. Hence, the prediction of the efficiency of the removal is a complex issue, requiring the investigation of the reactivity of model compounds towards the removal process. In this context, the main objective of this research was to investigate the ability of humic acid, extracted from Muthurajawela peat (MP), to remove Cu(II) from synthetic contaminated solutions. Humic acid was extracted from MP using the method recommended by the International Humic Substances Society. The variation of the extent of removal of Cu(II) from synthetic solutions by humic acid, determined under optimized experimental conditions, with equilibrium Cu(II) concentration obeys neither the Langmuir adsorption isotherm nor the Freundlich adsorption isotherm completely, based on regression analysis. Nevertheless, the Langmuir adsorption model leads to adsorption capacity in the range of 16,000-18,000 mg kg^{-1}, which is significantly higher as compared to that of many natural adsorbents. The reduction in the intensity of the spectral peak associated with Cu(II) after treatment with humic acid, and the change in surface morphology according to scanning electron microscopic images further support the transfer of Cu(II) from solution to the solid humic acid phase. Exchange of Cu(II) by Na$^+$ ions is also evident through X-ray fluorescence spectroscopy, and the influence of ionic species on Cu(II) removal was further supported by interferent studies, suggesting that ion-exchange contributes to the mass transfer process. In addition to ion-exchange, there is a strong possibility of complexation of Cu(II) and humic acid, as indicated by changes in the absorption spectral characteristics. This complexation would occur through carboxyl and hydroxyl groups present in humic acid.

Key words: Humic acid, peat, adsorption isotherms, Cu(II)

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GEOCHEMICAL CONSTRAINTS OF KADAPANAHA, ALANKULAMA AND POTHANEGAMA LAKES SITUATED IN AND AROUND ANURADHAPURA CITY

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The present study was carried out in three selected reservoirs in Anuradhapura district to understand the water quality variation in relation to agricultural activity and urbanization of the study areas. Thus, chemical analyses of water for the three different reservoirs systems; (a) Lake within agricultural land (Alankulama $n = 6$), (b) Lake within city (Kadapanaha $n = 4$), and (c) Lake partially covered by urban activity and partially by agricultural land (Pothanegama $n = 4$), were performed using the samples obtained during July and August 2015.

Physical and chemical parameters including pH, oxygen reduction potential (ORP), dissolved oxygen (DO), electrical conductivity (EC) and temperature were determined using field usable electrodes. Nitrate, phosphate, sulfate and fluoride contents were measured using a spectrophotometer. The flame photometer was used for Na^+, K^+, Ca^{2+} and Atomic Absorption Spectrophotometer was used for the analysis of Fe^{2+} and Mg^{2+}. All three reservoirs fall into the category of eutrophic having total phosphorus levels of 0.29 - 0.52 mg L^{-1}.

Compared to the excess fertilizer application rates, the average nutrient concentrations in water were relatively low in Pothanegama Lake (nitrate 0.37 mg L^{-1} and phosphate 0.52 mg L^{-1}) and in Alankulama Lake (nitrate 0.31 mg L^{-1} and phosphate 0.29 mg L^{-1}). Pothanegama Lake showed a positive correlation for nitrate vs. phosphate, and may closely relate to agricultural activities. Both Alankulama and Pothanegama lakes have sodium type water and Kadapanaha has magnesium type water based on ternary diagrams. Kadapanaha has comparatively better quality water with higher DO even though the lake is within a highly urbanized area.

The Alankulama and Pothanegama lakes are not facing a major threat of water contamination even with high application rate of fertilizers. However, intense agricultural practices have resulted in high levels of cations (Na) and nutrients in the water of agricultural lakes. The water quality of urban lake (Kadapanaha) is satisfactory and is not vulnerable to contamination.

Keywords: Agricultural, lake, urban, water

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OPTIMIZING A SOLVENT SYSTEM FOR LIPID EXTRACTION FROM CYANOBACTERIA

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Due to higher photosynthetic efficiency, higher biomass production, rapid lipid accumulation and faster growth than other conventional crop products, cyanobacterial lipids have great potential for the production of carbon neutral biodiesel. Biodiesel gives less harmful emissions than conventional diesel and hence the use of biofuel is a shift toward "sustainable energy". This study was carried out to optimize a solvent system to extract lipids from cyanobacteria.

Many solvent systems, namely, n-hexane, chloroform: methanol (2:1), n-hexane: ethanol (3:2), chloroform: n-hexane (1:1), dichloromethane: methanol (1:1), n-hexane: isopropanol (1:1) and diethyl ether systems were used to extract lipids from cyanobacteria. The extracted lipid yields (g/1 g of dried biomass) of solvent systems were 1.11, 1.61, 1.71, 2.15, 3.41, 4.33 and 1.95 wt.%, respectively. Fatty acid methyl ester (FAME) compositions were 81.32, 78.27, 76.39, 29.01, 85.72, 92.39 and 80.09%, respectively for each solvent system. The GC-MS analysis revealed that the most abundant fatty acid types of *Microcystis* were palmitic acid (C16:0) and its derivatives (14-methyl pentadecanoic acid) which are more suitable for a quality biodiesel product. About 4.33 wt.% of lipids and 92.39% FAME composition were obtained from the n-hexane/ isopropanol solvent system. Thus, this preliminary study indicates the potential use of cyanobacteria for biodiesel production and the optimized, n-hexane: isopropanol (1:1) solvent system found to be the most efficient when compared to the other solvent systems employed in the present study.

Keywords*: Cyanobacterial bloom, lipid extraction solvent systems, fatty acid methyl esters*

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DETERMINATION OF ATMOSPHERIC NITROGEN DEPOSITION IN AN INDUSTRIALSED AREA USING MOSS AS A BIOINDICATOR AND TO DETERMINE THE MOST SUITABLE BIOINDICATOR AMONG THREE COMMON MOSS SPECIES

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With the beginning of industrial revolution and utilization of fossil fuel, nitrogen deposition from the atmosphere has increased to a greater extent. One of the main environmental risks at present is eutrophication of aquatic systems. Excessive use of nitrogen fertilizers is leading to leaching of nitrogen from soil and thus directly responsible for eutrophication. Therefore, determining the amount and sources of atmospheric nitrogen deposition has become essential for the management of fertilizer application. Biomonitoring, using moss as a bioindicator, is a modern approach of monitoring deposition processes. In this study, the nitrogen accumulated in a bulk deposition is compared with total nitrogen in the moss to determine the correlation between two sources. Three moss species were studied in four different sampling sites including a background site at Bandarawela and three sites, each located in an industrialized area in Gampaha district (Sapugaskanda, Dalugama and Orugodawatta). Sample collection was done monthly from April to September, 2015. Sampling was carried out according to the recommendations of The International Cooperative Program on Effects of Air Pollution on Natural Vegetation and Crops (ICP) manual. Moss samples were dried and analyzed using the Kjeldahl digestion method to determine total Kjeldahl nitrogen (TKN) content. Bulk deposition samples collected were analyzed using ion chromatography to quantitatively determine NH_4^+ and NO_3^-.

The results of the moss analysis in all three species showed total nitrogen content distributed over a wide range from 0.32% to 1.68% (by dry weight). *Hyophila involuta* showed a positive correlation between the total tissue nitrogen content and bulk deposition nitrogen content (Pearson correlation coefficient 0.81; $p = 0.027$). Moreover, the relationship was linear with $r^2 = 0.6557$. The correlation is governed by ammonium nitrogen in the bulk deposition. There was no significant correlation for other two moss species studied. As evident by the linear correlation obtained between the *Hyophila involuta* tissue nitrogen content and the bulk deposition nitrogen content, this moss species can be used as an effective bioindicator in monitoring of atmospheric nitrogen deposition.

Keywords: Atmospheric nitrogen deposition, moss, biomonitoring, bioindicator, eutrophication

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ATMOSPHERIC DEPOSITION OF POLYCYCLIC AROMATIC HYDROCARBONS IN MOSS *Hyophila involuta* AROUND THE CITY OF KURUNEGALA IN SRI LANKA

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Atmospheric depositions of heavy metals and polycyclic aromatic hydrocarbons (PAHs) have a great impact on human health and other living organisms. Even though heavy metal deposition in the Kurunegala sub urban area in the Northwestern province of Sri Lanka has been recorded using bioindicators, such as lichen and moss, deposition of PAHs has not been recorded yet. Therefore, atmospheric deposition of 16 PAHs, defined as priority pollutants, was investigated around the city of Kurunegala, using the moss *Hyophila involuta* as a bioindicator.

Native moss species, *Hyophila involuta*, was collected from two sampling stations in Kurunegala (area around Kurunegala town and Kurunegala Lake) during the year from February 2013 to January 2014 for six months (February, April, June, September, December and January). The background level was monitored using moss (*Hyophila involuta*) collected from Sinharaja rainforest area, where anthropogenic influence is assumed to be minimum. Identification and quantification of PAHs in the moss samples were carried out using High Performance Liquid Chromatography with C-18 PAH column as the stationary phase and acetonitrile: water as the mobile phase. Two detectors were used for quantification of PAHs and diode array detector for low molecular weight (LMW) PAHs (up to 3 rings) and florescence detector for high molecular weight (HMW) PAHs (more than 3 rings).Sixteen PAH standards (Supelco) were used as calibration materials.

The annual average concentrations of total detectable PAHs were determined on a dry weight basis. The range of total detectable PAHs in moss around the Kurunegala town and Lake were 132.0 – 462.0 ng g^{-1} and 152.8 – 464.2 ng g^{-1}, respectively and the PAHs in moss area around the Sinharaja rainforest was below the detection unit. Detectable concentrations of naphthalene and acenaphthene were higher around the studied areas than other PAHs. Among 15 PAHs analysed, 10 PAHs [except benzo(b) fluoranthene, benzo(k) fluoranthene, dibenz(a,h) anthracene, benzo(g,h,i) perylene and indeno (l,2,3-cd) pyrene] were detected around the Kurunegala sampling location. Detectable concentrations of naphthalene and acenaphthene were higher around the study area than other PAHs. Percentage of LMW PAHs was significantly higher than HMW PAHs (ANOVA, $p \leq 0.05$) around the Kurunegala. The average percentage of HMWPAHs around the Kurunegala Lake and town were 2.8 ($\pm$ 2.5)% and 4.2 ($\pm$ 3.5)%, respectively and there was no significant difference between the percentages of HMW PAHs around the Kurunegala Lake and town (ANOVA, $p < 0.05$). Total PAHs around Sinharaja rain forest area was not at detectable levels, and high vehicular emissions around Kurunegala may have influenced the total detectable PAHs around Kurunegala than the background sampling location.

Keywords: Biomonitoring, PAH, moss

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MASS CORAL MORTALITY CAUSED BY UNPLANNED WATER MANAGEMENT SYSTEM ON LAND: A CASE STUDY FROM PASSIKUDAH, SRI LANKA

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Coral reefs are among the most diverse, complex, productive and beautiful ecosystems on earth. Loss of such a critical ecosystem may damage a large number of ecosystem services. Corals cannot survive in fresh water or near a freshwater input as they are completely intolerant of changes in salinities. A mass coral bleaching event was observed in Passikudah Bay on the east coast of Sri Lanka during 2014 and this paper discusses the consequences that led to this mass bleaching event in Passikudah. Passikudah reef is part of a series of discontinuous fringing reef systems along the east coast of Sri Lanka. The bay was occupied by hard coral species dominated by *Acropora* spp., with an estimated overall live coral cover of 64.31% in 2014. Soon after the monsoons (October 2014 to March 2015), an extensive survey was carried out using the reef check method to re-evaluate the status of the coral reef after heavy rains in December 2014. The Davis Drifter Equipment was allowed to float on water freely and its position was recorded at 10 minute intervals to measure the ocean current pattern in the bay.

It was found that the average sea surface temperature reduced to 28 ºC during the monsoon period. The most critical factor related to the rainfall during the period was the marked decrease in the salinity level of the sea water. The average salinity decreased to 262.3 ($\pm$ 4.8) $\times 10^{-4}$ pg mL^{-1} during the monsoon period. It was found that the water current pattern in the bay had a circular motion rather than a direct flow towards the outer bay. Further, the study revealed that soon after the monsoon period, the majority of the coral reef has been destroyed (53.96%) and only 12.5% corals remained alive. Most of the *Acropora* spp. had died; but species like *Montipora, Favites,* and *Pocillopora* had survived to some extent. Accordingly, the rapid dilution of sea waters in the reef area from storm generated precipitation and runoff has caused the coral reef to bleach. It is apparent that the runoff was caused by inappropriate use of modern land use patterns. Aerial maps from 2004 to 2014 indicated that there is a significant change in the land use pattern during the recent past. After 2011, the land use pattern has changed drastically due to large scale tourism development in the area which has resulted in a reduction of water channels and lagoons. Hence, most of the freshwater that had collected on land was flushed into the bay diluting the sea water without accumulation within the land. This has resulted in a rapid salinity drop which in turn has bleached the corals. However, if the freshwater that had entered the sea is swept off by oceanic currents, the effects could be minimal. The measured direction of ocean current movement suggests that flushed freshwater remained within the bay diluting the sea water. Therefore, the study highlights how land use patterns can cause unexpected damage to valuable ecosystems.

Keywords: Bleaching, unplanned water management, freshwater dilution

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IN VITRO SCREENING OF CYTOTOXICITY, ANTIOXIDANT AND ANTI-INFLAMMATORY ACTIVITIES OF THE FRESHWATER CYANOBACTERIUM *Oscillatoria* sp.

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Cyanobacteria is a highly diverse group of prokaryotes and are recognized as a potent source of biologically active compounds with antiviral, antibacterial, antifungal, and anticancer properties. In the present study, the cyanobacterium *Oscillatoria* sp. was isolated from the Senanayaka Samudraya reservoir, Sri Lanka. Methanol crude extract of *Oscillatoria* was used to screen antioxidant (DPPH, ABTS, phosphomolybdenum, nitric oxide scavenging, and reducing power assay), anti-inflammatory (inhibition of protein denaturaton) and cytotoxicity effects (brine shrimp bioassay). The total phenolic and flavonoid contents in the methanol and n-hexane extracts were determined using Folin-Ciocalteu reagent and aluminum chloride ($AlCl_3$) method, respectively. The total phenolic contents (TPC) 43.25 ($\pm$ 0.03) mg $GAEg^{-1}$ extract and total flavonoid contents (TFC) 47.13 ($\pm$ 0.01) mg qua (quercetin) g^{-1} of the *Oscillatiria* methanol extract was found to be higher in the n-hexane extract. The total antioxidant property of the methanol extract was detected as 13.24 ($\pm$ 0.01) mg GAE g^{-1} at 1000 mg L^{-1}. Free radical scavenging properties of the extract for IC_{50} was 180 mg L^{-1} (DPPH) whereas IC_{50} values of nitric oxide scavenging assay was 125 mg L^{-1}. Ferric reducing property of the extract was 9.46 ($\pm$ 0.01) mg GAE g^{-1} at 1000 mg L^{-1}. Anti-Inflammatory properties of the crude extract showed 90.23 ($\pm$ 1.48)% maximum inhibition at 570 mg L^{-1} and IC_{50} value was found as 288.04 ($\pm$ 2.78) mg L^{-1} (r = 0.946) respectively. The lethal concentration of 50% of crude extract against brine shrimp assay at 6, 12 and 24 h were recorded as 2500 , 1250 and 625 mg L^{-1} respectively. The result of the study revealed that *Osillatoria* sp. contains active compounds which have the potential for pharmaceutical applications.

Keywords: *Oscillatoria* sp., DPPH, ABTS, cytotoxicity, anti-Inflammatory

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EFFECT OF PHYSICOCHEMICAL AND BIOLOGICAL PARAMETERS ON THE OCCURRENCE OF MICROCYSTIN-LR AND THEIR DESTRUCTION BY MICROBES

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Microcystin-LR (MC-LR) is one of the most toxic cyanobacterial secondary metabolites present in Sri Lankan water bodies. MC-LR intoxication can cause serious health issues to humans and other organisms through the use of MC-LR contaminated water. MC-LR is produced within the cells of different genera of freshwater cyanobacteria: *Microcystis*, *Anabaena*, *Oscillatoria* (*Planktothrix*), *Nostoc*, and *Anabaenopsis.* However, heterotrophic bacteria in freshwater can degrade MC-LR into non-harmful products under optimal environmental conditions. The present study focuses on the effect of physicochemical and biological parameters of water on occurrence of MC-LR and their removal by bacteria.

The present study was carried out from 1st September 2011 to 31st August 2014 in some selected water bodies of Sri Lanka. Water samples were collected from five locations of each water body. Water temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), total phosphate (TP), nitrate nitrogen (NO_3^--N), chlorophyll-a, cyanobacterial cell density and total MC-LR were analyzed. Enrichment studies were carried out to isolate MC-LR degrading bacteria and BIOLOG MT2 plate method was employed in screening of the efficiency of MC-LR degraders. Pearson Correlation Coefficient (PCC) analysis and Principle Component Analysis (PCA) were used to analyze data.

PCC calculated between physicochemical parameters, cyanobacterial cell density and MC – LR levels of water bodies found that *p*-values for water temperature (0.009), pH (0.002), TP (0.001), NO_3^--N (0.01) and cyanobacterial cell density (0.001) were positively correlated with MC-LR concentration in water. However, cholorophyll-a concentration did not show a correlation with MC-LR concentration as chlorophyll-a is a pigment from green algae as well. Moreover, the PCA analysis found that the water bodies studied were clustered in three different ways: A,B and C. Cluster A included water bodies with low values for all measured parameters including MC-LR, whereas clusters B and C included water bodies with high values for all measured parameters and MC-LR. Cluster C was a sub set of cluster B. However, water bodies in cluster A did not show the presence of efficient MC - LR degraders, while water bodies belonging to cluster B and C had MC-LR degrading bacteria in their environment. The most efficient MC-LR degrader was detected in cluster C. Thus, unlike water bodies in cluster A, conditions prevailing in water bodies in cluster B and C favours MC-LR production by cyanoabcteria and heterotrophic bacterial metabolism of MC -LR. Therefore, it is clear that the analysis of physicochemical and biological parameters in water will be a useful monitoring tool to predict the presence of MC - LR in water and their destruction by microbes.

Keywords: Physicochemical parameters, biological parameters, microcystin-LR, principle component analysis (PCA), Pearson correlation coefficient (PCC)

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DISTRIBUTION AND ABUNDANCE OF ALGAE IN FOUR MAHAWELI RESERVOIRS OF SRI LANKA IN RELATION TO ENVIRONMENTAL CONDITIONS

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Power generating reservoirs of Mahaweli River Sri Lanka, namely, Kothmale, Victoria, Randenigala and Rantambe, are known to have environmental problems including algal outbreaks, reduction of water storage capacity, accumulation of toxic chemicals and nutrients. All these problems may be a reflection of human activities in the watershed area and also hydro-geochemistry of the drainage basin. As the intensification and the frequency of algal blooms are on the increase, especially toxic algae, the present study was carried out to determine the distribution and abundance of algae in relation to environmental variables.Both physicochemical and biological parameters were measured in all four reservoirs by monthly from January – June 2016. Biological sampling was done using 34 µm plankton net and environmental data (pH, conductivity, salinity, alkalinity, total dissolved solids (TDS), Secchi depth and nutrient) were obtained by field and laboratory analyses. In addition, information of the surface area, catchment area, ratio between catchment area and lake area and the time of concentration were obtained using secondary sources. The correlation between the environmental variables was obtained using Pearson correlation coefficient with Bonferroni-adjusted probabilities, using the computer programme SYSTAT$^®$ (v 09). Multivariate statistics were used to understand the relationship between the species and environmental variables and also to understand which environmental variable(s) is important to discriminate variation of reservoirs using computer program CANOCO for Windows (version 5.0).

According to biological analysis, 26 species of algae were encountered from all four reservoirs, and among them, five species were toxigenic which include three species of cyanobacteria, one dianoflagellate and one diatom species. Kothmale reservoir showed the highest diversity of cyanobacteria including toxigenic species. Among the toxigenic cyanobacteria, *Microcystis* sp.was the widely distributed species. A toxigenic dinoflegellate, *Peridinium aciculiferum* was found only in Randenigala and Rantambe reservoirs however with low relative abundance (< 3%). When compared with others, the highest diversity of 21 species was recorded in Rantambe reservoir which is the tail end reservoir of the main Mahaweli cascade. In all the reservoirs, *Aulacosiera granulata* was the dominant species which is known as an indicator species of eutrophication. Victoria and Randenigala reservoirs showed the highest abundance of *Aulacoseira granulata*, which was 80% and 82% respectively compared to the upstream Kothmale reservoir which recorded only 48%. Total phosphorous levels reveal that all the reservoirs studied are eutrophic or hypereutrophic and ranged from 30 µg L^{-1}(in Randenigala reservoir) to 105 µg L^{-1}(in Rantambe reservoir). According principal component analysis (PCA), catchment and temperature are the most important environmental variables that help discriminate the variation of reservoirs. However conductivity, salinity, TDS are the most important environmental variables which help in explaining species variation. The results of the Pearson correlation indicate that pH and catchment are positively and significantly ($r = 0.99$, $p \leq 0.01$) correlated than any other pair of environmental variables.

Keywords: Mahaweli reservoirs, toxic algae, eutrophication, catchment, salinity

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COMPARISON OF Cd CONTENT IN BATALAGODA PADDY SOIL WITH AND WITHOUT APPLICATION OF GLYPHOSATE

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N-phosphonomethyl glycine (glyphosate), the most widely used herbicide in the past, contains isopropylamine salt of glyphosate and a surfactant called polyoxyethyleneamine. The Government of Sri Lanka has recently banned glyphosate-based herbicides, as it is one of the suspected causative factors for Chronic Kidney Disease of unknown etiology (CKDu) in the dry zone of Sri Lanka. The Rice Research and Development Institute (RRDI) in Batalagoda has maintained two paddy fields; one was treated with glyphosate over six years to reduce the tilling cost and the other was maintained as the control tilled land, adding all the other chemicals without glyphosate. This was an ideal situation to study the effect of glyphosate on the adsorption of Cd(II) on soil in this environment. Soil samples were collected at three different depth layers (d_1, d_2, d_3) in monthly intervals for a five month period. The first sample set was collected before applying any chemical. Glyphosate had been applied only to the experimental paddy field when collecting the 2nd sample set and other chemicals, such as triple super phosphate (TSP), muriate of potash (MOP), urea and MCPA, had been applied to both paddy fields before collecting the 3rd sample set. Further, there was no chemical addition after the 3rd sampling. All the soil samples were digested according to the EPA 3050b method and Cd analysis was done using a graphite furnace Atomic Absorption Spectrometer (GFAAS), and the data obtained were analyzed with two-sample t test, using the statistical software Minitab 17. According to the analysis, there is no significant difference in total Cd content in soil in two paddy fields except that the samples collected in 3rd month (The samples collected after the application TSP, MOP, Urea and MCPA). The mean total Cd content in glyphosate treated soil for different depths are 0.06 (± 0.01), 0.06 (± 0.02) and 0.03 (± 0.01) mg kg^{-1}, while 0.33 (± 0.19), 0.19 (± 0.13) and 0.18 (± 0.02) mg kg^{-1}, for controlled tilled soil. According to the analysis of the chemicals, only glyphosate and TSP contain detectable Cd content, and the values were obtained as 0.12 (± 0.01) mg kg^{-1} for glyphosate and 2.75 (± 0.12) mg kg^{-1} for TSP, respectively. For all three depths, the mean total Cd content of controlled paddy soil is significantly greater than that of glyphosate applied paddy soil. It indicates that the Cd adsorption of soil is reduced with the presence of glyphosate and the excess Cd in water may be a potential risk to plant uptake and water systems.

Keywords: Glyphosate, herbicide, paddy field, Batalagoda soil, Cadmium

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EFFECT OF TRANSBOUNDARY POLLUTION ON ATMOSPHERIC DEPOSITION OF HEAVY METALS AROUND THE CITY OF KANDY IN SRI LANKA

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The effect of transboundary pollution on Kandy has been reported as a reason in increasing the concentrations of air pollutants, such as nitrogen dioxide, sulphur dioxide and ozone. However, a significant study has not been carried out yet to monitor the heavy metal air pollution sources in Kandy. Therefore, this study was carried out to monitor the atmospheric deposition of five heavy metals (Cu, Pb, Ni, Cr and Cd) using the moss *Hyophila involuta* as a bioindicator in the city of Kandy and to identify the effect of transboundary pollution from Colombo to Kandy towards heavy metals. Native moss *Hyophila involuta* was collected around Kandy and Colombo for eight months from March 2013 to January 2014 including four months from South-west (SW) monsoon season (May, June, July and September) and four months from other seasons (January, March, April and December). The heavy metal contents in moss samples were analysed by atomic absorption spectrophotometry.

The atmospheric deposition of heavy metal concentrations in all sampling stations is given for dry weight of moss. The ranges of heavy metals present in moss samples in Kandy during SW monsoon were Cu (11.34 – 437.40) μg g^{-1}, Pb (3.73 – 74.65) μg g^{-1}, Ni (15.18 – 78.30) μg g^{-1}, Cr (9.60 – 121.34) μg g^{-1} and Cd (0.05 – 0.54) μg g^{-1}, while heavy metal concentration during other seasons ranged as Cu (10.35 – 391.10) μg g^{-1}, Pb (5.97 – 147.30) μg g^{-1}, Ni (6.58 – 64.00) μg g^{-1}, Cr (5.28 – 43.68) μg g^{-1} and Cd (0.08 – 0.86) μg g^{-1}. The ranges of heavy metals in moss samples in Colombo during SW monsoon were Cu (9.80 – 93.00) μg g^{-1}, Pb (2.78 – 78.02) μg g^{-1}, Ni (14.62 – 122.80) μg g^{-1}, Cr (6.40 – 110.50) μg g^{-1} and Cd (0.12 – 2.70) μg g^{-1} while heavy metal concentration during other seasons ranged as Cu (4.60 – 97.15) μg g^{-1}, Pb (6.40 – 127.04) μg g^{-1}, Ni (11.55 – 113.97) μg g^{-1}, Cr (5.22 – 81.21) μg g^{-1} and Cd (0.11 – 1.58) μg g^{-1}.

Accumulation of Cu in moss around Kandy was considerably higher than that in Colombo. Brass industries around Pilimathalawa was identified as a point anthropogenic source of Cu, as the maximum values obtained for Cu was given by the sampling station in area around Pilimathalawa. According to statistical analysis, (Mann-Whitney test, $p < 0.05$), accumulation of Cr and Ni in moss around Kandy was significantly higher during SW monsoon season than for other seasons and there was no significant difference between two seasons for the element Pb and Cd. Monthly accumulation of Cr and Ni in moss around Kandy and Colombo was not significant (Mann-Whitney test, $p < 0.05$) during the SW monsoon and the correlation between two sampling locations was significant (Spearman rho correlation test, $p < 0.01$) for these two elements. Therefore, Ni and Cr accumulation in moss around Kandy was elevated during the SW monsoon possibly by the transboundary pollution from Colombo.

Keywords: Biomonitoring, heavy metals, transboundary pollution

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ASSESSMENT OF GROUNDWATER POLLUTION BY HEAVY METALS IN KELANI RIVER BASIN, SRI LANKA

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Water demand in Sri Lanka is gradually increasing, mainly for urban and rural household consumption, industrial use and irrigation. Therefore, the demand of water directly has an effect on available groundwater. The consumption of groundwater in Sri Lanka is estimated as 22% and 72% in urban and rural populations, respectively. Groundwater can be contaminated from a number of anthropogenic activities such as domestic, industrial, municipal and agricultural pollutants. Kelani river basin, is the most industrialized and urbanized basin and it is exposed to both point and non-point pollution sources. Therefore, the present study was carried out to determine the contents of some selected heavy metals (Cd, Cr, Cu, Al, Zn and Pb) in groundwater of the Kelani river basin. Seventy two sampling locations from head, transitional and meandering zones were selected. Sampling was carried out during the first inter-monsoon period from March 2015 to April 2015. Heavy metal analyses were carried out using Graphite Furnace Atomic Absorption Spectrometry (GFAAS). Heavy metals in groundwater from the river basin ranged for Cd (0.079 - 2.498) $\mu g\ L^{-1}$, Cr (< 0.025 - 13.231) $\mu g\ L^{-1}$, Cu (0.450 - 15.460) $\mu g\ L^{-1}$, Al (26.172 - 264.676) $\mu g\ L^{-1}$, Zn (2.983 - 258.346) $\mu g\ L^{-1}$ and Pb (0.349 - 6.585) $\mu g\ L^{-1}$. Elevated concentrations of Cu, Cd, Pb and Zn were recorded from the head region where Cr concentration (0.056 - 13.231) $\mu g\ L^{-1}$ was high in the latter part of the transitional region. Meandering region showed high concentrations of Al (49.008 - 173.100) $\mu g\ L^{-1}$ and Cd (0.079 - 1.235) $\mu g\ L^{-1}$. However, Cd, Zn, Pb, Cr and Cu remained within the SLS and WHO standards for drinking water except for Al in some sampling locations. The results of this study provided important information of heavy metal concentration in the groundwater of Kelani river basin.

Keywords: Kelani river basin, groundwater, anthropogenic activities, heavy metals

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CHALLENGES IN PROTECTING WATER QUALITY IN SRI LANKA: ARE THERE ENOUGH RULES AND REGULATIONS TO PROTECT WATER RESOURCES IN SRI LANKA?

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The environment includes air, water, minerals, organisms, and all other external factors. However, environmental challenges are some of the major current issues in the world as well as in Sri Lanka. At present, there are many water pollution causes and water protection challenges in Sri Lanka, such as the reduction of the resource caused by various anthropogenic activities. External inland waters in urban areas are polluted heavily with domestic and industrial effluents, and in rural areas with agricultural activities. Over-utilization, particularly through tube wells, is another major problem affecting ground water resources in Sri Lanka. Thus, the present study was carried out to discuss water protection challenges in the last decade (2006 - 2015). The objectives of the present study were to find out the water protection challenges in Sri Lanka in the past decade and to document the evolution of environmental laws which was created for water protection in Sri Lanka and to document how existing laws were developed by International Environmental Law and how they help to stop current pollution situation of water. To achieve the objectives, secondary data published in the internet, journal articles and books were used. Legislations were enacted in the 20th century for environmental protection in Sri Lanka and to make authority to find proper procedures to carry out industrial activities which are related with water pollution. The Central Environmental Authority is the main authority in Sri Lanka responsible for enforcing environmental laws in the past decade. Mainly the National Environmental Act and its amendments and Gazette Notifications were employed to enforce environmental laws. Furthermore, Sri Lanka faces a host of environmental problems such as land degradation, pollution and poor management of water resources, loss of biological diversity, coastal erosion, increasing scarcity of water for agriculture, waste disposal in urban areas, and traffic congestion in the main cities and these issues also make water protection challenges. In Sri Lanka, regulations are available to control most water related problems but application of these regulations is lacking. Therefore, it creates health problems as well as socio-economic impacts. Thus, the present study helps to signify the need for a stronger legislation for water protection and pollution prevention in Sri Lanka.

Keywords: Environmental challenges, Sri Lanka, environmental law of Sri Lanka, water pollution, water protection

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STUDY OF SEASONAL VARIATION OF THE OCCURRENCE OF POLYCYCLIC AROMATIC HYDROCARBONS IN WATER BODIES AROUND KERAWALAPITIYA AND KELANITISSA POWER PLANTS OF SRI LANKA

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Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds composed of two or more aromatic benzene rings. PAHs are generated due to incomplete combustion of fossil fuels such as coal and oil due to pyrolytic processes, forest fires and volcanic activities. There are hundreds of PAHs in the environment and among them, sixteen PAHs have been classified as priority pollutants by the United States Environmental Protection Agency. Due to the harmful effects of PAHs towards living organisms including humans, studies have been conducted on water bodies in different parts of the world. Our study aims to determine the type and concentration of PAHs in surface water and how the composition varies with the seasons around two power plants in Sri Lanka. Kerawalapitiya Power Station (KW) and Kelanitissa Power Station (KL) are diesel fuel fired combined cycle power stations, which might have an influence on accumulation of PAHs in surface water around these power stations.

Sampling was conducted in two rounds covering rainy and dry seasons of the year. The surface water samples which were collected from Hamilton Canal (KW) and Sebasthian Canal (KL) were extracted using dichloromethane. The identification and quantification of PAHs were carried out using HPLC system with UV-DAD at 254 nm and HPLC-FLD (excitation at 250 nm, emission at 410 nm). Individual PAHs in the samples were identified by comparing the corresponding retention times of standards. Confirmations of identified PAHs were done using spiking the samples with standard PAHs. As the reference site, water samples were collected from a freshwater spring in Bandarawela. The study shows the presence of low molecular weight PAHs: naphthalene, acenapthylene, acenapthene and fluorene in surface water samples. During the rainy season, the concentration of total measured PAHs in surface water ranged from (0.11 –1.71) μg L^{-1} in KL site, whereas it ranged from (0.16 –2.74) μg L^{-1} in KW site. Moreover, during the dry season the concentration of total measured PAHs in surface water ranged from (2.36 – 14.68) μg L^{-1} and (11.06 – 54.89) μg L^{-1} in KL site and KW site, respectively. The study indicates the occurrence of PAHs in significant amounts around the two power plants and the observed variation with the seasonal changes which needs to be investigated further.

Keywords: PAHs, priority pollutants, Polycyclic Aromatic Hydrocarbons

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CONSUMER AWARENESS FOR IDENTIFICATION OF PESTICIDE CONTAMINATION IN LEAFY VEGETABLES

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Consumer awareness is the best way to reduce pesticide related health effects. Many vegetables in the market are contaminated with agrochemicals. Therefore, the present study was designed to investigate the importance of consumer awareness for the identification of pesticide-contaminated leafy vegetables using appropriate methods. One hundred leafy vegetable samples were obtained from the market and the pesticide contamination was identified by smell. In addition, chop and smell method was used to identify the presence of pesticides in five kinds of leafy vegetables including *Brassica oleracea, Alternanthera sessilis, Centella asiatica, Allium cepa* and *Amaranthus blitum*. The leafy vegetable samples collected were chopped and kept in the closed containers for 15 min. Then the presence of pesticides was identified by smell with the help of expertise in the field. The data were analyzed using the descriptive statistics in SPSS Version 16. Around 79% of leafy vegetables contained pesticide residue. Pesticide contamination in *Brassica oleracea, Alternanthera sessilis, Centella asiatica, Allium cepa* and *Amaranthus blitum* were identified as 70%, 60%, 50%, 65% and 70%, respectively by the chop and smell method. Pesticide contamination in some leafy vegetables were difficult to identify by smell in the market, but chop and smell method is very useful for this kind of leafy vegetables. *Brassica oleracea, Alternanthera sessilis, Allium cepa* and *Amaranthus blitum* were contaminated with high amounts of pesticides. Therefore, we recommend carrying out awareness programs for consumers on how to identify pesticide contaminated leafy vegetables and their health impacts through government and other relevant institutions for better health.

Keywords: Awareness, consumers, leafy vegetables, pesticide contamination, smell

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FIELD INVESTIGATION ON TRIHALOMETHANE FORMATION IN CHLORINATED WATER AND POSSIBLE HEALTH IMPACTS: A CASE STUDY IN KANDY DISTRICT, SRI LANKA

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Trihalomethanes (THMs) have been identified as one of the main carcinogenic and mutagenic disinfection byproducts generated in conventional water treatment plants (WTPs). In particular, the longer retention of chlorinated water in transmission and distribution systems increases threat to human health. However, in general the designing of WTPs are done for a period of 25 – 30 years. Hence, the WTPs are being operated at low capacity till the service areas are saturated. Thus, a proper understanding on the byproduct formation will assist in better WTP management.

For the first time in hill country of Sri Lanka, a survey was carried out in this research to determine THMs levels at two water supply schemes in Kandy District. Based on the survey data an empirical model was developed to mitigate THMs formation. THMs measurements were performed with Thermo scientific trace 1300 computer operated gas chromatograph system with electron capture detector (GC-ECD) manufactured in USA. Total Organic Carbon (TOC) analyses were carried out by a computerized TOC system (Shimadzu L) equipped with ASI-L series auto sampler manufactured in Japan. The averaged total THMs (TTHMs) in both Greater Kandy (GK) and Kandy South (KS) water supply schemes were below the WHO maximum regulated limit (MCL 80 μg L^{-1}) but it exceeds European maximum regularity limits (30 μg L^{-1}). The compounds, $CHCl_3$ and $CHCl_2Br$ were the only detected THMs and showed strong positive correlations in both schemes. THMs in distribution network were positively correlated with residual chlorine, pH and conductivity. Average TTHMs levels were greater in KS than GK. Spatial analyses showed that in some areas THMs decreased as duration and contact time of the distribution networks are increased.

Accordingly, the variations of chlorine decay and $CHCl_3$ formation with time were fitted to empirical models. The empirical models thus developed were used to develop contour plots of empirical chlorine decay and THMs formation constant. The model validations were conducted with Mahaweli River Water. The newly developed contour plots of empirical chlorine decay and THMs formation constants can be effectively utilized with empirical equation in designing THMs mitigation programs.

Keywords: Trihalomethanes, conventional water treatment plants, chlorine decay, chlorinated water

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