CHALLENGES AHEAD 2021

WATER QUALITY AND HUMAN HEALTH

International Symposium

PROCEEDINGS

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All begins with water

26th & 27th November 2021

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

Organized by the

BOARD OF STUDY IN ENVIRONMENTAL SCIENCE
POSTGRADUATE INSTITUTE OF SCIENCE (PGIS)
UNIVERSITY OF PERADENIYA, SRI LANKA

PROCEEDINGS

8th International Symposium on
WATER QUALITY AND HUMAN HEALTH: CHALLENGES AHEAD
26 – 27 November 2021

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MESSAGE FROM THE VICE-CHANCELLOR

I am delighted and honored to bring this message to the 8th International Symposium on Water Quality and Human Health 2021 of the Postgraduate Institute of Science. As the Vice-Chancellor, I would like to take this opportunity to greet and thank all the speakers, paper presenters, and participants.

Water is the primary driving force behind everything in nature. It plays a significant role in the causation of diseases and highlights its role in the interrelationship among human health, animal health, and the environment. The importance of water in health emphasizes the significance of the symposium we are attending today. I believe this conference will be an excellent opportunity for our academia, students, and other researchers to showcase the most recent research and discoveries which will further strengthen the reputation of our university.

On behalf of the University of Peradeniya, I profusely compliment the Director/PGIS, Symposium Chairperson, Coordinator, members of the Organizing Committee, and all other personnel involved in organizing this event in keeping with the standards and traditions of the University.

I would like to convey sincere gratitude to Professor J.K.P. Wanigasuriya, University of Sri Jayewardenepura for accepting the invitation to deliver the keynote address. I congratulate all the presenters on their valuable contributions and wish them a productive and memorable experience.

I hope you will join us next year too.

I wish Water Quality and Human Health: Challenges Ahead 2021 a fruitful symposium!

Professor M.D. Lamawansa
Vice-Chancellor
University of Peradeniya
Sri Lanka

MESSAGE FROM THE DIRECTOR
POSTGRADUATE INSTITUTE OF SCIENCE (PGIS)
UNIVERSITY OF PERADENIYA, SRI LANKA

It gives me great pleasure to write a message on behalf of the Postgraduate Institute of Science (PGIS), University of Peradeniya, on the occasion of the 8th International Symposium on Water Quality and Human Health: Challenges Ahead, which is one of the major annual events of the Institute.

Water, as we all know, plays a critical role in influencing the quality of our lives. Freshwater supply of the world is sufficient to meet all present and future water demands, but its temporal and spatial distributions do not meet our expectations. Freshwater resources in many countries or regions are insufficient to meet domestic and environmental needs, and economic growth. Many scientists are exploring to find solutions to address the constraints in the water sector. However, we have several challenges in doing that due to changes in climate and a rapidly growing population. I hope that this Symposium will provide opportunities to share information on the challenges that water managers face at present, as well as future research needs, so that those working to create a more sustainable and pleasant future are equipped with knowledge. The topics covered by the Symposium are timely in a background where science-based solutions are needed to resolve problems associated with water resources.

The Organizing Committee of the Symposium has been working with the utmost dedication to make this event a great success. I congratulate Prof. Sudharma Yatigammana and Dr. Subhashini Gunatilake, Chairperson and Coordinator, respectively, of the Symposium, and their team. I extend my warm wishes to all the researchers who have shared their work in this symposium.

Thank you,

Prof. H.M.T.G.A. Pitawala
Director
Postgraduate Institute of Science

MESSAGE FROM THE CHAIRPERSON
BOARD OF STUDY IN ENVIRONMENTAL SCIENCE

I am delighted and honored to bring this message to the 8th International symposium on "Water Quality and Human Health - Challenges Ahead" 2021. With the increasing human demands for more comfortable life, urbanization, expansion of industrial activities and infrastructure developments have become a necessity. Consequently, deterioration of the environment, especially water quality, has been happening at an alarming rate, which has become a global problem nowadays. Toxic pollutants present in air, water and soil have already threatened the health of all living beings. Although the environment damage that has occurred is not completely irreparable, it is the responsibility of scientists in all disciplines to hold hands and disseminate their knowledge and expertise to mitigate environmental pollution. The theme of the symposium 'Water Quality and Human Health: Challenges Ahead' is created to leverage this amazing gathering of professionals to bridge the gaps in different disciplines in water quality research in a new and innovative way.

The symposium is organized by the Board of Study in Environmental Science of the Postgraduate Institute of Science (PGIS), which is actively involved in providing environmental awareness and education at postgraduate level, targeting the improvement of the environment including at policy making levels. I am constantly amazed by the support given by the Vice Chancellor, Prof. M.D. Lamawansa and Director/PGIS, Prof. H.M.T.G.A. Pitawala, who have a very clear desire to upgrade research on water quality and human health. In particular, I thank the organizing committee chaired by Prof. Sudharma Yatigammana for their wise advice and brilliant suggestions on organizing the conference. A note of appreciation to the academia for their thorough and timely reviewing of the papers. Most of all, I thank you, the presenters, for enriching the conferences by your participation. As is the tradition, I hope you will enjoy the content, get inspired, and above all, have a great discussion.

Thank you.

Professor G.W.A. Rohan Fernando
Chairperson
Board of Study in Environmental Science

MESSAGE FROM THE SYMPOSIUM CHAIRPERSON

As the chairperson of the event, I provide this message with great pleasure to mark the 8th International Symposium on Water Quality and Human Health: Challenges Ahead, organized by the Board of Study in Environmental Science, Postgraduate Institute of Science (PGIS), University of Peradeniya. Throughout the world, freshwater systems are in danger of pollution especially due to human activities. In addition, ever increasing human population and the growing demands for freshwater is increasing exponentially making the problem more serious. Consequently, over half of the human population especially in the developing world are known to suffer from both acute and chronic waterborne diseases. Sri Lanka is one of the countries which spends large amount of money despite its small GDP to treat the patients who suffer from such diseases. PGIS initiated a symposium under the theme "Water Quality and Human Health" to provide a forum for analytical and solution based discussions, to disseminate knowledge and information on current research for seeking viable solutions especially for a burning health problem associated with human kidney failure of unknown origin. Further, this forum provides an opportunity for young researchers to interact with nationally and internationally eminent researchers who are currently involved in water research.

I consider it as a privilege and honor to initiate this event and also to work with a group of highly energetic academic and non-academic staff of the institute in organizing this event. Therefore, I take this opportunity to thank all who supported in numerous ways to make the symposium a great success especially making the event as an annual event of the PGIS. I hope that the International Symposium on Water Quality and Human Health: Challenges Ahead, will be a rewarding opportunity for knowledge sharing for those who work in the field with the aim of finding solutions to current water problems existing in the world today.

Thank you.

Professor Sudharma Yatigammana
Department of Zoology
University of Peradeniya

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Keynote Address

DRINKING WATER AND CHRONIC KIDNEY DISEASE OF UNKNOWN ETIOLOGY IN SRI LANKA

Kamani Wanigasuriya

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Cholera pandemic, which occurred in London in 1854, is the first outbreak of a waterborne disease to be scientifically documented in history. Typhoid, dysentery, and hepatitis are common water borne diseases. Evidence has emerged that Chronic Kidney Disease of unknown etiology (CKDu) in Sri Lanka is related to the hydrogeology of the endemic region. CKDu prevalent areas in the country are mainly within the dry zone and shows a discrete geographical distribution. The disease mainly affects vulnerable populations from agricultural communities causing a major health, psychosocial and economic burden. In the endemic areas, dug wells are the major source of drinking water for 94% of the population. Approximately 75% of individuals consume water from wells situated in paddy fields during working hours. Low CKDu prevalence is noted in communities where drinking water source is either surface water or natural springs. The endemic CKDu area is also known to overlap with a hydro-geochemical region that contains elevated levels of Fluoride and hard water. The Fluoride content in most wells is above the WHO recommended levels. Further, residents in the endemic regions are subject to low levels of exposure to three nephrotoxic elements, *viz.* cadmium, lead and mercury. However, all the levels are below the hazardous levels indicating a synergy effect. In addition, clustering of CKDu patients around paddy fields and reservoirs have been noted. Cyanobacterial blooms are often found in reservoirs in CKDu-endemic areas of Sri Lanka. Some studies have revealed that MC-LR contamination in a number of irrigation and recreational water bodies exceeded the WHO standards of 1.0 μg L^{-1}. Among some water bodies that were studied recently, 10, which were located in the North-Central Province, recorded *Microcystis* sp. and *Cylindrospermopsis* sp. as dominant and co-dominant cyanobacteria, respectively. Ingestion of cyanotoxin via water and food can lead to hepatic and renal toxicity. In conclusion, etiology of CKDu in Sri Lanka is multi-factorial and related to the hydro-geochemistry of the region. Studies have shown a strong association with drinking well water and CKDu. Cyanobacterial toxins may not be the root cause of CKDu, but exposure to this nephrotoxin could play a role in disease progression. Therefore, providing access to safe drinking water is one of the most effective tools in mitigating CKDu in Sri Lanka.

Invited Speech

DO YOU FIND ACCESS TO SAFE DRINKING WATER ACROSS SRI LANKA?

Sujithra K. Weragoda

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The World Health Organization reports that only 71% of the global population (5.3 billion people) used a safely managed drinking-water service in 2017. However, safe drinking water is a fundamental right of people. As a developing country, Sri Lanka still needs to create and add further improvements to ensure and safeguard water for consumers. Hence, the National Water Supply and Drainage Board (NWSDB) has an enormous responsibility to provide safe and clean drinking water to its consumers. The safe water supply covered 87.8% of the population by December 2016, and it consisted of pipe-borne water (47.7%), protected dug wells (36.4%), hand pump/tube well systems (3.2%), and other means (such as harvested rainwater) (0.5%).

The U.S. EPA has set standards for more than 80 contaminants that may occur in drinking water and pose a risk to human health. Sri Lanka faces various challenges due to unresolved groundwater pollution-related issues. Even though causative factors are not yet proven, contaminated groundwater has been proposed as the most probable factor for Chronic Kidney Disease of unknown etiology (CKDu) prevalent in some regions of Sri Lanka. Various research conducted during the recent history showed that the potential cause could be associated with Fluoride and some heavy metals including arsenic, cadmium, lead, and chromium. Further, Dissolved Organic Carbon (DOC) in shallow groundwater and the interactions of DOC with calcium and magnesium ions and metabolites of selected pesticides could also be a causative factor of the deadly disease. Further, some other studies suspect that the environmental toxins, especially algal toxins, contribute to kidney damage in humans.

Current global challenges caused by climate changes, urbanization, and industrialization have prompted the need for safe, clean, and readily treatable water resources. The production of high-quality water is becoming more challenging because of alignments in the detection limit concentration that correlates with the WHO and EPA standards. In Sri Lanka, NWSDB has the responsibility of ensuring the safety of drinking water provided to the 21 million of its human population. Hence, it has implemented collaborative water safety plans (WSP) with the WHO to achieve this objective. WSP is a methodological approach for risk minimization at the source, treatment, and distribution. Under WSPs, integrated water pollution prevention mechanisms are also being implemented in collaboration with the farmer organizations, local authorities, the Ministry of Industries, and the Ministry of Environment. Further, the recent developments in the analytical capacities may assist the water sector in Sri Lanka to reach its goals of ensuring safe drinking water for all.

Invited Speech

NOVEL RESEARCH TRENDS ON ADSORPTION FOR TREATMENT OF INDUSTRIAL EFFLUENTS

Namal Priyantha

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Industrial effluent, an undesirable by-product of industrial processes, requires adequate treatment before released to surface water or reused in various applications. Consequently, it is of vital importance that treatment should be carried out efficiently to meet relevant environmental regulations. At present, the methods adopted by industries include advanced oxidation processing, adsorption, ion exchange, membrane filtration, coagulation/flocculation, flotation, electrochemical treatment, incineration, and chemical immobilization. Among these, adsorption of pollutants released by industrial operations on waste material has become attractive, mainly due to its environmentally friendly and cost-effective nature. Development of effective adsorption methods using low-cost material, such as minerals, clay types, plant parts and food waste, followed by possible automation has thus been researched upon. Although much research has been satisfactorily performed, extension of its outcome toward the application in large-scale industrial operations has not advanced much owing to the limitations of accurate predictions on kinetics and equilibrium of the complex mass transfer processes based on small-scale static experiments, followed by small-scale and large-scale dynamic studies. As the adsorbent-adsorbate interactions are unique to each molecular entity, the strength of adsorption which leads to the capacity of removal depends on both process parameters and solution parameters, requiring the necessity of optimization of each parameter. Current trends in this area of research include the application of pseudo order kinetics where the activity of either the adsorbent or the adsorbate should be kept relatively unchanged, and adsorption isotherm models, namely Langmuir, Freundlich, Tempkin and Dubinin-Radushkevich, under static conditions, for removal of pollutants from contaminated solutions. Moreover, diffusion models have been applied to predict the predominant mode of mass transfer, while dynamic adsorption models, namely, Thomas, Adam's-Bohart and Yoon Nelson, have been used for the estimation of necessary parameters. Further, surface modification of low-cost adsorbents in an attempt to improve efficiency and selectivity of the removal of pollutants from various matrices has also been attempted.

Invited Speech

EFFECT OF GEOGENIC FACTORS IN GROUNDWATER POLUTION: A CASE STUDY FROM RATHUPASWALA, SRI LANKA

G.W.A. Rohan Fernando

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Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka

Groundwater is known as the least contaminated source of freshwater on Earth. It is being excessively used in different sectors for diverse purposes including drinking, agriculture, industrial use, and aquaculture. Approximately 1.5 billion people throughout the world depend on underground water sources. Groundwater quality is greatly affected by subsurface geology, topography, climate change, and natural events such as earthquakes, floods, and landslides. A geogenic pollutant is defined as the surpassing of certain thresholds related to drinking water standards in subsurface water systems devoid of direct or indirect anthropogenic intervention. Longer residence time, often combined with favorable geologic conditions and mineralogy of the aquifer, lead to groundwater pollution by geogenic contaminants. A case study from Rathupaswala, Sri Lanka shows how the geogenic pollutants, leaching and weathering of rocks, changing in rock types and anthropogenic activities such as intensive pumping of water has burdened the groundwater quality. During the past few decades, Gampaha District showed a high rate of urbanization with the rapid growth of industrial activities. Thus the demand for groundwater has increased due to the limitation, pollution, and inadequacy of existing surface water resources. During 2013 in Rathupaswala Village, a vast community uprising took place against a rubber glove manufacturing factory, claiming that the factory was responsible for the high acidity (pH < 4) of the groundwater. The spatial and temporal changes of geochemical parameters of groundwater including pH, Electrical Conductivity (EC), and anion concentrations (SO_4^{2-}, NO_3^-, Cl^-, and F^-) of the various geological formations were measured laterally from sea side to land side (sandy, peaty, lateritic, and crystalline rocks) since 2013. Principal Component Analysis (PCA) and Factor Analysis (FA) for the geochemical parameters explained three factors with eigenvalue summing to 86.0% of the total variance. Of this, Factor 1 accounted for 40.6% which correlated primarily with pH, EC, and sulphate (salt water intrusions from sea side) whereas Factor 2 accounted for 32.0% with a positive correlation of nitrates and depth to the water table (nutrient pollution via anthropogenic sources; excessive industrial pollutants and domestic sewage). A geochemical transport model explaining the plausible reason for such geochemical changes shows the formation of a cone of depression, which could be recharged only by the infiltration of groundwater from surrounding peaty soil aquifers with acid sulphate soil (low pH values). The infiltration of acidic water could result in the formation of a low pH area in the Rathupaswala village. The plausible reason identified for the lowering of the pH is the pumping of a high load of water than recommended by the rubber glove manufacturing factory which resulted in the temporary drawback of the water table. However, it has now been recharged. The results show that the groundwater acidity has a major effect on lateritic soil available in the Rathupaswala area, which shows natural acidification of groundwater due to the prolonged water-rock interaction of groundwater and iron-rich lateritic aquifers. However, the pH of the groundwater of the entire area is controlled by local climate, lateritic formation, topography, and drainage.

Invited Speech

CHRONIC KIDNEY DISEASE OF UNCERTAIN ETIOLOGY: WATER AND HUMAN HEALTH

Nishantha Nanayakkara

Consultant Nephrologist, National Hospital, Kandy

Drinking water quality is paramount for public health. Despite improvements in recent decades, access to safe drinking water remains a critical issue. During the last century, water borne infections was a major challenge for humans, killing millions of people due to Cholera, Polio, Typhoid, Hepatitis-A, and diarrheal diseases. Groundwater contamination, both due to natural and manmade contaminates is an emerging public health worldwide. Malignancies, noncommunicable diseases, metabolic diseases, nutritional disorders have been identified in association with poor quality water. Chronic Kidney Disease of uncertain etiology (CKDu) is observed among farming communities in dry and temperate regions in the world. In Sri Lanka, the disease has been mainly reported in defined geographical pockets in the Dry Zone. There is limited access to safe drinking water in these areas, suggesting contamination of water as the root cause of the disease. Initially Fluoride, but later Al-F, Cd, As, Cyanobacterial toxins, and weedicides were proposed without conclusive evidence. Alarming differences of water between CKDu endemic areas and nonendemic areas include hardness, high F, high phosphate and microbiome in the former.

Invited Speech

PATHOGENIC BACTERIA, CYANOTOXINS, ODOR AND TASTE CONTAMINANTS IN DRINKING WATER IN SRI LANKA: REQUIREMENT OF ADVANCED DRINKING WATER TREATMENT OPTIONS

Pathmalal M. Manage

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Faculty of Graduate Studies, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

Sri Lanka has 103 rivers and approximately 10,000 man-made reservoirs that are heavily used for domestic purposes, irrigation, and agricultural applications. For drinking water and industrial purposes, dug wells, tube wells, and springs are used. Pathogen, cyanotoxin, taste and odor contaminants in drinking water sources has received increased attention from national and international agencies in recent years. Recent studies in 44 well water samples from the Anuradhapura District revealed pathogen contamination occurring in almost all sampling locations, the main agents being total coliform and *Escherichia coli* bacteria. The values were higher compared to the World Health Organization and Sri Lanka drinking water quality standards. Around 32% of sampling locations tested positive for *Salmonella* spp. However, *Shigella* spp. were not detected during the study period.

Cyanotoxins are an ominous threat to human health, and due to cultural eutrophication, the global occurrence of cyanobacterial blooms in aquatic systems has increased in recent decades. In recent studies, our researchers discovered cyanobacteria in 75% of freshwater bodies tested in CKDu endemic areas compared to 40% of freshwater bodies tested in CKDu non-endemic areas. Toxin-producing cyanobacteria (e.g., *Microcystis aeruginosa*, *Cylindrospermopsis* spp. and *Anabaena* spp.) have also been found in most reservoirs from which drinking water is routinely obtained. Studies have recorded that most reservoir water contains a spectrum of toxin-producing, filter-clogging, taste and odor-forming nuisance algae and cyanobacteria, rendering the water unfit for human consumption. Many of the blooms are highly toxic, posing a significant risk to human and animal health. Peptide hepatotoxins, microcystins (MCs), and nodularin cyanotoxins are the most common cyanotoxins. Studies have recorded that chronic exposure to cyanotoxins, microcystin (MCs), nodularin (NOD), and cylindrospermorpsin (CYL) can cause severe progressive damage to organs such as the liver and kidneys. Human exposure to toxins produced by freshwater cyanobacteria has been associated with the emergence of the disease. There is evidence on the deaths of humans and other animals due to the toxins formed by cyanobacterial blooms from a recent outbreak in Brazil. Contact with MCs via swimming, bathing, swallowing, or airborne droplets generated from nearby contaminated ponds or reservoirs has also been documented. The presence of MCs is a serious health risk, and acute doses have caused illness and death in humans and other animals, prompting the WHO to establish a guideline of 1 g L^{-1} microcystin-LR (MC-LR) as the maximum permissible level in drinking water.

Furthermore, in epidemiological studies, chronic exposure to cyanotoxins has been linked to primary liver cancer. Cyanobacteria produce a wide range of bioactive secondary metabolites, including alkaloids, polyketides, and nonribosomal peptides that are classified as cyanotoxins. The toxic secondary metabolic compounds produced by cyanobacteria can affect organisms, posing health risks to livestock and wildlife, and even causing human intoxication. Furthermore, cyanotoxin absorption through crop root systems has been documented. Thus, our studies have revealed that providing clean drinking water is a critical factor in protecting consumer health in the long run.

Even though the health aspects of water are the primary focus, consumers generally judge water quality based on its appearance. Geosmin (trans-1,10-dimethyltrans-9 decalol) and 2- Methylisoborneol (2-MIB) (1R-Exo)-1,2,7,7 tetramethyl bicyclol [2.2.1] heptane-2-ol) are the most common taste & order causing earthy (muddy) and musty (moldy) odors in water. Geosmin and 2-MIB are semi-volatile tertiary alcohols produced by two types of microorganisms, cyanobacteria and actinomycetes, respectively. Geosmin and 2-MIB have stable chemical structures. Therefore, traditional water treatment processes, namely aeration, flocculation, coagulation, filtration, chlorination, and even boiling at 100 °C have failed to remove the taste & odor compounds from drinking water. Recent research found that the taste & odor problem in raw and treated drinking water in the North-Central Province is critical and that concentrations of Geosmin and 2-MIB in treated water were higher than in raw water, indicating that advanced drinking water treatment options are required.

In conclusion, these studies have shown that there is a requirement to undertake continuous surveillance measures to determine the presence of pathogens, cyanotoxins and taste & odor contaminants in all water samples that are used by humans for drinking purposes, and to take remedial action when the contaminants are above the thresholds of drinking water standards deemed fit for human consumption.

WATER QUALITY

ANTHROPOGENIC IMPACT ON GROUNDWATER IN SANDY AQUIFER SYSTEMS IN KALPITIYA PENINSULA, SRI LANKA

K. Jayathunga[1*] and R. Chandrajith[2]

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Coastal aquifers are important sources of freshwater in the world, but are highly vulnerable to salinization and pollution, mainly due to seawater intrusion and anthropogenic influences. We investigated the groundwater in the Kalpitiya peninsula in Sri Lanka, to identify the saltwater intrusion and effects of agriculture on this sandy coastal aquifer system. In this region, agricultural and domestic water supplies entirely depend on groundwater resources extracted from unconfined Holocene sandy aquifers. A total of 43 groundwater samples from both dug and tube wells were collected covering the entire peninsula and analyzed for dissolved ions including major ions, trace elements, and water stable isotopes. Anions were measured using ion chromatography while cations were quantified by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Water isotopes of $\delta^{18}O$ and $\delta^{2}H$ were determined using a cavity ring-down laser spectrometer. The major solute composition of groundwater in the region was dominated by Cl^-, SO_4^{2-}, and HCO_3^- that were mostly balanced by Ca^{2+}, Na^+, and Mg^{2+}. Among the four main water types, Na^+– Cl^- and Ca^{2+}– SO_4^{2-} types were predominant in the region. It was observed that nitrate levels in the region ranged from 3.0 to 846 mg L^{-1} (mean = 61 mg L^{-1}). The $\delta^{18}O$ vs. $\delta^{2}H$ plot showed the regression line of $\delta^{2}H = 5.34\ \delta^{18}O - 3.75$ ($R^2 = 0.930$) that deviated from the local meteoric water line. This indicated the modifications of groundwater, most likely due to evaporation during irrigation activities, and may also be due to seawater intrusion in certain parts of the study area. The seawater intrusions were more dominant in the northern part, while agricultural contributions with extensive fertilizer applications and excessive abstraction of water were more obvious in the southern part of the peninsula. Established mass balance calculations revealed that local groundwater had saltwater admixing up to 12%. Our results indicate that an integrated water management system needs to be established and the water resources should be monitored critically to avoid overexploitation and further seawater intrusion.

Keywords: Agricultural, Anthropogenic, Groundwater, Isotopes, Seawater intrusion

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WATER QUALITY AND ITS SUITABILITY FOR AQUATIC LIFE IN THE VAVUNIYA TANK, VAVUNIYA, SRI LANKA

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Data on water quality is a valuable source of information to identify suitability of the quality of water for aquatic life. In view of this aspect, the present study was mainly focused on the analysis of physicochemical parameters of the water from the Vavuniya Tank in Vavuniya District. Thirty-six randomly selected samples were collected from the Vavuniya Tank at various points, during the period from July to December 2019 to assess the quality of water and to compare with the standard water quality parameters. Standard procedures were used for the physicochemical analyses and the results were compared with the values recommended by the Central Environmental Authority (CEA), Sri Lanka. The results of this study revealed that Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS) of Vavuniya Tank water are within the standards recommended for aquatic life. However, the mean value of pH, Biological Oxygen Demand (BOD) and nitrate content were significantly lower compared to the required water quality standards (95% CI). The mean values of phosphate, oil and grease content were significantly lower than the desirable levels of the water quality standards (99% CI). Furthermore, the Dissolved Oxygen (DO) was significantly higher than the required standard (99% CI). It is recommended to monitor the water quality on a regular basis to maintain the quality of water. However, further studies and proper management plans are required to reduce water pollution.

Keywords: Aquatic life, Pollution level, Vavuniya Tank, Water quality

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GEOCHEMICAL BEHAVIOR OF ARSENIC-ENRICHED GROUNDWATER IN THE SEDIMENTARY AQUIFER SYSTEMS IN MANNAR ISLAND, SRI LANKA

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Elevated levels of arsenic in groundwater are reported in sedimentary aquifer systems in Mannar Island of Sri Lanka. Therefore, a detailed investigation on geochemical and isotopic composition of groundwater was carried out. Groundwater samples were collected from five tube wells and 15 dug wells. Using the previous records, a piezometer well was constructed in an arsenic rich zone of the island. Fifteen water samples were then collected from the piezometer well for further studies. The geochemical analyses of groundwater samples were done using HANNA HI9829 multiparameter meter while arsenic and other trace elements were measured using Inductively Coupled Plasma Mass Spectroscopy (ICP-MS). The results revealed that the arsenic content in groundwater obtained from the wells in the island varied from 0.63 - 28.30 μg L^{-1}. In the piezometer well, the arsenic values ranged from 13.39 - 26.35 μg L^{-1} with depth and the highest content of 26.34 μg L^{-1} was observed at a 3 m depth. In addition, Mn, Fe, Ni, and Sr contents exceeded the WHO recommended limits (Mn- 0.5 mg L^{-1}, Fe- 0.3 mg L^{-1}, Ni- 0.1 mg L^{-1}, Sr- 4 mg L^{-1}) for drinking water. Concentrations of Al, K, Cr, Mn, Fe, Zn, and As showed decreasing trend with the depth in the constructed piezometer well, while Na, Mg, and Sr showed an increasing trend with the depth. Lower sulfate and nitrate levels indicated reducing conditions of groundwater that poses the conversion of Fe(III) to Fe(II) as well as As(V) to As(III). High phosphate levels also may due to reductive dissolution of Fe(III) phosphate that lead to the dissolution of arsenic in groundwater. Isotope signatures of δ^2H and $\delta^{18}O$ in groundwater deviated from the local meteoric water line, indicating higher evaporation before the infiltration. The decomposition of organic matter by the microbes causes depletion of oxygen in the infiltrated rainwater and dissolve the released CO_2. The resulting water will then dissolve iron-oxyhydroxides in aquifer material and consequently increase the arsenic levels in groundwater.

Financial assistance from the National Water Supply & Drainage Board is acknowledged.

Keywords: Aquifers, Groundwater, Stable water isotopes, Trace elements

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EFFECTS OF COPPER ON THE EMBRYOGENESIS OF FISH

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Significant contamination of water bodies in Sri Lanka due to Copper (Cu^{2+}) associated with local industries, urbanization, and agrochemicals has been recorded during previous studies. Despite such evidence, the effects of Cu^{2+} on aquatic organisms have not been studied thus far. Fish larvae are useful vertebrate models for toxicity screening of harmful metals. Since copper is considered as one of the most harmful metals for fish development, the present study investigated the teratogenic effects of copper on embryogenesis using three commercially important ornamental fish species, *Danio rerio, Betta splendens* and *Pterophyllum scalare,* as models. Based on previous studies and the levels of Cu^{2+} detected in water sources in Sri Lanka, early blastula stage (128-cell) embryos (n = 20) were exposed to either 0.15 µM, 0.30 µM, 0.45 µM or 0.55 µM copper chloride for 20 minutes, washed with distilled water and allowed to develop at room temperature. The external morphological and internal anatomical defects of the chemically treated larvae were observed using live embryos and larvae, Borax Carmine-stained whole mounts, and Hematoxylin-Eosin-stained histological sections of preserved larvae. The head region of larvae exposed to copper chloride exhibited lack of midbrain and/or hindbrain and malformation of the jaw. Histological sections of this area indicated reduction in brain tissues and cartilage associated with the jaws. In the trunk region, malformation, reduction, or complete absence of swim bladder of larvae were observed. The cardiovascular system exhibited unlooping of the heart, pericardial edema, and internal bleeding at several locations of the larval body. Histological sections of some larvae indicated a reduction in the heart size. In the gastrointestinal system, yolk sac edema, enlarged gut, lack of liver and/or intestines, and abnormal arrangement of yolk were observed. Furthermore, enlarged mesonephric tubules and pronephric ducts were apparent in the internal anatomy of treated fish. Larvae treated with Cu^{2+} presented an increased incidence of body axis deformities including lordosis and kyphosis. Enlarged somites were observable in curved areas of the trunk of such larvae and histological sections through this area revealed malformed myotomes and neural tube. Several larvae also had wavy notochord and fragmented notochord. A novel observation recorded from chemically treated larvae was the occurrence of a separated ball of cells in the pericardium. The abnormalities observed in larvae after copper chloride treatment may be due to the downregulation of the Wnt cell-cell signaling pathway that is crucial for early embryonic development. However, further research is essential to determine the exact molecular mechanism through which Cu^{2+} affect embryogenesis. Finally, the findings of the present study suggest that ornamental fish species other than the commonly used *D. rerio* can also be used as vertebrate models for toxicological screening.

Keywords: Copper toxigenicity, Embryogenesis, Larviculture, Teratogenicity

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IDENTIFICATION OF DRINKING WATER WELLS WITH HIGH NITRATE CONCENTRATIONS IN WALPOLA AREA, GAMPAHA DISTRICT, SRI LANKA

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Nitrate is considered to be a widespread chemical contaminant in aquifers and groundwater. High intake of nitrates and nitrites is known to be hazardous to health causing methaemoglobinaemia in infants and long-term exposure may cause cancer in adults. The majority of the people in the Walpola area in the Gampaha district rely on, on-site sanitation and the population density in the area is also high. In the study area, the dug wells are located close to onsite sanitation and residents use water from dug wells for domestic purposes including drinking. A total of 13 dug wells were analyzed monthly by taking three samples from each well in the study area, for a period of six months from October 2020-April 2021 (except in February), using ion chromatographic technique. On-site measurements of pH, Total Dissolved Solids (TDS), Electrical Conductivity (EC), salinity and temperature were taken using multi-parameter PCSTestr 35. Results of laboratory analysis showed that nitrate concentrations varied from 8.36 ± 0.19 mg dm^{-3} to 70.34 ± 0.41 mg dm^{-3} with a mean value of 35.10 ± 12.74 mg dm^{-3}. A total of 33 samples out of 222 (14.86%) were above the World Health Organization (WHO) and Sri Lanka Standards (SLS) of 50 mg dm^{-3}, while average nitrate concentration within six months of two wells (15.38%) exceeded the WHO as well as SLS (50 mg dm^{-3}) standards The instability of nitrite due to its ready oxidation may cause it to be found less in dug wells The mean values obtained for pH, TDS, EC, salinity, temperature were 6.13 ± 0.74, 125.2 ± 55.9 mg dm^{-3}, 178.2 ± 81.3 µS cm^{-1}, 86.9 ± 37.5 mg dm^{-3}, and 27.1 ± 0.7 °C respectively. The range of values obtained for each of these parameters were 4.55-7.04, 62.9-241.0 mg dm^{-3}, 84.7-353.6 µS cm^{-1}, 46.8-168.3 mg dm^{-3}, and 26.5-28.1 °C, respectively. High TDS, EC, salinity and nitrate were observed in wells which were not having well lining as well as that were closer to the pit latrine. A significant relationship with nitrate contamination could not be identified due to the shortage of rain. According to the Pearson correlation coefficient (r) values, strong positive correlations were observed between TDS and EC ($r = 0.975$, $p = 0.001$), EC and salinity ($r = 0.982$, $p < 0.001$), and TDS and salinity ($r = 0.939$, $p = 0.005$). Further, these three water quality parameters were positively correlated with nitrate concentrations. A negative correlation between the average nitrate concentration of the well water and distance from well to sanitation system and a positive correlation between the number of users for a sanitary system was observed, implying that these two factors may have contributed to elevate nitrate concentrations in groundwater. The well depth was not significantly correlated with nitrate levels. The nitrate concentration was found to increase when the distance from well to the sanitation system decreases. Though different entities have established minimum safe distances between the sanitary systems and the drinking water wells, only a few houses have maintained the recommended distance. Nitrate contamination may become more serious in the study area in near future with its increasing population. The community in the area should be educated to maintain proper sanitary conditions.

Keywords: Nitrates, Nitrites, On-site sanitation, Walpola area

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TEMPORAL VARIATIONS IN THE NITRATE CONCENTRATION OF A DRINKING WATER WELL AT A PILGRIMAGE SITE IN WAVURUKANNALA, SRI LANKA

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The chemical composition of surface and subterranean minerals has a significant impact on drinking water sources. Anthropogenic activities are a major cause of pollution of dug well water. The present study was carried out to investigate the variation of nitrate concentration in an open dug well in Wevurukannala pilgrimage site, in Matara district. Many residents around the pilgrimage site, as well as pilgrims visiting the place, consume water from the selected dug well. A pit latrine is located at a 15 m distance from the selected dug well. Agricultural runoff, open dump leachate, and sewage can add excessive amounts of nitrate to groundwater. According to the WHO standards, the maximum permissible limit for the nitrate concentration in drinking water is 50 mg dm^{-3}. The temporal variations of nitrate concentration were determined from August to October, 2020 (south-western monsoon period) and January to April, 2021 (north-eastern monsoon period). The samples were collected in triplicate once a month and the average value for each parameter was determined. Temperature, total dissolved solids, salinity, pH, and electrical conductivity of the water samples were measured on-site using PCSTestr 35 multi-parameter and the nitrate concentrations were determined using ion chromatographic instrument. The average temperature, total dissolved solids, salinity, pH, and electrical conductivity values were 28.3 ± 0.1 °C, 545 ± 2 mg dm^{-3}, 339 ± 3 mg dm^{-3}, 7.90 ± 0.02, and 728 ± 3 µS cm^{-1} respectively. The average nitrate concentration during the southwestern and northeastern monsoon period ranged from 36.33 ± 0.01 mg dm^{-3} to 93. 80 ± 0.01 mg dm^{-3} and 33.61 ± 0.01 mg dm^{-3} to 51.84 ± 0.01 mg dm^{-3}, respectively. The observed highest nitrate concentration was 93.80 ± 0.01 mg dm^{-3} detected in September 2020. During the study period, total dissolved solids (440 ± 2 mg dm^{-3} to 630 ± 2 mg dm^{-3}) and electrical conductivity (620 ± 3 µS cm^{-1} to 876 ±3 µS cm^{-1}) exceeded the WHO standards (600 mg dm^{-3} and 50 µS cm^{-1}-500 µS cm^{-1}). Pearson correlation revealed a positive correlation ($r = 0.118$, $p = 0.801$) between the rainfall and nitrate concentrations. The pit latrine located near the dug well above the inclined earth and the rise of the groundwater table may be the main reasons for nitrate pollution in the well. During the study period, the number of pilgrims were less. However, a higher contamination may be expected with an increased number of pilgrims.

Keywords: Dug well, Nitrate contamination, Pit latrines, Wevurukannala

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GEOCHEMICAL PROVENANCE OF GROUNDWATER IN A HIGHLY FRACTURED METAMORPHIC TERRANE – NETIYAGAMA, MIHINTALE, SRI LANKA

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Rainwater plays a dominant role in aquifer recharging and determining groundwater composition. Therefore, the isolation of the relative contribution of rainwater for groundwater recharging is essential to determine the geochemical provenance of groundwater. The present study examined the geochemical provenance of groundwater in Netiyagama (area ~ 0.36 km^2), Mihintale. The area is composed of upper amphibolite facies to granulite facies metamorphic rocks such as granitic gneiss, hornblende-biotite gneiss and charnockitic gneiss with shallow regolith. Two prominent joint sets orienting from EW to NW–SE and NE–SW can be recognized. Samples were collected from dug wells which extract groundwater from regolith (depth is 110 cm) and tube wells, which extract groundwater from the fractured zone. Collected groundwater samples were analyzed for major ions by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) and non-suppressor Ion Chromatography (IC). Rainwater samples from the same locations were also collected (8º 19' 53.2''N 80º 36' 04.8" E) for analysis. The measured concentrations of Mg^{2+}, Ca^{2+}, Na^{+}, K^{+}, Cl^{-}, NO_3^{-}, and SO_4^{2-} in Netiyagama rainwater were 30.4, 18.5, 12.2, 3.3, 14.7, 4.5 and 0.9 µmol L^{-1}, respectively. The ion fractionation factors (F) of the rainwater Na (F_{Na}) were also used to determine physicochemical processes that affect rainwater composition. The F values for Mg^{2+}, Ca^{2+}, K^{+}, Cl^{-}, SO_4^{2-}, NO_3^{-} were 22.02, 68.75, 12.48, 1.32 and 3.60E+07 respectively. When F ~ 1 the rainwater seems to be diluted seawater. As the observed fractionations were extensive (>1), it was concluded that the composition of rainwater was due to multiple sources in addition to sea water. The calculated other source contribution values for Mg^{2+}, Ca^{2+}, K^{+}, Cl^{-}, SO_4^{2-}, NO_3^{-} were 0, 3.0, 28.9, 18.2, 3.7, 0.2 and 4.5 respectively. Rainwater contribution for the groundwater of the study area was investigated comparing the rainwater and groundwater compositions. The concentrations of Mg^{2+}, Ca^{2+}, Na^{+}, K^{+}, Cl^{-}, NO_3^{-} and SO_4^{2-} in Netiyagama groundwater were 1.67, 2.48, 2.82, 0.05, 1.78, 0.22 and 0.23 mmol L^{-1} respectively. While the average rainwater contribution for the Netiyagama groundwater recharge is <40%, a significant influence (>60%) come from rock/mineral composition of the area. The electric conductivity of groundwater varied between 360 µS cm^{-1} and 1852 µS cm^{-1} that is higher than the standard value of 300 µS cm^{-1}, indicating a high salinity. Gibbs diagram, which explains the groundwater quality, indicate that rock water interaction is the major contributor to the water chemistry in this aquifer. Therefore, the weathering of minerals causes a change in the geochemistry of the groundwater at Netiyagama.

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Keywords: Metamorphic rocks, Shallow-regolith, Fractionation-factor, Salinity, Weathering, Gibbes-diagram

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KINETICS OF FLUORIDE RELEASING FROM WEATHERED BIOTITE-BEARING GNEISSES

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Excess quantities of fluoride (F^-) in groundwater have significantly affected the water quality in several regions of the Dry Zone of Sri Lanka. Apart from the well-known prevalence of dental fluorosis, Chronic Kidney Disease of uncertain etiology (CKDu) is widespread in different pockets in the Dry Zone of Sri Lanka. Fluoride is one of the main risk factors for CKDu which is released through the water-rock interaction. It is necessary to understand the factors influencing the release of F^- into waters and therefore, the objective of the study is to assess the proton promoted release dynamics of F^- into water. A weathered rock sample was collected at 3 m depth from Girandurakotte, one of the CKDu prevalent areas in Sri Lanka. The mineralogy of the weathered rock was analyzed using X-Ray Diffraction (XRD). Leaching of F^- from weathered biotite-bearing gneiss in the presence of inorganic acids and artificial rainwater was investigated at room temperature for 12 days. Hand-ground weathered rock sample (< 100 µm size fraction) was moistened separately with artificial rainwater, hydrochloric acid, nitric acid and sulfuric acid at three different concentrations (0.001, 0.005 and 0.010 M). Samples were analyzed for F^- and major metals ions (Ca^{2+} and Mg^{2+}) at the end of days 1, 2, 5, 8 and 12 using Ion Chromatography. Primary minerals observed in the weathered rock sample were quartz, biotite and carbonate fluoroapatite. This study showed that the weathered rock contains alkaline earth metals such as Mg (753.74 mg kg^{-1}) and Ca (2069 mg kg^{-1}), as well as F, Al and Fe (152.41, 614.60, 21.15 mg kg^{-1}, respectively). The leached concentrations of F^- in the presence of H_2SO_4, HCl, HNO_3 and rainwater after 12 days were found to be 152.41, 74.32, 78.43, 2.45 mg kg^{-1}, respectively. Dissolution experiments showed the maximum leaching of F^- with H_2SO_4 compared to HCl and HNO_3 of the same concentration. The release of F^- exceeded a rate of 1.64×10^{-11} mol g^{-1} s^{-1} with H_2SO_4 acid concentrations above 0.010 M after 12 days than HCl and HNO_3 (7.97×10^{-12} mol g^{-1} s^{-1} and 8.41×10^{-12} mol g^{-1} s^{-1}, respectively). Similarly, the highest releasing rate of Ca^{2+} was governed by H_2SO_4. The releasing rate of Mg^{2+} and Ca^{2+} were 2.99×10^{-11} mol g^{-1} s^{-1} and 4.98×10^{-11} mol g^{-1} s^{-1} respectively at 0.010 M H_2SO_4. In biotite treated with HCl, HNO_3 and H_2SO_4 in various concentrations, a strong positive association between Ca^{2+} and Mg^{2+} with F^- showed that F^- is readily leached through an ionic exchange mechanism into groundwater. Sulfuric acid is a diprotic acid and it gives two H^+ ions to the medium which is two times higher than that released by HCl and HNO_3. Maximum cumulative rates of release for Mg^{2+}, Ca^{2+} and F^- at 0.010 mol L^{-1} acid concentrations were facilitated by H_2SO_4 acid and it is the optimum leaching solution for separation of all three ions from the weathered rock.

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Keywords: Dissolution kinetics, Fluoride, Geogenic contaminants, Proton-promoted release

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METEOROLOGICAL DROUGHTS IN ANURADHAPURA AND VAVUNIYA DISTRICTS IN THE DRY ZONE OF SRI LANKA

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Sri Lanka is ranked second among the countries most affected by extreme weather events in the Global Climate Risk Index, 2018. Drought is one of the extreme events and is considered as a hydro-meteorological disaster that affects some regions for months or years. Meteorological drought is one of the extreme weather events which occur when the dry weather pattern dominates an area. It is one of the most distressing extreme weather events, which impacts especially agricultural activities and livelihood of farmers. The frequency of meteorological droughts has been increasing, resulting in increasing dry weather conditions in the Dry Zone of Sri Lanka. This study examined absolute and partial droughts in the districts of Anuradhapura and Vavuniya from 2003 to 2018. Drought frequency and trends was examined on a monthly, annual, and seasonal basis. The results revealed that the highest number of absolute drought events occurred from May to August. The highest number was recorded in June in Vavuniya, and June and August in Anuradhapura. The highest number of absolute drought events were recorded during the Southwest monsoon (May to September). Although the Dry Zone gets rainfall from the Northeast monsoon (December to February), absolute drought events were recorded during that period as well. Absolute drought events are fluctuating at an increasing rate. The majority of partial drought events occurred from May to August, with June having the highest number. Seasonally, the highest number of partial drought events were noticed during the Southwest monsoon. It is clear that there are peaks and slants when considering the trend of meteorological droughts in the Dry Zone of Sri Lanka.

Keywords: Absolute drought, Dry Zone, Extreme weather, Meteorological drought, Partial drought

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WATER QUALITY AND CYLINDROSPERMOPSIN CONTAMINATION OF SURFACE WATER SOURCES IN NORTH-CENTRAL PROVINCE, SRI LANKA

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The North-Central Province is the largest province in Sri Lanka. There are two main districts in the province: Anuradhapura and Polonnaruwa, with a semi-arid climate. The water samples for the present study were collected from Padaviya wewa, Tissa wewa, Nuwara wewa, Kala wewa, Basawakkulama wewa and Rajanganaya wewa in the Anuradhapura district and Parakrama samudraya, Minneriya wewa, Ambagas wewa, Kaudulla wewa, and Girithale wewa from the Polonnaruwa district. These water bodies are used for domestic, fisheries and recreational activities. Sampling was carried out in November 2020, during the wet season. In each water body, surface water was sampled in triplicate covering three different locations. On site measurements were taken for water temperature, Dissolved Oxygen (DO), pH, and Electric Conductivity (EC) using standard field instruments. The laboratory analyses were done for nitrate nitrogen ($N\text{-}NO_3^-$), nitrite nitrogen ($N\text{-}NO_2^-$), ammonium nitrogen ($N\text{-}NH_3$) and Total Phosphate (TP) using standard methods. Enzyme-Linked Immunosorbent Assay (ELISA) was employed to detect the Cyanotoxin, Cylindrospermopsin (CYN) at μg L^{-1} level, following the manufactures instructions. Water temperature, pH, EC and DO ranged from 25.0 °C to 33.4 °C, 6.1 to 8.5, 98.3 μS cm^{-1} to 887.7 μS cm^{-1} and 5.9 mg L^{-1} to 8.2 mg L^{-1} respectively. Concentration range of $N\text{-}NO_3^-$ and TP were 0.97 μg L^{-1} to 2.67 μg L^{-1} and 0.14 μg L^{-1} to 4.27 μg L^{-1} respectively. $N\text{-}NO_2^-$ and $N\text{-}NH_3$ levels in all the water bodies were < 0.05 mg L^{-1}. Out of 11 surface water sources tested, 45% exceeded TP given by the Sri Lanka Standards (SLS) for drinking water (2 mg L^{-1}). Padaviya wewa and Nuwara wewa in Anuradhapura district and Parakrama Samudraya in Pollonnaruwa district recorded 0.072, 0.053 and 0.052 μg L^{-1} of CYN respectively and the concentration of CYN in rest of the water bodies were less than 0.05 μg L^{-1}. The recorded concentrations of CYN in the study were below the standard value (2 μg L^{-1}) established by the WHO and SLS for drinking water. Further, CYN producing cyanobacteria were examined under a light microscope following the Lugals' sedimentation method and *Cylindrospermopsis* sp. that produce CYN, were detected in Basawakkulama wewa (32 ± 7.55 cells L^{-1}), Nuwara wewa (156 ± 8.54 cells L^{-1}), Padaviya wewa (340 ± 6.80 cells L^{-1}) and Tissa wewa (26 ± 7.64 cells L^{-1}) in Anuradhapura district. However, none were observed in the Polonnaruwa district. The study indicated that the water quality of surface water in the North Central Province fluctuated within the accepted ranges during the period of sampling.

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Keywords: CYN contamination, North central, Water quality

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SOURCE AND MECHANISM OF RECHARGE OF DEEP GROUNDWATER IN DIFFERENT FLOW REGIMES OF SRI LANKA: A STUDY BASED ON ENVIRONMENTAL ISOTOPIC AND CHEMICAL SIGNATURES

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In many instances, it is difficult to describe the groundwater dynamics, availability and geochemical characteristics due to its hidden nature. The current study evaluated deep groundwater in the form of thermal and non-thermal springs with artesian conditions in the Palavi and Vanathavillu basins of sedimentary terrain, as well as in the southern, eastern, and eastern-north central lowlands of crystalline terrain in Sri Lanka, using chemical and isotopic methodologies. The important factors that affect groundwater chemistry include the evaporation-fractional crystallization process and cation exchange in sedimentary aquifers, and rock-water interactions in crystalline deep aquifers. Artesian aquifers in sedimentary terrain are recharged by 100-200 m above mean sea level by meteoric water moving through fractured basement rocks over the region and have longer flow pathways and a long residence time. Despite the proximity to the west coast, the data acquired indicate that there is no sign of sea water mixing in the study areas. Percolation of locally evaporated surface water into sedimentary aquifers is possible, especially where the aquifer is semi-confined. Non-mixed, non-evaporated, and young groundwater with higher elevation recharge characterizes the recharge and discharge conditions of artesian non-thermal water in the southern lowlands of crystalline terrain. The same properties have been seen in artesian non-thermal waters in the eastern-north central plains, but with evaporated conditions. As artesian thermal waters do not contain tritium, they are older and deeply percolated. Artesian thermal water in the Eastern flow regime shows that there is an intensive rock-water interaction and the origin of the water may be from a location of higher altitude. Some spring clusters in the same area with weathered overburden have shown significant mixing of recent local rains, resulting in overall younger ages. The non-mixed, non-evaporated and less rock-water interacted nature of thermal springs that emerge through quartzite bed rocks is significant. Freshwater springs are recharged by local rain followed by shallow percolation.

Financial assistance from the Sri Lanka Atomic Energy Board is acknowledged.

Keywords: Artesian aquifers, Crystalline terrain, Deep groundwater, Meteoric water, Sedimentary terrain

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PHYTOPLANKTON AND WATER QUALITY IN SELECTED DRINKING WATER BODIES IN THE DRY AND WET ZONES OF SRI LANKA

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Phytoplankton, being primary producers, serve as the base of the food chain in aquatic habitats. Excessive growth of algae and cyanobacteria may cause water quality problems, resulting in social, environmental, and economic implications. In the present study, algae and cyanobacteria species composition, density, and the relationships with the physicochemical parameters were studied. Labugama and Kalatuwawa reservoirs were selected from the Wet Zone, whereas seven water bodies namely Thissa Wewa, Nuwara Wewa, Mahakanadarawa Wewa, Nallachchiya Wewa, Parakrama Samudraya, Minneriya Wewa, and Kondawattuwana Wewa were selected from the Dry Zone. Phytoplankton and water sample analyses were carried out following standard protocols from August to October 2019. The highest phytoplankton density was recorded in Mahakanadarawa Wewa (208,393 ± 15,973 cells mL^{-1}) in the Dry Zone whereas the lowest was from Labugama (4,070 ± 986 cells mL^{-1}) and Kalatuwawa (3,963 ± 1,136 cells mL^{-1}) reservoirs in the Wet Zone. Cyanotoxin producing *Cylindrospermopsis raciborskii*, *Microcystis* sp. and *Anabaena* sp. were identified. Phylum Chlorophyta was the most diverse phylum in both zones. Algal density exhibited significant positive correlations to Electrical Conductivity ($r = 0.791$, $p < 0.01$) Total Dissolved Solids ($r = 0.790$, $p < 0.01$), chloride ($r = 0.862$, $p = 0.05$), alkalinity ($r = 0.700$, $p = 0.01$), hardness ($r = 0.727$, $p < 0.01$), phosphate ($r = 0.650$, $p < 0.01$) and sulfate ($r = 0.863$, $p < 0.01$). According to principal component analysis, Labugama and Kalatuwawa reservoirs separated into one cluster and Parakrama Samudraya, Minneriya Wewa, Thissa Wewa, and Nallachchiya separated into another cluster. Kondawattuwana Wewa, Nuwara Wewa and Mahakanadarawa Wewa clustered together due to deviation of physicochemical parameters of the reservoirs.

Keywords: Algae, Cyanobacteria, Dry Zone, Physicochemical parameters, Wet Zone

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MONITORING OF RAINWATER QUALITY IN THE KANDY REGION, SRI LANKA

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Atmospheric deposition is the process, whereby precipitation, particles, aerosols and gases move from the atmosphere to the earth's surface. The objective of this study was to determine the rainwater quality in selected areas in the Kandy region, namely, Kandy city, Polgolla and University of Peradeniya (UOP), and to identify possible correlations between quality parameters. Kandy is the second major city in Sri Lanka with high atmospheric pollution than Colombo due to its geographical location and poor road system. Bulk depositions data were collected into 5.00 L high density polyethylene bottles through a polyethylene funnel of 20.6 cm diameter that was placed 1.5 m above ground. Forty rainwater samples from the UOP site and seven samples each from the Kandy and Polgolla sites were collected from May 2020 to April 2021. Conductivity, pH, salinity and total dissolved solids (TDS) of the samples were determined using standard analytical methods; hardness was determined using the EDTA titration method; and anions (Cl^-, NO_3^-, SO_4^{2-}) were determined using ion chromatography. The volume-weighted average (VWA) pH values of UOP, Kandy and Polgolla sites were determined to be 7.44, 7.19 and 7.19, respectively, and acid rain (pH < 5.6) occurrences were not detected during the sampling period. The VWA values of rainfall, conductivity, salinity, TDS and hardness of the UOP site were 40.12 mm, 51.93 µS cm^{-1}, 0.0300 ng L^{-1}, 26.59 mg L^{-1}, and 13.55 mg L^{-1}, respectively. The corresponding values of the Kandy site were 16.52 mm, 64.04 µS cm^{-1}, 0.0361 ng L^{-1}, 30.80 mg L^{-1}, and 19.49 mg L^{-1}, respectively, and those of the Polgolla site were 33.10 mm, 53.90 µS cm^{-1}, 0.0310 ng L^{-1}, 25.76 mg L^{-1} and 19.31 mg L^{-1}, respectively. The VWA values of conductivity, salinity and TDS were the highest in Kandy city site. Further, the VWA values of hardness at Kandy and Polgolla sites were approximately equal. This could be due to the Ca^{2+} and Mg^{2+} particulates coming from the dolomite quarry located in Digana area which is close to these two sites than to the UOP site. The most predominant anion was identified as Cl^- in bulk deposition in all three sites, while NO_3^- showed the lowest concentration in all sites. Moreover, very strong significant positive correlations were identified between conductivity-TDS, conductivity-salinity, conductivity-hardness, TDS-hardness, TDS-salinity, salinity-hardness, SO_4^{2-}-Cl^- and NO_3^--Cl^- according to Pearson correlation coefficient. It is thus concluded that the pollutants are coming from the same natural or anthropogenic source.

Keywords: Deposition, Rainwater, Volume weighted average, Water quality parameters

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WATER POLLUTION AND REMEDIATION

PREPARATION OF SILICA ADSORBENT USING SPENT DIATOMACEOUS EARTH FOR REMOVAL OF METHYLENE BLUE IN WASTEWATER

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Diatomaceous Earth (DE) is used as a filter media in brewing industry. Spent Diatomaceous Earth (SDE), as an industrial waste, is mainly generated once this DE pores are filled with impurities generated from brewing industries. In this research, DE was used as the adsorbent for dye removal because of its unique properties including, high silica content, porosity, surface area and chemical inertness. This work reports the preparation of Thermally Regenerated DE (TRDE) adsorbents from the SDE under two different thermal conditions (400 °C and 800 °C labelled as SDE-400 °C and SDE-800 °C, respectively) and identifies the effectiveness and efficiency of methylene blue (MB) removal from aqueous solution. The surface morphology of SDE dry form was obtained by Field Emission Scanning Electron Microscopy (FE-SEM). The SEM image of SDE dry form indicates a well-arranged porous structure with some particles on the surface. According to the nitrogen adsorption-desorption analysis performed at -196 °C for Raw DE (RDE) and dry form of SDE, a relatively higher specific surface area (3.70 $m^2 g^{-1}$) and total pore volume (0.015 $cm^3 g^{-1)}$ was observed in RDE than that of in SDE-dry form (specific area of 2.22 $m^2 g^{-1}$ and 0.015 $cm^3 g^{-1}$ of total pore volume). The maximum MB adsorption capacity was obtained, with the adsorbent dosage of 80 mg and contact time of 300 minutes at pH of 6.0 for 50 mL MB solution maintained at 25 °C. The equilibrium adsorption data were analyzed using the Langmuir and Freundlich adsorption isotherm models. The Langmuir model best describes the adsorption characteristics of MB on RDE, SDE, SDE-400 °C and SDE-800 °C with the maximum adsorption capacities of 22.03, 35.34, 52.91, 78.74 mg g^{-1}, respectively. The present study suggests a favorable application of SDE-800 °C as an effective material for MB removal from aqueous solutions than other three adsorbents due to both chemisorption and physisorption. Chemisorption probably occurs due to the breakdown of C-O-C bonds to form -C-OH bond when it was heated to high temperature and hence the interaction between adsorbate and the adsorbent surface occurred probably via electrostatic attractions and H- bonds. On the other hand, physisorption may occur due to Van der Waals forces between the adsorbate and the pores available on the adsorbent surface.

Keywords: Adsorption, Isotherms, Methylene blue, Spent diatomaceous earth, Thermal regeneration

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REMOVAL OF HEAVY METALS FROM WASTEWATER USING NEEM (*Azadirachta indica*) LEAVES AND SEEDS

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Presence of heavy metals in industrial wastewater is a major environmental issue at present. Various methods of heavy metal removal from wastewater have been studied including adsorption. Both seeds and leaves of Neem (*Azadirachta indica*) have been used as a low-cost adsorbent for removing metal ions from contaminated water. This study aimed to investigate the capability of metal ion removal by Neem leaves powder (NLP) and Neem seeds powder (NSP) as adsorbents. The study was carried out in the presence of different concentrations of metal ions and a varying amount of adsorbent. The concentration of metal ions before and after the adsorption applications was determined using Atomic Absorption Spectrophotometer (AAS). The results revealed that the percentage removal of Pb^{+2} increases with the amount of adsorbent, and decreases with the increased initial Pb^{+2} concentration. The Pb^{+2} removal was 96.31% and 90.50% for NLP and NSP, respectively, at 300 minutes optimum agitation time, pH 5.6, and 302 K. The study further revealed that extractions of both neem leaves and seeds have metal ion reducing capability. This ability was confirmed by the color change of aqueous solutions of heavy metals (Pb^{+2}, Fe^{+3}, Co^{+2}, Cu^{+2}, and Ni^{+2}) upon stirring these solutions in the presence of a different amount of both neem leaves and seeds extraction. Upon treating with the extractions of neem leaves and seeds separately, Fe^{+3}, Co^{+2}, Cu^{+2}, and Ni^{+2} ions gave colored precipitates characteristic to metal ions. The black precipitates formed in the Fe^{3+} containing solutions was separated using magnetic decantation. After leaving these colored solutions for one day, the metals or metal oxides of these ions settled at the bottom of the reaction vessel were isolated easily from the clear supernatant solutions. Therefore, the study revealed the possibility of using neem leaf and seed extracts to treat water contaminated with Pb^{+2}, Fe^{+3}, Co^{+2}, Cu^{+2}, and Ni^{+2} ions.

Keywords: Adsorption, *Azadirachta indica*, Heavy metals removal, Wastewater treatment

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CINNAMON WOOD DRIVED BIOCHAR FOR DETOXIFYING SULFAMETHOXAZOLE FROM AQUEOUS SOLUTIONS

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Sulfamethoxazole (SUL) is one of the sulfonamide antibiotics used to treat the urinary infections in human and veterinary animals. About 30% of SUL is excreted through the urine in the unmetabolized form and hence it possibly contaminates water sources. Thus, it is essential to remove the SUL from the water in a greener and cost-effective manner. The present study is mainly focused on the utilization of cinnamon wood biochar (CWBC) as a waste by-product from a bioenergy plant for removing SUL from water. The chemical and morphological state of CWBC was first characterized by Fourier Transformed Infrared (FTIR), Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD), and Brunauer–Emmett–Teller (BET). The pH, where the zero-point charge (pHzpc) of CWBC occurs was also analyzed. The batch adsorption of SUL by CWBC was investigated at different pH values ranging from 3-10. The adsorption kinetics were investigated at different contacting times (10 min-24 h). The adsorption isotherms were developed at various initial concentrations (10-100 mg L^{-1}). The SEM image shows the development of a porous structure on the CWBC, while BET surface area and pore sizes were 589 m^2 g^{-1} and 1.23 nm, respectively, indicating micro-pores on CWBC. The pHzpc was close to 7.7 demonstrating that the removal of SUL by CWBC may be mediated by the ionization effect of the adsorbent which is pH dependent. The highest adsorption occurred at pH 4.5, may be due to the interaction between zwitter ionic form of SUL and the positively charged CWBC. Kinetic study results demonstrated a good fit with the pseudo-second order model and it predicted an adsorption capacity of 95.64 mg g^{-1}. Among different adsorption isotherm models, Toth isotherm and Hill isotherm models well-fitted with experimental data on the basis of R^2 of 0.99. The maximum adsorption capacity predicted by both isotherm models was 113 mg g^{-1}. The fitted models suggested that the adsorption of SUL takes place at the heterogeneous surface of CWBC via cooperative adsorption involving chemical interactions. According to the findings, the CWBC could be a potential adsorbent for removal of SUL from wastewater.

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Keywords: Biochar, Detoxification, Pharmaceutical and personal care products, Urinary antibiotic

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DEVELOPMENT OF A BIPOLAR ELECTROCHEMICALLY GENERATED CHEMILUMINESCENCE DETECTOR FOR Pb(II) IONS IN WATER

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Less than 1% of the Earth's total water is potable and even this diminutive amount is at risk given the pollution from anthropogenic activities including the release of heavy metals into water sources. Lead (Pb) is one such highly toxic heavy metal. The quantification of Pb in water at low levels is crucial for the consumption of drinking water. Various methods can be used to detect Pb in water. Among the many spectroscopic techniques employed in the quantification of Pb in water, atomic absorption spectroscopy appears to be the most popular method. However, Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) is the best method for the detection of heavy metals as it has very low detection limits. However, ICP-MS has a very high capital cost, and most spectroscopic techniques require conventional laboratories. Conversely, electrochemical methods are more appropriate for the development of low-cost and portable methods. Stripping analysis is one of the most important electroanalytical techniques. However, its applicability may have restrictions in the industry owing to the need for high-level technical skills. Consequently, this work is dedicated to developing a simple, versatile, and low-cost bipolar electrochemically generated chemiluminescence detector that can be used for the detection of trace amounts of Pb(II) in water. A bipolar electrode (BPE) is an electrically conductive material without direct ohmic contact. Wireless capability and the ability to control a large array of electrodes facilitate bipolar electrodes for microscale and point-of-care measurements by performing redox reactions at their two respective poles. Accordingly, this work aims at developing a novel method for the detection of trace amounts of Pb(II) in water by bipolar electrode-based electrogenerated chemiluminescence incorporated with sophisticated smartphone detection techniques. Home-built monitoring system was developed to measure electrogenerated chemiluminescence by incorporating (a) a lightproof black box as the sample holder, (b) the OSnap app (available on iPhone XS) as the image capturing device, and (c) ImageJ as the image analysis software. Here, the ability to measure chemiluminescence by using this platform and a luminol-hydrogen peroxide system was successfully demonstrated. A calibration curve was obtained with an R^2 of 1. Two glassy carbon electrodes were embedded on a silicone-based material and were connected to create the bipolar electrode. This bipolar electrode was integrated with the home-built smartphone-based platform, and potassium ferricyanide was selected as the reducible analyte. A DC power supply was used to bias the bipolar electrode to oxidize luminol at the anodic pole of the BPE and to reduce ferricyanide at the other extreme. Luminescence produced at the anode was successfully detected and a calibration curve with an R^2 of 0.961 was obtained for ferricyanide. As the next step, the system will be improved by introducing microelectrodes along with a microfluidic platform. The improved system will be first used to detect Pd(II) in water, and in the future, the developed device will be integrated with a paper-based separation device to detect multi elements.

Keywords: Bipolar electrode, Chemiluminescence, Heavy metal, Smartphone

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SYNTHESIS AND CHARACTERIZATION OF SILVER-SODA LIME GLASS NANOCOMPOSITES USING *Neolitsea cassia* LEAF EXTRACTS

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The fabrication of green synthesized silver nanoparticles (AgNP) on solid substrates is a recent advancement of nanocomposites. Since AgNP has proven for its antimicrobial effects, there is a potential for utilizing it for water purification by fabricating into a suitable substrate. The objective of this study was to green synthesize AgNP using *Neolitsea cassia* ("dawul kurundu") leaf extracts as reducing and stabilizing agents, and fabricate a nanocomposite by coating AgNP on soda lime glass beads. Fresh and mature leaves of *N. cassia* were cleansed with tap water, followed by distilled water and air dried. Methanol (80%) extract of *N. cassia* leaves was prepared using the maceration technique. Fifty milliliter volumes of 0.10 M $AgNO_3$ solutions were reduced by 10.00 mL volumes of macerated leaves extract while stirring for 3 hours for synthesizing AgNP. In fabrication of silver-soda lime glass nanocomposites, the synthesis was followed by stirring with 4 mm soda lime glass beads. The experiments were conducted in triplicate. The nanoparticle dispersions were centrifuged at 1500 rpm for 1 hour. After discarding the supernatants, the coagulants were dispersed with distilled water and centrifuged twice at 1500 rpm for 1 hour. The nanocomposites were filtered and washed with distilled water. The centrifuged nanoparticles and separated nanocomposites were oven dried at 60.0 ± 0.2 ℃ for 1 hour, weighed, and stored at 4 ℃ until further use. The nanoparticles were characterized by Ultraviolet-visible spectroscopy (UV-vis), Scanning Electron Microscopy (SEM), Energy Dispersive X-ray analysis (EDX), Fourier Transform Infrared spectroscopy (FTIR), and Powder X-Ray Diffraction (PXRD) techniques whereas, only SEM, and EDX techniques were used to characterize nanocomposites. The amount of AgNP coated on 1 cm^2 surface area of glass beads was estimated as 0.0004 ± 0.0001 g by averaging the weight measurements of thirty coated glass beads, ten from each of three trials. A characteristic surface plasmon resonance peak at around 430 nm in UV-vis spectrum was detected for reddish orange nanoparticle dispersions. Quasi-spherical shaped nanoparticles were detected under SEM. Presence of elemental silver was quantitatively determined as 36.82% for AgNP and 17.15% for silver-nanocomposites by EDX analyses. The FTIR spectra showed common bands within the ranges of 3650-3200 cm^{-1}, 1680-1400 cm^{-1}, 1300-1000 cm^{-1}, and at 2925 cm^{-1} indicating the involvement of the corresponding functional groups as reducing, stabilizing, and capping agents in AgNP synthesis. The XRD peaks at 2ϑ = 38.090°, 44.202°, 64.484°, and 77.365° confirmed face centered cubic lattice structure of metallic silver. The average crystalline size was estimated as 11.7 nm for AgNP by using Debye Scherrer's formula. It can be concluded that the green synthesized silver-nanocomposites using *N. cassia* leaves can be utilized for practical applications subject to further research.

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Keywords: Green synthesis, Nanoparticle characterization, *Neolitsea cassia*, Silver nanoparticles, Silver-soda lime glass nanocomposites

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AQUATIC BIOLOGY

VARIATION OF PLANKTON COMMUNITIES IN RESPONSE TO PHYSICOCHEMICAL PARAMETERS IN A SELECTED REGION OF MAHAWELI RIVER IN KANDY DISTRICT, SRI LANKA

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Mahaweli River is the longest river (335 km) in Sri Lanka which supplies water for drinking, irrigation, agriculture, domestic uses, industrial activities, and power generation. Both natural phenomena and anthropogenic activities cause rapid deterioration of the quality of water in the river. The current study was conducted to investigate the relationship between physicochemical parameters and plankton communities in six sites from Tennekumbura Bridge to Victoria Reservoir of the Mahaweli River. To understand the quality of water, physicochemical and biological (plankton) parameters were studied from August 2020 to April 2021. A total of 29 physicochemical parameters including pH, temperature, electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS) were measured using portable meters whereas orthophosphate, total suspended solids (TSS), 5-day Biological Oxygen Demand (BOD5), hardness, anions (nitrate, nitrite, sulphate, fluoride, bromide, chloride) and metals (As, Cd, Pb, Hg, Zn, Cu, Ti, Fe, Cr, Ni, Na, K, Ca, Mg) were analyzed in the laboratory following the American Public Health Association's (APHA) standard methods. The results of the study showed that most of the water quality parameters were well below the Sri Lanka Standards (SLS), Central Environmental Authority (CEA) standards of aquatic life and World Health Organization's (WHO) guidelines for drinking water, except for TSS and orthophosphate. According to weighted arithmetic water quality index (WA WQI) values, only two sites had good water quality (45.98, 47.71) whereas the other four sites had poor or very poor water quality (50.32, 53.65, 57.59, 81.37). Planktons were studied to assess the community characteristics and to determine if they could be used as bioindicators. Among the 72 species recorded, 63 (87.5%) species were phytoplankton while only 9 (12.5%) species were zooplankton. Nauplius larvae and *Daphnia* sp. Appeared to respond to orthophosphate, conductivity, and temperature variations. Pearson's correlation revealed that the temperature, DO, TDS, TSS, orthophosphate, sulphate, chloride, and fluoride significantly correlated to spatial and temporal variations in plankton abundance and distribution. Canonical Correspondence Analysis (CCA) ordination shows that the most important measured environmental variable for the determination of phytoplankton species variations was sodium, followed by TDS, and DO. Zooplankton species were more sensitive to variations in TSS, followed by BOD5 and pH. Thus, the results of the present study reveal that planktons can be used to assess the quality of a flowing water system.

Keywords: Bioindicator, CCA, Environmental variables, Water quality, Water Quality Index

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EFFECT OF WATER QUALITY PARAMETERS ON PLANKTON COMMUNITIES IN A SELECTED REGION OF THE MAHAWELI RIVER IN KANDY DISTRICT, SRI LANKA

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Mahaweli River, the longest river in Sri Lanka, drains water from 16% of the total land area of the country and the river basin consists of a diverse array of landscapes. The river is known to experience pollution mainly due to human activities. The current study was designed to assess the level of the water quality change using plankton as biological indicators. The analysis of the water quality of the river starting from Polgolla Dam to Thannekumbura Bridge was carried out at three occasions in six sampling sites. The sampling sites were chosen considering water depth, riparian zone, and the level of human activities carried out along the river banks. Sampling was done in August 2020, and February and March 2021. Onsite measurements of temperature, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Dissolved Oxygen (DO) were taken using calibrated field instruments. A total of 39 species were recorded including 35 species of phytoplankton and four species of zooplankton with relative abundance of 98.8% and 1.19%, respectively. *Aulocoseira* sp. was the most abundant among the recorded plankton species and occupied 16.74% of the entire plankton community. *Navicula* sp., *Nitschia* sp., *Tribonema* sp., *Pandorina* sp., and *Pediastrum* sp. also showed high abundance. According to the identified zooplankton species, *Vorticella* sp. showed the highest abundance. Among the physicochemical parameters, pH ranged from 6.94 to 7.85 and the average DO ranged from 4.39 mg L^{-1} to 6.58 mg L^{-1}. The average TDS ranged from 49 mg L^{-1} to 57 mg L^{-1} and the conductivity ranged from 104 µS cm^{-1} to 124 µS cm^{-1}. According to the results of Canonical Correspondence Analysis (CCA), *Oscillatoria* sp. prefer high DO levels and *Phacus* sp., *Ankistrodesmus* sp., and *Gloeocapsa* sp. prefer low TDS and low conductivity levels. High abundance of certain diatom species indicates unpolluted water. However, an increase in the eutrophication indicating taxa (e.g. *Mycrosystis* sp.) from August 2020 to March 2021 warns the possibility of algal blooms within pool areas of the downstream regions.

Keywords: Mahaweli River, Phytoplankton, Water quality, Zooplankton

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ENVIRONMENTAL VALIDATION OF PLANKTON COMMUNITIES IN SELECTED VILLAGE RESERVOIRS AND ASSOCIATED INTERCEPTOR RETENTION BELT (KATTAKADUWA)

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There are several interrelated components in Sri Lankan reservoirs. Among them, Kattakaduwa is the area between the reservoir bund and the downstream paddy field which plays a vital role by absorbing salts and heavy metals from the seepage through the reservoir bund. Hence, there is a high salinity level in Kattakaduwa compared to the associated reservoir. It is generally accepted that plankton can serve as bioindicators of water quality as they are sensitive to many environmental factors. In this study, the variations of the environment in reservoirs and associated Kattakaduwa were assessed using the plankton communities. During the study, six reservoirs and associated Kattakaduwa were studied. Sampling was carried out monthly for four months. The environmental variables including pH, temperature, conductivity, Total Dissolved Solids (TDS), Dissolved Oxygen (DO) were measured on-site. Ion Chromatography was used to measure anions. The Relative Abundance, Shannon-Wiener Diversity Index, Simpson Diversity Index, Shannon Evenness Index and Species Richness values were calculated for both reservoirs and associated Kattakaduwa. Microsoft Excel, Minitab 17 and Canoco 5 for Windows were used for statistical analysis. Forty-seven phytoplankton species and eight zooplankton species from reservoirs and 44 phytoplankton species and six zooplankton species from Kattakaduwa were identified. Plankton community comprised of 93.8% phytoplankton and 6.2% of zooplankton in reservoirs and 97.1% of phytoplankton and 2.9% of zooplankton in Kattakaduwa. The most common plankton species were *Chroococcus* sp., *Cyclotella* sp., *Fragilaria* sp., *Navicula* sp., *Pediastrum* sp., *Nitzschia* sp., *Synedra* sp., and *Scenedesmus* sp. The most abundant phytoplankton species were *Nitzschia* sp. and *Navicula* sp. In reservoirs and *Cyclotella* sp., *Chroococcus* sp. and *Scenedesmus* sp. In Kattakaduwa. Among the zooplankton community the highest abundance was reported from *Vorticella* sp. (27.7%) and Cladocera (27.7%) in reservoirs and Rotifers (32.0%) in Kattakaduwa. *Lyngbya* sp. was limited to Kattakaduwa and several species were found to be limited to reservoirs including *Muogeotia* sp., *Spirogyra* sp., *Desmidium* sp., and *Chlorella* sp. and zooplankton species including Calanoid copepods and Nauplius larva. Commonly observed plankton species are considered to have a wider tolerance and found in both reservoirs and associated Kattakaduwa. Plankton diversity and species richness were confirmed to be high in reservoirs compared to the associated Kattakaduwa. Conductivity and TDS of Kattakaduwa were always greater than those of the associated reservoir. The salinity causes species to adjust to the saline conditions through osmoregulation. However, only a few species can overcome this pressure. Therefore, the lower species richness and diversity in Kattakaduwa was possibly due to the high salinity level.

Keywords: Kattakaduwa, Phytoplankton, Reservoir, Salinity, Zooplankton

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KEY DETERMINANTS OF FRESHWATER GASTROPOD COMPOSITION IN HULU GANGA AND MA OYA

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Studies on taxonomy, biology and ecology of Sri Lankan freshwater gastropods are extremely limited. Freshwater gastropods are found in a variety of habitats and their distribution is influenced by many environmental factors, especially water quality, of which there are only a few studies in Sri Lanka. The present study was conducted to determine the distribution of freshwater gastropods in relation to the water quality parameters, and elevation, in two tributaries of the Mahaweli River, namely Hulu Ganga and Ma Oya. Sampling was carried out from October 2020 to January 2021 and from April to May 2021 at 30 sampling locations each along the two streams. The elevation, pH, conductivity, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), temperature and flow rate were measured at each location. Correlation, regression and ordination analyses were used to see the relationship of the species abundance and environmental parameters of the study sites. Eight freshwater gastropod species belonging to five genera were recorded from the two streams. Correlation analyses indicated that specific environmental factors had significant species-specific effects. The elevation had a significant negative (-0.709, $p < 0.01$) while conductivity (0.567, $p = 0.005$)) and TDS (0.587, $p = 0.003$) had significantly positive correlations with the abundance of *Paludomus chilinoides* in Ma Oya. The abundance of *P. bicinctus* had significant positive correlations with elevation and flow rate in both streams while conductivity (-0.531, $p = 0.023$) and temperature (-0.669, $p < 0.01$) had negative correlations in Hulu Ganga. *P. decussatus* showed a negative correlation with TDS (-0.609, $p = 0.008$)). *Indoplanorbis exustus* abundance decreased significantly with the increase in conductivity (-0.668, $p < 0.01$), TDS (-0.619, $p = 0.02$) or flow rate (-0.665, $p = 0.001$) while elevation (0.413, $p = 0.05$) had a positive correlation. Furthermore, Canonical Correspondence Analysis (CCA) indicated that DO, TDS, conductivity and elevations have a combined effect on the gastropod assemblage in Hulu Ganga, whereas pH, conductivity, DO and temperature affect the gastropod composition in Ma Oya. However, the measured environmental variables were able to explain 95.76% variation in gastropod abundance in Hulu Ganga, whereas only 60.63% variation in gastropod abundance was explained by measured environmental variables in Ma Oya. Hence, there may be other unmeasured environmental factor(s) that influence the diversity and distribution of freshwater gastropods in Ma Oya.

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Keywords: Elevation gradient, Environmental parameters, Freshwater, Gastropods

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REPRODUCTIVE IMPACTS OF TRIBUTYLTIN (TBT) IN MARINE MOLLUSKS IN SRI LANKA

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Tributyltin (TBT) has been widely used in a variety of consumer and industrial products including aquaculture, pesticides, antifouling paints for ship hulls, and other structures exposed to marine waters. TBT adversely affects and interrupts steroid metabolism through the conversion of testosterone to estradiol 17β causing development of reproductive impairments such as imposex in female invertebrates. The present study aimed to assess the current state of reproductive impairments and tributyltin concentrations in five species of mollusks, namely *Crassostrea madrasensis, C. cucullata, Perna viridis, P. perna,* and *Thais clavigera* collected from eight different harbors in Sri Lanka: Trincomalee, Hambanthota, Kirinda, Dewundara, Mirissa, Galle, Dikkowita, and Colombo port. Biological samples were collected and immediately frozen at -80 °C. In 50% of the samples, the shells were removed and the soft tissues were weighed individually. The tissues of *T. clavigera* were kept for dissections and the examination of imposex development. Tissue samples were freeze-dried, ground, and used to analyze TBT. The results of the study showed that the highest TBT contamination was in *P. viridis* (234 ± 3 ng kg^{-1}) collected from Dikkovita harbor. Based on the availability of test organisms, *T. clavigera* was selected as the most suitable bio indicator to assess reproductive impairment incidence in selected harbors in Sri Lanka. Relative Penis Length Index (RPLI) of imposex affected females *T. clavigera* ranged from 15.53% to 24.77%. The highest RPLI and imposex frequency (1%) were recorded in Dikkovita which is one of the busiest fishery harbors in Sri Lanka. This study provided baseline data that could serve for long-term monitoring of TBT pollution in Sri Lankan coastal waters.

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Keywords: Bioindicator, Colombo port, Imposex, Marine mollusks, Tributyltin

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SPECIES DIVERSITY AND ABUNDANCE OF PHYTOPLANKTON AND ZOOPLANKTON ALONG THE HAMILTON CANAL, SRI LANKA

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The overall quality of a selected ecosystem depends on the species diversity and abundance. Major environmental conditions including seasonal changes and changes in water quality drive the species composition and richness of aquatic ecosystems. The present study focused on reporting the present status of the species diversity and abundance of plankton, and water quality in the Hamilton Canal during the dry and wet seasons. Ten sampling sites were selected to represent its variability. Sampling was carried out during both wet (August and September) and dry (February and March) seasons. Sampling sites were accessed using a motorboat and on-site water quality parameters were measured. Water samples were also collected for laboratory analysis and transported at 4 °C. All the water quality parameters and plankton samples were collected and analyzed following standard methods. Pearson correlation and Principal Component Analysis were performed to determine the correlations of species diversity, water quality and sampling sites. During the study period a total of 167 phytoplankton species and seven zooplankton species were identified. *Nitzschia reversa* dominated the phytoplankton community with a relative abundance of 35.6% while copepod species in the zooplankton community were dominant in both seasons during the study period. Results revealed that the Electrical Conductivity (EC), salinity, Secchi depth, Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and Biochemical Oxygen Demand (BOD_5) values significantly correlated ($p < 0.05$) with the abundance of phytoplankton whereas the EC, salinity, TDS, orthophosphate and alkalinity significantly correlated with the abundance of zooplankton ($p < 0.05$). The diversity and abundance of the plankton species greatly increased during the dry season compared to the wet season. The water quality parameters showed that the Hamilton canal is a unique ecosystem with dynamic water quality changes.

Keywords: Species abundance, Species diversity, Phytoplankton, Water quality, Zooplankton

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POTENTIAL OF HOT SPRING THERMOPHILIC BACTERIA TO ENHANCE THE PRODUCTION OF ORGANIC FERTILIZERS

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Maximizing the productivity of agricultural lands is an essential process. Chemical and organic fertilizers are utilized to obtain the maximum productivity. Excess usage of chemical fertilizers affects floral and faunal diversity and causes soil infertility, water pollution, eutrophication, and accumulation of heavy metals. Hence, the use of organic fertilizers in agricultural fields is encouraged. However, the production of organic fertilizers in adequate amounts remains a major challenge. Therefore, it is essential to develop strategies to enhance the process of organic fertilizer production. This can be achieved using high temperatures during the production process. However, high temperatures may hinder the activity of mesophilic microbial communities and adversely affect the productivity of organic fertilizer. Instead, thermal-tolerant bacteria may be successfully used in organic fertilizer production. Hot springs are a major habitat for thermo-tolerant bacteria that produce thermo-stable enzymes. Identification and characterization of potential microbial communities in hot springs that produce such enzymes could lead to novel developments in the fertilizer industry. In the present study, the potential of the hot spring microbial community in Sri Lanka for the production of organic fertilizer was studied. Water samples were collected from the surface and bottom of Maha Oya, Wahava, Madunagala, and Kivlegama hot springs in Sri Lanka during May 2018. The temperature, conductivity, pH, and Dissolved Oxygen (DO) were measured on-site using portable meters. To analyze the microbial community (bacteria and archaea) of hot springs, extracted DNA was sequenced through 16s rDNA amplicon sequencing on Illumina MiSeq platform. The metabolic functional diversity of the bacterial and archaeal communities was predicted using taxonomic data. The temperature of the hot springs ranged from 33.7 - 55.4 °C whereas conductivity, pH and DO levels ranged from 801 - 1507 µS cm^{-1}, 7.20 - 8.27, and 1.05 – 3.5 mg L^{-1} respectively. *Chloroflexus, Rubellimicrobium, Acinetobacter,* and *Pseudomonas* were the major genera of bacteria recorded in all hot springs. According to the metabolic inference analysis of the microbial community, the hot springs are mostly comprised of nitrogen fixing bacteria, lignin degraders, nitrogen and sulfate reducers, sulfur reducers, denitrifying bacteria, cellulose degraders, and pollutant degraders which are commonly and efficiently used in organic fertilizer production. Thus the results of the present study implied that the hot springs could be a useful source of bacteria for the production of organic fertilizers. The applications of culturable bacterial isolates to enhance the organic fertilizers are being investigated.

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Keywords: α-amylase, Biotechnology, Enzymes, Hot springs, Thermophiles

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ASSESSMENT OF WATER QUALITY AND PLANKTON DIVERSITY IN A SELECTED REGION OF THE MAHAWELI RIVER IN KANDY DISTRICT, SRI LANKA

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Mahaweli River is one of the main sources of freshwater in Sri Lanka. Due to human activities, the river has been subjected to severe threat of pollution, in recent times. Planktons are highly sensitive to surrounding environmental conditions and thus are used as bioindicators to investigate the temporal and spatial changes in the environment. The aim of the present study was to explore the possibility of using planktons to measure environmental changes in a selected region of the Mahaweli River. The study was carried out from February to July 2019, and physicochemical and biological parameters of the river starting from the Katugastota bridge to the Polgolla dam were analyzed. Temperature, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), pH, and Electrical Conductivity (EC) were measured onsite, once a month from six study sites. Water samples were collected from the same locations using standard methods for laboratory analysis of fluoride, chloride, nitrate, nitrite, and sulfate. Water samples were taken using a plankton net with 20 μm mesh size for qualitative and quantitative analysis of both zooplankton and phytoplankton. Planktons were analyzed using a research microscope with phase contrast optics. Data were analyzed using Canonical Correspondence Analysis (CCA), Cluster Analysis, and Pearson Correlation to visualize the correlations (if any) between physicochemical and biological parameters. During the study, 40 species of phytoplankton (97.78%) and six species of zooplankton (2.22%) were recorded. The most abundant zooplankton were rotifers (1.25%) and the most abundant phytoplankton were diatoms (56.97%). Among the physicochemical parameters, pH ranged from 7.05 to 7.36, and the average DO ranged from 3.74 mg L^{-1} to 5.67 mg L^{-1}. Average TDS ranged from 45 mg L^{-1} to 84 mg L^{-1} and the EC ranged from 101 μS cm^{-1} to 150 μS cm^{-1}. The CCA showed that the most important environmental parameters that determine the species variation among the sites include nitrite and pH. Moreover, a high level of nitrite appears to favor *Arthrodesmus* sp. and a high level of DO and fluoride are best suited for *Alonella* sp. In addition, *Micractinium* sp. prefers a high level of conductivity. Diatoms including *Synedra* sp. and *Navicula* sp. thrive well in unpolluted waters. Thus, it is evident that the plankton respond to changes in the surrounding environment.

Keywords: Freshwater, Mahaweli River, Phytoplankton, Zooplankton

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WATER QUALITY AND HUMAN HEALTH

ASSESSMENT OF GROUNDWATER QUALITY IN RELATION TO CHRONIC KIDNEY DISEASE IN YAN OYA RIVER BASIN, SRI LANKA

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Chronic Kidney Disease of unknown etiology (CKDu) is a widespread health issue in the Dry Zone of Sri Lanka. Geographically, the disease is more prevalent in the North Central Province and its bordering regions. The disease occurs in certain pockets (hotspots) in the Dry Zone regions. However, it is not reported in some Dry Zone villages (cold spots) and the Wet Zone of the country. This study focused on the Yan Oya watershed, which encompasses CKDu hotspots such as Kebitigollewa, Horowpathana and cold spots including Huruluwewa. A majority of the population in these regions uses groundwater as their source of drinking water. Among the various causative factors proposed for the disease, the quality of drinking water is of high concern. Eighty-five groundwater samples were collected from dug wells and tube wells, from February to April 2021. pH and electrical conductivity (EC) were measured *in-situ* using portable pH and conductivity meters. Alkalinity, hardness, and chloride were measured using a digital titrator while fluoride, sulfate, phosphate, and nitrate were determined using a spectrophotometer. Major cations (Na, K, Ca, and Mg) were measured using Atomic Absorption Spectrophotometry (AAS), while trace metals (Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, and Pb) were measured by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The mean contents of pH, EC, alkalinity, hardness, fluoride, chloride, sulfate, phosphate, and nitrate in water were higher in CKDu hotspots than in cold spots. The fluoride levels of water in CKDu hotspots varied from 0.02 to 4.00 mg L^{-1} with a mean value of 0.84 mg L^{-1}, while it varied from 0.02 to 2.26 mg L^{-1} with a mean value of 0.74 mg L^{-1} in CKDu cold spots. The fluoride contents in most wells (60%) in the hotspots were above 0.5 mg L^{-1}, while it was 57% in cold spots. Sixty-nine per cent of groundwater samples in hotspots exceeded the highest desirable level of hardness (250 mg L^{-1}) (SLS 614; 2013), whereas only 58% of samples exceed the limit in cold spots. Although toxic heavy metals (Cd, As) are widely attributed to CKDu, none of them were found in excess in the analyzed samples. This study showed that water hardness and fluoride have a considerable impact on CKDu, either for the etiology or the disease progression.

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Keywords: CKDu, Dry Zone, Fluoride, Groundwater, Water hardness

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CORRELATION OF LOW-GRADE TEA CONSUMPTION WITH CHRONIC KIDNEY DISEASE OF UNKNOWN ETIOLOGY (CKDu): A CASE STUDY FROM MADAWACHCHIYA, SRI LANKA

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Chronic Kidney Disease of unknown etiology (CKDu) is a burning health issue in the Dry zone of Sri Lanka causing a number of socio-economic and health care issues. This study was designed to investigate the effect of daily tea consumption on CKDu in Mahadivulwewa Grama Niladhari Division. The study consisted of two major parts: a demographic study to obtain patients' data and laboratory procedures to analyze tea and water samples from the area. In the laboratory procedures, Electrical Conductivity (EC), Total Dissolved Solids (TDS), anions, cations and trace metals were analyzed for both water and tea infusions. Tea infusions were prepared with low grade tea (unpacked and dust tea) and water obtained from Reverse Osmosis (RO) filter from the study area while BOPF tea and bottled water were used as the reference. Tea brewing was done according to the ISO standard procedure. EC, TDS and pH were analyzed using portable meters. The anion content was analyzed by ion chromatography while the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was used to analyze the cations and trace metal content. The demographic analysis revealed that more than 95% of the patients consume low grade tea, 80% of patients are elderly (age > 55 yrs.) and more than 75% are farmers. Majority of the patients were elderly farmers working under direct sunlight. Hence, they are more prone to dehydration and tend to use refreshing drinks such as tea. There were four RO plants in the study area and filtered and unfiltered samples from all these sources were studied. All filtered and unfiltered water were within the WHO permissible limits for all the measured parameters, but unfiltered water had significantly high anion, cation and trace metal concentrations which are identified as major risk factors for CKDu. Tea infusions that are made from low grade tea recorded excessive concentrations of chromium (> 50 µg L^{-1}), cadmium (> 5 µg L^{-1}), lead (> 5 µg L^{-1}), calcium (> 70 mg L^{-1}), magnesium (> 40 mg L^{-1}) and fluoride (> 10 mg L^{-1}) which are major risk factors for CKDu. The results support the most defended hypothesis of combined effect of fluoride and hardness as the cause for CKDu. The BOPF tea samples which were used as the reference have shown significantly low cation and trace metal contents compared to the low-grade tea infusions. Usually, younger tea leaves are used to manufacture BOPF and higher-grade tea types in which the particle size is higher than the low-grade tea which is manufactured using the older tea leaves and this should be the reason for lower trace metals and cation contents in BOPF tea. Thus, it is evident that there is a significant contribution from the high consumption of low-grade tea to CKDu. Therefore, it can be recommended that the usage of high-grade tea types (BOPF or above grades) could significantly reduce the risk factors for CKDu by tea consumption.

Keywords: Cations, CKDu, Risk factors, Tea, Trace metals

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NEPHROTOXICITY EFFECTS OF MICROCYSTIN-LR ON MAMMALIAN KIDNEY

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Microcystin-LR (MC-LR) is known as a potent hepatotoxin, and recent, limited studies have shown nephrotoxicity of MC-LR in mammals. Thus, the aim of this study was to evaluate the potential chronic effects of MC-LR on the kidney of Wistar rats. Rats were randomly divided into five groups (n = 7) and four groups were treated with different concentrations of MC-LR: 0.105 µg kg^{-1}, 0.070 µg kg^{-1}, and 0.035 µg kg^{-1}, and distilled water as the control. The fifth group was treated with water contaminated with MC-LR (0.091 µg kg^{-1}) collected from a dug well in Padaviya, an area identified for high prevalence of Chronic Kidney Disease of unknown etiology (CKDu) in Sri Lanka. Blood samples were collected on 0, 7, 14, 28, 42, 60 and 90 days to evaluate urine creatinine and serum creatinine. Kidney Injury Molecule-1 (KIM-1) level in urine was quantified weekly using Enzyme-Linked Immunosorbent Assay (ELISA). At the end of the 90 days, rats were euthanized, and the kidneys of each rat were fixed for histopathological assessment. The results showed that the mean body weight of the treated groups gradually increased until the 12th week and thereafter decreased ($p < 0.01$) compared to the control group. The absolute and relative weights of kidneys of the treated groups were significantly less ($p < 0.05$) than the control group. A serum creatinine concentration increment from 0.50±0.01 to 0.59 ± 0.05 mg dL^{-1}, 0.50 ± 0.02 to 0.55 ± 0.06 mg dL^{-1}, 0.50 ± 0.02 to 0.54 ± 0.09 mg dL^{-1}, 0.50 ± 0.02 to 0.57 ± 0.06 mg dL^{-1} were detected in rats treated with 0.105 µg kg^{-1}, 0.070 µg kg^{-1}, 0.035 µg kg^{-1} and 0.091 µg kg^{-1} doses of MC-LR respectively compared to the control (0.50 ± 0.01 to 0.51 ± 0.02 mg dL^{-1}) at 90 days of exposure. A reduction in urine creatinine concentration from 52 ± 1 to 43 ± 5 mg dL^{-1}, 51 ± 1 to 44 ± 1 mg dL^{-1}, 52 ± 2 to 46 ± 7 mg dL^{-1} and 52 ± 2 to 43 ± 7 mg dL^{-1} was found in rats treated with above MC-LR doses. The highest KIM-1 concentrations were recorded in rats treated with the 0.105 µg kg^{-1} MC-LR whereas it was low at the lower doses of MC-LR, while it was not detected in the control group. The second highest KIM-1 concentration was recorded in rats treated with the dug well water sample. The histological changes were subtle with occasional luminal proteins, mild tubular epithelial swelling, vascular congestion, and interstitial inflammation at MC-LR 0.105 µg kg^{-1}, mild tubular epithelial swelling, and occasional luminal proteins at 0.091 µg kg^{-1} and 0.070 µg kg^{-1} and mild epithelial swelling at 0.035 µg kg^{-1}. The results of this study suggest that prolonged exposure to MC-LR is associated with histologically subtle and variable kidney injury.

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Keywords: Histopathology, KIM-1, MC-LR, Serum Creatinine, Urine Creatinine,

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EVALUATION OF SYNERGISTIC EFFECT OF FLUORIDE AND HARDNESS ON NEPHROTOXICITY USING WISTAR RATS AS AN ANIMAL MODEL

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The prevalence of Chronic Kidney Disease of unknown etiology (CKDu) has been escalating and reported among the rural farming communities in the North Central Dry Zone of Sri Lanka. The geographic areas with high CKDu prevalence are well correlated with the areas of high concentrations of both fluoride and hardness in drinking water. The present study focused to evaluate the synergistic effect of water hardness and fluoride on nephrotoxicity using Wister rats expose to water samples collected from Galnewa in Anuradhapura district (CKDu prevalent) and Angunukolapelessa in Hambanthota district (CKDu non prevalent) areas. Twenty-one Wistar rats were randomly assigned into three groups (n = 7), control, test 1 and test 2. Control group was given de-ionized water and test groups 1 and 2 were treated with well water collected from Galnewa and Angunukolapelessa areas, respectively. Prior to the treatment, physicochemical and microbiological parameters of water samples were analyzed using standard methods. Body weight and daily water consumption of each rat were measured and blood and urine samples were collected on 0, 7, 14, 28, 42, 60, 90, 120 and 150 days for serum creatinine, urine creatinine and urinary biomarker Kidney Injury Molecule-1 (KIM-1) analysis. The concentrations of fluoride and hardness in water samples collected from Galnewa and Angunukolapelessa were 1.53 and 216 mg L^{-1} and 0.281 and 92 mg L^{-1}, respectively and the other water quality parameters remained within the Sri Lanka standards for drinking water. No significant differences in body weights and daily water consumption of treated and control groups were recorded ($p > 0.05$). An increment in the average serum creatinine concentration was observed from test 1 (0.35 to 0.72 mg dL^{-1}) ($p < 0.05$) to test 2 (0.66 to 0.95 mg dL^{-1}) ($p > 0.05$) compared to the control (0.56 to 0.71 mg dL^{-1}). Decrease of the average urine creatinine of the control, test 1 and 2 ranged from 152.54 to 142.85, 142.53 to 112.34 ($p < 0.05$) and 165.28-139.28 ($p > 0.05$) mg dL^{-1} respectively. KIM-1 was not detected in the control and test group 2 which was treated with water collected from CKDu non-prevalent area. However, the test group 1 that was exposed to water collected from the CKDu prevalent Galnewa area, KIM-1 was detected at 0.26 ng mL^{-1} by the 150th day. Thus, the increment of serum creatinine level, reduction of urine creatinine level and detection of KIM-1 levels in test group 1 indicate the nephrotoxic effect of the rats exposed to water collected from Galnewa where CKDu is prevalent. Thus, the results of this study suggest that the chronic synergistic effect of water hardness and fluoride may contribute to the etiology of CKDu in Sri Lanka.

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Keywords: CKDu, Fluoride, Nephrotoxic effect, Water hardness, Wistar rats

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PRESENCE OF ANTIBIOTICS IN AQUACULTURE WASTEWATER: A CHALLENGE FOR ANIMAL AND HUMAN HEALTH

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Heavy usage of antibiotics in aquaculture has resulted in the emergence of antibiotic-resistant bacteria in the environment. The present study was carried out to quantify the 12 commercially used antibiotics [Oxytetracycline (OTC), Tetracycline (TET), Sulfanomide (SDI), Sulfadiaoxine (SUF), Amoxicillin (AMX), Amphicillin (AMP), Cloxacillin (CLOX), Ciprofloxacin (CIP), Gentamycin (GEN), Azythromycin (AZY), and Erythromycin (ERM)] in wastewater discharge from 16 aquaculture facilities in Sri Lanka. Wastewater samples were collected in triplicate from each facility. Following Solid-Phase Extraction (SPE), antibiotics in the samples were quantified using High-Performance Liquid Chromatography (HPLC). Recoveries for each antibiotic ranged from 83 ± 0.021% to 95 ± 0.034%. Range of OTC concentrations in shrimp hatcheries were recorded from 0.056 ± 0.001µg mL^{-1} to 0.234 ± 0.014 µg mL^{-1}, and in food fish and, ornamental fish farms from 0.008 ± 0.002 µg mL^{-1} to 0.221 ± 0.012 µg mL^{-1} and from 0.009 ± 0.001 µg mL^{-1} to 0.031 ± 0.005 µg mL^{-1}, respectively. Similarly, high TET concentrations were recorded in shrimp hatcheries (0.012 ± 0.009 µg mL^{-1}-0.112 ± 0.017 µg mL^{-1}) compared to ornamental (0.001 ± 0.001 µg mL^{-1}-0.002 ± 0.001 µg mL^{-1}) and food fish farms (0.001 ± 0.001 µg mL^{-1}-0.076 ± 0.012 µg mL^{-1}). Penicillin (AMX, AMP, CIP) and sulfonamide (SDI, SUF) group antibiotics were not detected in effluent water tested. The results of the study revealed that contamination levels of antibiotics in some effluent water have exceeded the maximum permissible level (< 0.001 mg L^{-1}) given for aquatic environments by the WHO. Thus, the present study suggests that antibiotic contaminated wastewater is a potential source for antibiotic residues and antibiotic-resistant bacteria that may cause health risks for both aquaculture organisms and humans.

Financial assistance from the Centre for Water Quality and Algae research, University of Sri Jayewardenepura is acknowledged.

Keywords: Antibiotics, Aquaculture, Oxytetracycline, Resistance, Tetracycline

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HUMAN HEALTH RISKS ASSOCIATED WITH HIGH FLUORIDE INTAKE IN WALAWE RIVER BASIN, SRI LANKA

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Health risks associated with excessive intake of fluoride through drinking water in the Dry Zone of Sri Lanka have become a nationally important environmental health problem. Lower Walawe River basin has been identified as a region with higher incidence of fluoride related health issues. In this study, spatial and temporal variations in groundwater fluoride content and potential health risks for residents in the Walawe River basin were investigated. One hundred and twenty-six groundwater samples were collected from 38 deep and 25 shallow wells covering the entire basin during pre-and post-monsoon periods. The potential health risks associated with elevated fluoride intake through drinking water in adults and school-aged children in the study region were calculated by the hazard quotient ($HQ_{fluoride}$) using the model recommended by the United States Environmental Protection Agency. Elevated levels of fluoride (> 1.5 mg L^{-1}) were detected in deep groundwater during the pre- and post-monsoon periods (1.45 and 1.96 mg L^{-1}, respectively) in the Dry Zone area of the basin. High fluoride in groundwater was primarily of geogenic in origin, mainly due to dissolution of fluoride-bearing minerals and evapotranspiration. Based on the results obtained from $HQ_{fluoride}$, 45% pre- and 55% post-monsoon groundwater samples in the Dry Zone area were unsuitable for drinking purposes for school-aged children, as it causes dental fluorosis. The results of this study also indicated that school-aged children are more vulnerable to non-carcinogenic risks induced by fluoride than adults. The findings further emphasized the need for continuous water quality monitoring and development of mitigation systems in the Dry Zone to ensure the health of residents.

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Keywords: Climatic regions, Dental fluorosis, Groundwater contamination, Hydro-geochemistry, Water-rock interaction

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WATER TREATMENT

POLYETHYLENEIMINE/SAWDUST COMPOSITE FOR ADSORPTIVE REMOVAL OF HEXAVALENT CHROMIUM FROM AQUEOUS SOLUTIONS

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Releasing chemical hazards to water bodies causes a major pollution issue in today's world. Heavy metals are one of the chemical pollutants that persists in the environment as they are non-biodegradable, and they have the ability to bioaccumulate. They cause severe health hazards when their concentration exceeds the optimum threshold. Chromium and its compounds are released to water bodies from various industries such as electroplating, leather tanning, paint, textile, and steel industries. Hexavalent chromium [Cr(VI)] is identified as carcinogenic, mutagenic and known to cause liver damage, pulmonary congestion and skin irritation resulting in ulcer formation. Several methods such as adsorption, chemical precipitation, reverse osmosis, ion- exchange, and foam flotation are used for chromium removal. In comparison with other techniques, adsorption offers significant advantages such as low cost, availability, ease of operation, efficiency, and profitability. Therefore, the adsorption of Cr(VI) from aqueous solutions by polyethyleneimine/sawdust (PEI/SD) composite was investigated in this study. The chromium concentration was measured by the Atomic Absorption Spectrometer (AAS). PEI was synthesized using ethanolamine as the starting material. The composite was characterized by Fourier Transform Infrared Spectrometer (FTIR) and Scanning Electron Microscope (SEM). The best composite was found as the composite which had saw dust particle size less than 100 µm and monomer to sawdust ratio 5:1. The maximum removal of Cr(VI) was found to be 80% for the Cr(VI) concentration of 60 mg L^{-1} at room temperature and pH 6 with the composite dosage of 0.2000 g, shaking time of 60 min and settling time of 15 minutes. In comparative studies of adsorption by sawdust, PEI and PEI/SD composite the highest adsorption of Cr(VI) was recorded for the composite. The adsorption process follows second order kinetics, indicating that the rate determining step is chemisorption. In equilibrium adsorption studies, adsorption data better fitted with Langmuir adsorption isotherm, indicating monolayer adsorption. The pH at the point of zero charge of the adsorbent was 9. Under desorption studies, highest desorption was achieved at pH 2 and the desorbed percentage is almost zero around pH 6 – 8. Hence, the Cr(VI) adsorbed composite is harmless to natural water bodies as acidic conditions are not usual in natural water bodies.

Keywords: Adsorption, Chromium, Polyethyleneimine, Sawdust

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POST-CONSUMER PET BOTTLES AS A SOURCE OF MIL-53(Al) MOF SYNTHESIS AND ITS APPLICATION IN ADSORPTIVE REMOVAL OF CONGO RED DYE FROM AQUEOUS SOLUTIONS

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Plastic pollution has now become a global concern since plastic is found everywhere on the planet, threatening the ecological balance of the environment and its components. Polyethylene terephthalate (PET) bottles are a type of single use plastic found as a major component of plastic waste. The objective of this study was to use these waste, post-consumer PET as a source in the synthesis of the MIL-53(Al) MOF and to study its potential as an adsorbent in the removal of carcinogenic, anionic Congo red dye. The PET bottles were chemically recycled using the acid hydrolysis method. The polymer was depolymerized into its monomer units, benzene-1,4-dicarboxilic acid (BDC) and ethylene glycol (EG) using H_2SO_4 as a catalyst at 80 °C. BDC was isolated by precipitation, and it was characterized using Fourier Transform Infrared (FTIR) spectrometry. It was then used with Al_2O_3 in the hydrothermal synthesis of MIL-53(Al) MOF at 200 °C for 72 h. The resulting MOF was purified with DMF and activated by heating. The MOF was characterized with FTIR and Power X-Ray Diffraction (PXRD) analysis. Adsorptive studies and kinetic studies were carried out to determine the adsorption capacity of Congo red to the synthesized MIL-53(Al) MOF. The parameters *viz*. pH, initial dye concentration, adsorbent dosage, shaking time and settling time were optimized to get the maximum dye removal. According to the results, the depolymerization of post-consumer PET by acid hydrolysis resulted in BDC, in an average of 70% yield. The optimized parameters for adsorptive removal of the Congo red dye by the synthesized MOF were found as pH of 3, 40 mg L^{-1} of initial concentration of the dye, 0.05 g of dosage of adsorbent and 20 minutes of shaking time. It was found that the settling time had no effect on the adsorption. The kinetic study revealed that the reaction follows pseudo-second order kinetics, where the adsorbent is chemisorbed to the MOF particles. Based on these results, it can be concluded that the post-consumer PET waste can be used as a source for MOF synthesis which can be effectively used as an adsorbent to remove Congo red dye present in aqueous solutions.

Keywords: Acid hydrolysis, Adsorbent, Congo red, MIL-53(Al) MOF, Poly(ethylene terephthalate)

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REMOVAL OF FLUORIDE IN WATER USING HYDROXYAPATITE NANOPARTICLES DERIVED FROM NATURALLY OCCURRING DOLOMITE

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Water pollution is due to two causes which are natural and anthropogenic. Contamination of groundwater by fluoride is basically through natural causes due to weathering of fluoride-containing minerals. Fluoride in drinking water has both beneficial and detrimental effects on human health which depend on the concentration and the amount ingested. Fluoride is beneficial to maintain human dental and skeletal health. Therefore, the fluoride level of drinking water should be within the tolerable limit. The present critical level is set at 0.5 - 1 mg L^{-1} by the World Health Organization. Above this level is detrimental due to chronic effects causing dental and skeletal fluorosis and damage to organs such as kidneys. Drinking water in chronic kidney disease of unknown etiology (CKDu) affected areas is known to contain excess fluoride. As such, the removal of fluoride to desirable levels is of prime importance for human health. As a solution to this problem, we have developed hydroxyapatite (HA) nanoparticles from naturally occurring dolomite and used them to remove fluoride in drinking water. In this method, dolomite was used as the source of calcium oxide/calcium hydroxide and it was reacted with calcium sucrate solution and then with ammonium phosphate solution to develop HA nanoparticles. Then, the synthesized nanoparticles were characterized by powder X-ray diffraction, Fourier-transform infrared spectroscopy, particle size analyzer and scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy. In addition, the fluoride removal efficiency of synthesized hydroxyapatite nanoparticles was tested with different concentrations of fluoride solutions, pH, adsorbent dosages, and contact times. Before and after treating with synthesized HA nanoparticles, fluoride concentration in water was analyzed using ion chromatography. A maximum fluoride removal percentage of 98% was obtained with 50 mL of 10 mg L^{-1} fluoride solution, 20 minutes of contact time and 0.30 g of synthesized HA nanoparticles. It was found that fluoride adsorption by HA nanoparticles is less sensitive to pH variations (4 – 9). Adsorption data fitted with the Langmuir isotherm model and pseudo second order kinetic model with $R^2 = 0.99$. Therefore, this study presents a viable option for removing excess fluoride in water to desirable levels as a means of controlling fluoride-induced diseases.

Keywords: Adsorption, Dolomite, Fluoride removal, Hydroxyapatite nanoparticles

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IMPLEMENTING NATURAL RECHARGE WELLS IN SRI LANKA FOR A BETTER STORM WATER MANAGEMENT

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The impact of climate change has modified the weather patterns all over the world. Exceptionally heavy frequent rainfall events and associated local floods have been reported in many areas in Sri Lanka during the recent past. The amount of surface run-off depends on the rate of infiltration which is determined by soil characteristics. Particularly, urbanization and development projects often convert existing surfaces impermeable. Such surfaces reduce the groundwater recharge and therefore storm water management to reduce the local flooding. can make a significant positive impact on the environment and people. Local floods destroy settlements, roads, irrigation reservoirs and in some instances spread infectious diseases. Recovery takes a long time before coming back to normalcy. Therefore, this paper aims to propose implementing of Natural Recharge Wells (NRWs) for management of excess storm water, which involves storm water harvesting and recharge to groundwater aquifers. Hydrology, of the watershed and ground water level should be considered to select any place for recharge well. Well digging is done up to the desired depth and diameter to accommodate the incoming water. Concrete rings are then lowered into the well to protect collapsing of walls. The bottom of the well is kept un-plastered to allow infiltration. The annular space between the rings and the wall of the well is filled with granular material such as tock chips or gravel. to ensure protection of the rings while infiltration is also enhanced. The well size, depth and number of recharge wells are determined based on the catchment area, the rate of rainwater run-off, soil characteristics, geological condition, and infiltration rate into the soil. The Opening of the NRWs are covered with a wire mesh of good quality protect the well from falling impurities and to avoid accidents. NRWs have no standardized size, each has its own size. NRWs are one of the several structures that can help achieving long-term water sustainability by increasing the natural recharge of groundwater aquifers while also mitigating water logging, local flooding and in coastal areas, controlling the salt water intrusion. However, initial cost of construction, quality of the recharge water, proper maintenance and required technical skills need to be considered.

Keywords: Infiltration, Local flood, NRW, Precipitation, Water logging

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MAGNETIC MgO NANOADSORBENT FOR EFFECTIVE REMOVAL OF Pb(II) FROM AQUEOUS SOLUTIONS

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Among heavy metal ions, Pb(II) is a common pollutant found in industrial wastewater. Magnesium oxide shows a high adsorption capacity towards Pb(II) and can be magnetically separated from treatment systems by immobilizing a magnetic particle inside. In this study, MgO encompassed Fe and Fe_3O_4 nanoparticles were synthesized considering the high adsorption capacity of MgO and strong magnetism of Fe and Fe_3O_4. Iron core was prepared by using $FeCl_3.6H_2O$ with the dropwise addition of $NaBH_4$ in an inert N_2 environment. $Mg(OH)_2$ cover was prepared by using $MgCl_2.6H_2O$ with the dropwise addition of NH_4OH. Finally, the product was calcined to produce magnetic MgO nanoparticles. X-Ray Diffraction (XRD) analysis indicated that the final product was composed of cubic structures of Fe, Fe_3O_4, and periscale MgO. Scanning Electron Microscope (SEM) image analysis on magnetic MgO showcased a granular particle morphology with an average particle size of about 100 nm. Fourier Transformed Infrared (FTIR) analysis data confirmed successful Pb(II) adsorption onto magnetic MgO. Pb(II) adsorption experiments were carried out to study the adsorption process. Experimental data obeyed the Langmuir isotherm model and the pseudo second order kinetic model with higher regression correlation of 0.9955 and 0.9672 respectively. This suggests a fast monolayer chemisorption process. Langmuir theoretical adsorption capacity was determined to be 1178.6 mg g^{-1}. Further experiments were carried out to determine the effectiveness of magnetic MgO as an adsorbent for Pb(II) at different initial pH values. The highest Pb(II) adsorption was achieved when the initial solution was pH 5. The absorbed Pb(II) can be desorbed effectively via a CO_2 treatment. Magnetic MgO nanoparticles can be regenerated by the calcination of the Pb(II) desorbed product. Magnetic MgO nanoadsorbent has promising applications for removing Pb(II) from water considering the advantages of high adsorption capacity, high efficiency, easy separation, and eco-friendliness.

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Keywords: Adsorption, Lead, Magnetic MgO, Nanoadsorbent

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MEMBRANE-DRIVEN WATER TREATMENT FOR WATER DESALINATION WITH NEAR-ZERO WASTES GENERATION

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Over 3.8 million people living in the Dry Zone of Sri Lanka experience lack of drinking water largely due to palatability issues. As an interim measure, the National Water Supply and Drainage Board and private organizations introduced Reverse Osmosis (RO) technology to water desalination which removes almost all solutes in water. However, when inappropriately used, the RO technology desalinates water excessively, which also results in palatability problems due to lack of solutes. Nonetheless, membrane-based technologies are at the forefront of the world since they do not require chemicals excessively. In this research, an appropriate membrane configuration to desalinate groundwater using commercial membranes was examined. Particular attention was paid to treat wastes to minimize soil salinity issues. The concentrate of the community plant which has an approximate Total Dissolved Solids (TDS) of 3000 mg L^{-1}, was mixed with raw water and supplied for washroom use. The flushing water was used for gardening purposes. An automated laboratory-scale Nano Filtration (NF)/RO plant was developed to desalinate water collected from the dry zone using commercially available membranes. Based on the model plant, protocols were made for reverse flush, backwash, and chemical cleaning and used to upgrade a remote controlling application for a plant. The NF/RO treatment configuration was optimized for a community plant, and water quality parameters were modelled for at plant outlets. A chemical cleaning process was established for the community plant to avoid the efficiency decrement from carbonate fouling. The remote controlling application is functioning for a laboratory model. The predicted values of hardness, TDS and F^- from the model for treated water were 27.7 mg L^{-1}, 69.0 mg L^{-1} and 0.31 mg L^{-1} respectively. The measured values for the same parameters were 30.0 mg L^{-1}, 70.0 mg L^{-1}, and 0.30 mg L^{-1} indicating calculations are agreeing with the measurements. The use of rainwater for membrane cleaning and alternation for conventional pre-treatment units are some of the aspects we wish to examine in the future.

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Keywords: Desalination, Hardness, Membranes, Water

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KINETIC STUDIES OF ADSORPTIVE REMOVAL OF FLUORIDE FROM DRINKING WATER USING γ–Fe_2O_3 COATED SAND

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Safe and readily available water is an important basic need of humans, whether it is used for drinking, domestic use, food production or recreational purposes. Hence, the Sustainable Development Goals (SDG 6) of the United Nations is to make sure universal access of safe drinking water to all by 2030. The problem of fluoride in water has become a major issue in different countries such as Pakistan, India, Sri Lanka, Germany, Sweden, Netherlands, and Japan. Fluoride is considered as an important element that prevents dental caries. Hence, fluoride is added to several water systems and toothpaste. However, daily consumption of fluoride concentrations over 1.5 mg L^{-1} is toxic for health. The removal of fluoride from drinking water has received much attention recently and, different fluoride removal methods have been tested. Adsorption is an efficient and economic method with a high potential for the removal and recovery of fluoride from water. In the present study, an adsorbent material was synthesized using sand and γ-Fe_2O_3 nanoparticles. The adsorption capacity of synthesized γ−Fe_2O_3 coated sand was 0.501 mg dm^{-3} g^{-1} at optimum conditions. The adsorption data for the removal of fluoride fitted with Langmuir isotherm for all concentrations and indicated that the monolayer adsorption process for the removal of fluoride. The first adsorbed fluoride ion initiates the next fluoride ion, and the second fluoride ion adsorbs adjacent to the first molecule because of the strong adsorbent-adsorbate interaction. Kinetic studies were performed to predict the mechanisms of fluoride adsorption on iron oxide coated sand. Reaction kinetics showed the mechanism of adsorption fitted with second-order kinetics. According to the adsorption kinetic data, fluoride ions are chemisorbed to the surface of the adsorbent and the adsorption mechanism is chemically controlled. Fluoride interaction with the γ-Fe_2O_3 surface may happen electrostatically through protonated iron hydroxyl sites or via ligand exchange with the uncharged surface sites. γ-Fe_2O_3-fluoride interaction was strong and fluoride is well chemisorbed to the γ-Fe_2O_3 surface. Raman spectra also showed the formation of Fe-F complexes as the characteristic Fe-F stretching band at 465 cm^{-1} was present in the Raman spectrum of fluoride-treated sample.

Keywords: Adsorbent, Adsorption, Fluoride, Sand, γ-Fe_2O_3 nanoparticles

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THERMALLY TREATED BRICK CLAY PARTICLES FOR REMOVAL OF BENZETHONIUM CHLORIDE, A TOXIC SURFACTANT, FROM AQUEOUS SOLUTIONS

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Benzethonium chloride, commonly known as hyamine, is a synthetic quaternary ammonium salt. It is a cationic surfactant, used as a topical antimicrobial agent in first aid antiseptics, in cosmetics and household items, and in the food industry as a hard surface disinfectant. Hyamine causes serious eye damage, and is highly toxic to aquatic life and hazardous to the aquatic environments. Therefore, it is of vital importance that hyamine be removed. In contrast to the vast number of findings on the efficiency and the mode of removal of heavy metal ions from contaminated water, not much information is available on the removal of surfactants despite their increased use in various sectors. Among techniques available in wastewater treatment, adsorption has become attractive as a cost-effective method, especially with the use of adsorbents which are readily available as waste or as industrial byproducts. In this context, raw brick clay pieces, fired at controlled temperatures, demonstrated their strong affinity toward this cationic surfactant, hyamine, which would be attracted to the negatively charged surface of brick clay particles. Indirect calculation of concentrations after batch experiments performed by measuring the electric potential of the supernatant solutions of hyamine using an ion-selective electrode, which leads to the extent of removal of this surfactant, provides optimum values of experimental parameters, namely, firing temperature (300 °C), dosage (3.00 g), shaking/stirring time (45 minutes), settling time (60 minutes) and solution pH (3.00). Moreover, the extent of adsorption of hyamine obtained after establishment of equilibrium with the adsorbent at different concentrations conforms to the Langmuir adsorption model, indicating that the interaction of hyamine with fired brick clay particles leads to monolayer coverage. The adsorption constant determined according to the Langmuir model provides a reasonably high value, demonstrating strong affinity of hyamine on fired brick clay surfaces. Results of such studies could be extended in the development of methodologies for large-scale removal of this emerging pollutant.

Keywords: Adsorption isotherms, Burnt brick, Cationic surfactant, Parameter optimization

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ISOLATION OF BACTERIA TO REDUCE CHEMICAL OXYGEN DEMAND (COD) IN SOLID WASTE LEACHATE

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The increased generation of landfill leachate has become a challenging issue in the world. Landfill leachate is considered as one of the wastewater types, which requires extensive treatment due to the varying composition of the pollutants. Direct discharge of the untreated leachate to the environment causes adverse environmental impacts for aquatic and terrestrial life, ground and surface water quality. Therefore, the present study was carried out to formulate a low-cost bacteria consortium to treat solid waste leachate. Soil, solid waste and leachate samples were collected from the Karadiyana controlled open dumpsite and the water quality parameters of leachate including pH, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Nitrate concentration (N-NO_3^-), Nitrite concentration (N-NO_2^-), and Ammonium concentration (N-NH_4^+) were measured. Morphologically different bacterial isolates were isolated from the leachate, soil and solid waste samples and they were separately inoculated into sterilized leachate samples which had $3.2 \cdot 10^4$ mg L^{-1} initial COD level to screen potential COD reducers. The water quality parameters of pH, DO, COD, BOD, N-NO_3^-, N-NO_2^-, N-NH_4^+ were in the ranges of 5-6, 1.00-1.94 mg L^{-1}, $1 \cdot 10^4$-$6 \cdot 10^4$ mg L^{-1}, $4 \cdot 10^3$-$1.3 \cdot 10^4$ mg L^{-1}, 120-280 mg L^{-1}, 220-340 mg L^{-1}, and 420-480 mg L^{-1} respectively. Moreover, they were not within the permissible level of wastewater effluent standards published by the Central Environmental Authority (CEA) in Sri Lanka. In the study, five gram-negative bacterial isolates (A, B, C, D and E) were identified as potential COD reducers of the sample. The COD removal percentages of isolated bacteria were recorded as 50.85% (A), 48.21% (B), 45.21% (C), 49.60% (D), and 55.00% (E), within 14 days, at room temperature compared to the control. Thus, the results revealed that these bacterial isolates may be successfully used for leachate treatment process. Further studies for optimization of COD removal rate along with characterization of specific enzymes with different co-factors to formulate a green microbial consortium to treat solid waste leachate are in progress.

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Keywords: Bacteria, Biological treatment, COD, Leachate, Water quality

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BIOSORPTION KINETICS OF Ni(II) REMOVAL FROM SYNTHETIC WASTEWATER BY MIXED SAW DUST

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Nickel compounds have been used in many industrial activities including battery industry and alloy fabrication. These industries release contaminated water containing different compounds of nickel. As this is harmful to the surrounding environment, treatment is essential. Among different methods, biosorption is considered as an environmentally friendly, low-cost alternative. In this study, mixed saw dust was used as the biosorbent as it is readily available. Investigation of kinetics of biosorption is important as such studies provide information on mechanisms of the metal ion-adsorbent interactions with insight of the solute uptake rate and the residence time required for the completion of the reaction. Adsorption system consisting of mixed saw dust and 8.0 mg L^{-1} Ni(II) solution, prepared at optimized pH of 4.50 at an ambient temperature of 25 °C, is found to reach equilibrium at 35 min contact time according to batch-mode kinetics experiments with the adsorbent dosage to solution volume ratio of 1:100. Among different adsorption kinetics models, pseudo first order, second order and pseudo second order, the pseudo second order model fits the best having a linear regression coefficient of 0.94 to experimental kinetics data within the initial stage of adsorption. Further, the pseudo second order model leads to an apparent rate constant of 6.4×10^{-3} g mg^{-1} s^{-1} and an equilibrium adsorption capacity of 250 mg kg^{-1}. Among two adsorption diffusion models, McKay and Poots, and Weber and Morris, the McKay and Poots model fits better with a linear regression value of 0.90 with the intercept of -1.028 mg kg^{-1}. The numerical value of the intercept is a measure of the boundary layer thickness, while the negative sign is indicative of boundary layer retarded diffusion. As the above results give much valuable explanation on the mechanism, further studies on the kinetics behavior of this system are currently underway. These results would be valuable in extending laboratory findings to industrial applications.

Keywords: Biosorption, Diffusion models, Kinetics, Nickel, Saw dust

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