



CHALLENGES AHEAD

WATER QUALITY AND HUMAN HEALTH

International Symposium
PROCEEDINGS



History Culture Ecosystems Biodiversity Sustainability Livelihood Services Leisure Future

All begins with water

27th & 28th June 2014

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

Organized by the POSTGRADUATE INSTITUTE OF SCIENCE (PGIS), UNIVERSITY OF PERADENIYA
in collaboration with the
Faculty Of Medicine, University Of Peradeniya,
Institute Of Fundamental Studies, SRI LANKA,
PLAN SRI LANKA,
International Research Center, University of Peradeniya
and in technical association with the
CAFET INNOVA Technical Society, INDIA



PROCEEDINGS

International Symposium on WATER QUALITY AND HUMAN HEALTH: CHALLENGES AHEAD

27-28 June 2014

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Oliver Heperuma (Editor-in-Chief)
Namal Priyantha
Sudharma Yatigammana
Sumedha Madawala
Chaminda Wijesundara

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POSTGRADUATE INSTITUTE OF SCIENCE (PGIS), UNIVERSITY OF PERADENIYA, SRI LANKA

in collaboration with the
**FACULTY OF MEDICINE, UNIVERSITY OF PERADENIYA,
INSTITUTE OF FUNDAMENTAL STUDIES, SRI LANKA,
PLAN SRI LANKA,
INTERNATIONAL RESEARCH CENTER, UNIVERSITY OF PERADENIYA**

and in technical association with the
CAFET INNOVA Technical Society, INDIA

Symposium Coordinator:

Dr. Sudharma Yatigamma
Department of Zoology
University of Peradeniya
Peradeniya

Tel: +94 81 2394479
sudharma_y@yahoo.com

Symposium Co-coordinator:

Mr. Chaminda Wijesundara
Department of Zoology
University of Peradeniya
Peradeniya

Tel: +94 81 2394478
chaminda@hawaii.edu

Symposium Assistants:

Ms. Achele Rajapakse
Ms. Ishara Perera
Mr. Waruna Agalawatta
Ms. Chathurika Munasinghe
Ms. Shamindri Tennakoon
Mr. Saumya Bandara
Ms. Nuwanthika Perera

Organizing Committee:

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Welcome address by

**Director of the Postgraduate Institute
of Science (PGIS)
Sri Lanka**



It is with great pleasure that I welcome you to the Third International Symposium on “Water Quality and Human Health: Challenges Ahead” organized by the Postgraduate Institute of Science (PGIS), University of Peradeniya.

With the continuous race of humans to have more comfortable life, urbanization and expansion of industrial activities have become a necessity. Consequently, deterioration of the environment has been happening at an alarming rate, which has already become a global problem. Toxic pollutants present in air, water and soil have already threatened the health of all living beings. Although the environmental damage that has already occurred is not completely reparable, it is the responsibility of scientists in all disciplines to hold hands together, and provide their knowledge and expertise to mitigate environmental pollution.

The Postgraduate Institute of Science (PGIS), Sri Lanka, has been actively involved in providing environmental education and promoting research in the diversified area of environmental science related to biological, chemical, geological and physical aspects in an attempt to improve the quality of the environment. In this context, this timely activity has been organized in collaboration with Faculty of Medicine (University of Peradeniya, Sri Lanka), Institute of Fundamental Studies (Sri Lanka), PLAN (Sri Lanka) and International Research Centre (University of Peradeniya, Sri Lanka), and in technical association with CAFET INNOVA Technical Society (India), to bring scientists of academic, research and industrial sectors in Sri Lanka and abroad, who are interested in environment and health, to a common forum to disseminate their novel findings.

This is the third symposium under the theme of “Water Quality and Human Health: Challenges Ahead”, at which about thirty five research papers will be presented under the themes: Water Pollution, Water Quality, Aquatic Biology, Human Health, and Remediation of Water Pollution. I have no doubt that this symposium will be a great success. I congratulate the organizing committee of the symposium for having this event at international level.

Prof. H.M.D. Namal Priyantha

Director

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



**Message from
the Dean
Faculty of Medicine
University of Peradeniya
Sri Lanka**



Water related diseases are a grave concern. According to the World Health Organization, up to 80 % of all deaths in some developing countries are due to water related diseases.

Sources of drinking water are subjected to contamination and require appropriate treatment to remove disease-causing contaminants. There are two ways by which the drinking water gets contaminated: presence of naturally occurring chemicals and minerals in the drinking water and the contamination as a result of human activities during agricultural, manufacturing, and waste disposal processes. The important contaminants could be toxic chemicals, minerals or infectious biological materials. Another way in which water poses a threat is by providing a breeding ground for many arthropod vectors which transmits serious diseases.

Sri Lanka, like many other countries is experiencing an epidemiological transition. This is clearly observable when the changing pattern of water related diseases are studied over the past few decades. Epidemics of diarrheal diseases, poliomyelitis, typhoid fever, malaria are rare or not seen today. On the contrary, dengue fever, leptospirosis, and chronic kidney diseases which are related to water are seen quite frequently.

The fact that water plays a significant role in the causation of diseases highlights its role in interrelationship between human health, animal health and the environment in which we live in. The interconnectedness between these three is referred to as ONE HEALTH which is gaining momentum as a concept on which the disease causation and prevention are addressed.

The role played by water in diseases underscore the importance of the conference we are attending today.

I wish the conference a great success!

Prof. M.D. Lamawansa

Dean

Faculty of Medicine, University of Peradeniya, Sri Lanka.



**Message from
the Director
Institute of Fundamental Studies
Kandy
Sri Lanka**



It is with pleasure that I provide this message to mark the Third International Symposium on Water Quality and Human Health: Challenges Ahead. To fulfill the needs of an ever increasing human population, the industrialization has become a global need. Since the industrial revolution, the global environment has faced several health problems which have threatened the health of humans. Although corrective measures have been initiated for certain environmental problems, some damages have become permanent. However, if the changes of the environment and the consequences are identified at initial stages, repairing could be possible. Thus it is the utmost responsibility of scientists in relevant disciplines to protect the environment for present and future generations.

Both Postgraduate Institute of Science (PGIS) and Institute of Fundamental Studies (IFS), Sri Lanka, have been actively involved in environmental education through workshops, seminars, symposia, conferences and postgraduate programs. In addition, initiation and promotion of research in the areas of environmental science help sustain a healthy environment parallel to development. In light of this, the Postgraduate Institute of Science, Sri Lanka has organized this valuable event to meet scientists of academic, research and industrial sectors, who are interested in conserving the environment and assuring human health.

I hope that the third symposium under the theme of “Water Quality and Human Health: Challenges Ahead”, with several scientific papers under the themes of water quality, aquatic biology, water pollution and water treatment and remediation will contribute to the awareness of the scientific community as well as the general public.

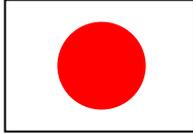
I wish the symposium every success.

Prof. C.B. Dissanayake

Director

Institute of Fundamental Studies, Kandy, Sri Lanka.

Address by



**Chair of the Department of Environmental
Engineering,
Toyama Prefectural University, Japan**



It is my great pleasure to write this message to the Third International Symposium on Water Quality and Human Health: Challenges Ahead organized by Postgraduate Institute of Science, University of Peradeniya

The 21st century has been called century of water. It is said that the amount of the water is used in the world will increase about 30% in 2025 from 2007. Meanwhile, 20% of the world population is still not able to access safe drinking water. One third of the world population, approximately one half of the people in the developing countries is suffering from a disease associated with water. For example, diarrhea caused by drinking water kills 500,000 children every year. Rapid increase of world population and the global warming will worsen the water crises from the point of view of both water quality and quantity. It is estimated that 48 nations will face water shortage in 2025. Access to safe water is one of the pressing global issues of the 21st century.

To keep good quality of freshwater as water resource is another global issue. Regulation of wastewater against industry and agricultural operations is not enough to keep good water quality of lakes, streams, and rivers in some developing countries. Technologies those offer a solution in the form of expensive filtration and treatments are not practical in these countries.

Therefore, it is very important for researchers and policy makers to discuss politically, economically, and technically the water issues at this kind of symposium to find the best solution to conserve water resources.

I hope all the participants in this symposium will hold fruitful discussion on the future of this country.

Thank you very much.

Professor Tomonori Kawakami

Toyama Prefectural University, Japan

Keynote Paper

WATER: THE MOST VITAL AND MOST ABUSED RESOURCE

Namal Priyantha

Senior Professor, Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka.

Water (IUPAC name: oxidane), a transparent fluid which forms streams, lakes, oceans and rain, is the most widely used of all solvents. Water is a liquid at ambient temperature and pressure, but it often is at equilibrium on Earth with its solid state (ice) and gaseous state (water vapour) when suitable conditions are present. Water, the major constituent of fluids of living beings, is essential to human life and to the health of the environment. As a valuable natural resource, it comprises marine, estuarine, freshwater (river and lakes) and groundwater environments, across coastal and inland areas. Water has multi-functional uses: drinking, recreation, irrigation, industrial processes, navigation and shipping, protection of aquatic ecosystems, wildlife habitats, scientific research, etc.

Water covers 71% of the Earth's surface. On Earth, 96.5% of the planet's water is found in seas and oceans, 1.7% in groundwater, 1.7% in glaciers and the ice caps, and a small fraction in other large water bodies, and 0.001% in the air as vapour, clouds and precipitation. Water on Earth moves continually through the water cycle of evaporation and transpiration, condensation, precipitation, and runoff, usually reaching the sea. Further, dissolution of carbon dioxide in water promotes the dissolution of natural metal carbonates exposed to water reservoirs.

Safe drinking water is essential to humans and other life forms although it provides neither calories nor nutrients when present in pure form. Access to safe drinking water by public has improved over the last few decades on a global scale. Nevertheless, approximately one billion people still lack access to safe water and over 2.5 billion lack access to adequate sanitation. It has already been warned that more than half of the world population will be facing water-based problems by 2025.

Water is a substance having unique properties, such as the ability for hydrogen bond formation and ion-dipole interactions. It is considered to be the universal solvent, providing the medium for many chemical and industrial processes, significantly contributing to the world economy. On the other hand, having unique properties of water creates undesirable situations for the health of the ecosystem. Ionic and polar pollutants show a great affinity to interact with water through intermolecular attractive forces, most of which are spontaneous. Such interactions subsequently promote to carry pollutants through water, leading to water pollution, which will then extend to air and soil pollution as well. Deliberate introduction of pollutants to water resources aggravates this situation. It is estimated that 10,000-20,000 children die due to water-borne diseases daily. In many developing countries, 95% sewage and 75% industrial waste are dumped without being properly treated, and further, increasing salinity intrusion into rivers threatens the entire water supply in coastal areas.

Among many different types of natural resources, water is one of the most intensively used as well as the largely abused natural resource. As such, fresh water is becoming a scarce resource, and its availability has already become limited. Consequently, many communities have rated water quality as one of the highest priority environmental issues, and have expressed their wish that water quality be improved or, at the very least,

not further degraded. The entire community of all different professions would be responsible to preserve this resource for future generations. Activities such as introduction of awareness programmes, strengthening national programmes for continuous monitoring of water quality and treatment of waste water, would thus be of utmost importance. The methods used in wastewater treatment are numerous, and combine physical, chemical and biological methods. Treatment methods may also be generally grouped as preliminary treatment, primary treatment, secondary treatment, disinfection, sludge treatment and tertiary treatment. Recently, attention has been paid to design industrial effluent treatment methods based on environmentally-friendly and naturally available substances, such as plant materials in fresh or dead forms.

As scientists interested in studying water pollution and remedial measures, let us make an effort in whatever way to safeguard this valuable resource for our future generations. The price we pay for clean water will be a profitable investment in the future!

Keynote Paper

AMELIORATION OF POLLUTION OF INLAND FRESH WATER BODIES IN SRI LANKA

S. A. Kulasooriya

Emeritus Professor of Botany, University of Peradeniya, Peradeniya, Sri Lanka and Visiting Research Professor, Institute of Fundamental Studies, Kandy, Sri Lanka.

Importance of water

Ninety seven point five per cent (97.5%) of water on earth is salt water (in oceans) leaving 2.5 % as fresh water and nearly 70% of this fresh water is frozen in the ice caps of Antarctica and Arctic as glaciers. Most of the remaining fresh water exists as soil moisture or lies in deep underground aquifers that are not accessible to humans. Therefore, less than 1% of the Earth's water is fresh and accessible for the human use. The human body is about 75% water. A person can survive almost a month without food, but only 5 to 7 days without water. On an average a person in Sri Lanka drinks about 4 liters of water although the optimum is around 8 liters and nearly 70 % of the freshwater in Sri Lanka is used for food production.

A primary goal of the World Health Organization (WHO) and its member states is to ensure that all people irrespective of their economic and social standing have access to an adequate supply of safe drinking water. An average human being requires 20 to 50 L of water per day for his essential domestic uses, but a large segment of the world population does not have access to such a supply, primarily due to water pollution. It has been suggested that consumption of polluted water is the leading cause of deaths worldwide and it accounts for an alarming rate of 14,000 deaths per day!

Water pollution and its consequences

The series of international symposia on *Water Quality and Human Health: Challenges Ahead* which commenced in 2012 has provided enough evidence presented as keynote lectures as well as research presentations to convince us that most of our inland fresh water bodies have become polluted, largely due to anthropogenic activities. Among the common chemical pollutants of water in Sri Lanka phosphorus and nitrogen in the form of phosphate and nitrate are noteworthy and the major source of such pollution is attributed to chemical fertilizers used in agriculture. Besides these a number of heavy metals such as lead, chromium, cadmium, arsenic, zinc and mercury have been detected in some of our reservoir waters above the levels considered as safe for consumption. Furthermore, high levels of fluoride indigenously present in certain areas of the North Central Province have been shown to be responsible dental fluorosis and bone diseases. Most toxic chemical pollutants (heavy metals in particular) are cumulative poisons and their adverse effects are felt after several years of exposure. Even worse, such cumulative toxins can pass from parents to progeny and sometimes the victims can be the innocent newborns who were not directly exposed to the toxins. Continuous use of chemical fertilizers in crop production particularly for rice cultivation in Sri Lanka for several decades has depleted these soils of beneficial microorganisms. Today we are practicing agriculture on virtually 'dead soils' and crop yields have remained stagnant with very little response to fertilizer additions. What is worse is that such soils are unable to retain the added chemicals and most of them are lost due to leaching and percolation and finally end up polluting the inland fresh water bodies. Heavy metals such as cadmium suspected to be present as contaminants in imported fertilizers and other agro-chemicals is cited as a major contributory factor for Chronic Kidney Diseases of Uncertain Etiology. In northern Sri Lanka

accumulation of high nitrate levels in their ground water has been attributed to excessive use of nitrogen fertilizers for crop cultivation. Instead of citing any particular chemical or chemicals, the overall high ionicity or ionic concentration in the Rajarata waters has been suggested as responsible for the incidence of CKDu in a comprehensive short communication. This cites evidences provided by a number of soil chemists to suggest that excessive use of chemical fertilizers is largely responsible for this condition in the water reservoirs of Sri Lanka.

A number of research presentations in the current series of symposia on 'Water quality and Human Health' also provided evidence for the predominance of toxigenic cyanobacteria (blue-green algae) in most of our inland fresh water reservoirs. Such algal toxins have also been shown to be detrimental for kidney function in experimental rats.

It has also been shown that the excessive use of agro-chemicals including mineral fertilizers for high input agriculture is largely responsible for chemical pollutants particularly phosphates and nitrates accumulating in these reservoirs often leading to periodic formation of algal blooms, mostly of toxigenic cyanobacteria. A Sri Lankan soil chemist of international repute, a former Director-General of Agriculture, is today leading a virtual crusade against the use of excessive amounts of soluble phosphate fertilizers particularly for vegetable cultivation in the highlands of Sri Lanka. Writing informative articles in national newspapers and giving impressive lectures and talks to school children, professional bodies and public organizations, he has provided evidence to demonstrate that most of the phosphorus so added get washed down loading the irrigation reservoirs of low lying areas where they get accumulated in their sediments. During the dry seasons along with the dry winds these sediments get disturbed resulting in upwelling releasing the PO_4 ions that trigger off algal blooms. Although NO_3 ions have also been reported to contribute to algal bloom formation, PO_4 is often the critical nutrient because a number of bloom forming species of toxigenic cyanobacteria such as *Anabaena*, *Nostoc*, *Cylindrospermopsis* and *Nodularia* are heterocystous and capable of nitrogen fixation. An interesting observation was made by the author on the algal bloom that occurred in the Ulhitiya reservoir last year. Microscopic observation of the bloom forming population showed that the dominant alga was a non-nitrogen fixing, toxigenic *Microcystis* but it had an intimate relationship with mini-filaments of a *Nostocacean* nitrogen fixing species. Even in this case the critical nutrient that has triggered off bloom formation could have been PO_4 rather than NO_3 .

Amelioration of water pollution

From the foregoing discussion it is quite evident that pollution of our inland water bodies both chemically and biologically is rampant resulting in a significant increase in environmental health problems that is affecting a large segment of our rural population particularly that of the farming communities. It is therefore imperative that we look for measures that could be taken to minimize these trends in order to avoid disastrous consequences in the future.

Heeding the views expressed by scientists and environmentalists, it is encouraging to note that the Government has made some positive pronouncements. For instance none other than His Excellency the President of Sri Lanka has declared that the use of agro-chemicals including fertilizers should be minimized by applying alternative substitutes, particularly organic matter. However, it is necessary to realize that the response of high input responsive crop varieties currently used in Sri Lanka could compromise on crop yields. This would not only adversely affect the income of rural farmers but also negatively impact the country's agricultural productivity and food security. Therefore the transition has to be gradual and both basic and problem oriented research has to be conducted to achieve such objectives. We are not alone in this, because today there is a worldwide interest in revisiting modern agriculture and base it upon environmentally benign, non-polluting technologies.

Currently available technologies for the reduction of chemical fertilizers include the use of biofertilizers and addition of organic matter including recycling of crop residues, domestic

waste through composting and wormy culture and the application of green manure. At the Institute of Fundamental Studies (IFS) rhizobial biofertilizer inoculants for certain legume pulse crops are produced and marketed. Among them, inoculants for soybean that could replace the entire application of urea fertilizer to this crop have been in field use for the past seven years. And last year inoculants were supplied to nearly 4,000 ha of soybean. Field trials done with vegetable beans, ground nut and mung bean have given very encouraging results and these inoculants are earmarked to be released in the near future.

Another unique achievement at the IFS is the development of 'Biofilm-Biofertilizers' (BFBFs). These specialized multi-microbial communities establish intimate relationships with the root system of the targeted crop and significantly enhance its growth and activity. Such BFBFs for tea were field tested by the Tea Research Institute of Sri Lanka during the past eight years in all the tea growing areas. These biofertilizers have been shown to be capable of replacing 50% of all NPK chemical fertilizers without any drop in yields. Their use also improves drought resistance of the crop, minimizes soil pathogenic and pest attacks and changes the rhizosphere microbial population of the crop to a more benign community. BFBF technology has given extremely encouraging results with rice and maize and vegetables and in most of these cases a 50% reduction in the application of NPK chemical fertilizers could be achieved without any reduction in yield. A widespread use of such biofertilizers could be expected to revolutionize agriculture to be an environmentally benign activity. Hence the use of biofertilizers provides an effective alternative to reduce chemical fertilizer application in crop production and plantation agriculture.

Recycling of crop residues, use of domestic wastes by composting and worm-culture and the application of green manure all suffer due to the slow decomposition of these organic materials to provide nutrients to a standing of high fertilizer responsive crops. This of course depends upon the microbial processes of decomposition which are naturally slow. However, substantial progress has been made in other countries such as Japan, Thailand and the Philippines to prepare microbial inoculants that could significantly accelerate decomposition of organic matter. Such preparations termed Effective Microbial Inoculants (EMIs) are in use in many countries, but not in Sri Lanka. A few attempts to apply this technology in Sri Lanka using imported inoculants did not succeed. In any case research and development of such inoculants should be attempted using indigenous microorganisms rather than introducing foreign organisms onto our soils. Funding and other inducements should be provided for the use of such alternatives to minimize the application of chemical fertilizers without compromising on crop yields. Similar incentives should also be provided for research and development of bio-pesticides because if chemical pesticide and herbicide applications are banned without providing alternatives, a large proportion of our crop harvests could be destroyed. Integrated pest management systems that are currently been introduced cannot protect large scale crop production systems. We do have several traditional techniques of preparing bio-pesticides and research and development on them should be encouraged and supported.

Restoration of Riparian Vegetation

The results of a decade of research studies done in the Kalpitiya area in collaboration with National Water Supply and Drainage Board (NWSDB) was presented at the water quality and human health symposium last year. Convincing evidence was presented to show how the nitrate concentration of Kalpitiya aquifers was restored to potable levels through the restoration of riparian vegetation. Even during the ancient hydraulic civilizations of our ancestors, the feeder canals of traditional reservoirs had curved contours and each bend had reeds and other water plants grown in them. These were meant to slow down the inflows as well as retain the suspended particles and prevent the particle bound nutrients and other pollutants reaching the reservoir. They were also planted with trees such as Kumbuk (*Terminalia arjuna*) which grow well under inundation and absorb large amounts of nutrients. Although the British colonial

engineers failed to understand the science behind these practices and cleared such vegetation, straightened the canal contours and lined the canals with concrete to accelerate the flow rates, such changes promoted large and rapid transport of pollutants reaching the reservoirs and building up of polluted sediments in them.

Bio-manipulation

Another approach to purify water bodies particularly of phytoplankton build up is bio-manipulation. A review paper presented at the last symposium on Water Quality and Human Health covered the methods available for such water management systems. This is another approach on which research studies are warranted to adopt such practices in Sri Lanka because bio-manipulation techniques have been quite successful in water quality management in certain countries.

Water purification

Despite all these remedial measures stagnant water retained in reservoirs and ponds will not be suitable for direct human consumption without any purification. The conventional water treatment techniques practiced by the NWSDB and other water suppliers have to continue to provide safe drinking water devoid of water borne human pathogens. However modifications and improvements have to continue such as to minimize the accumulation of Tri-Halo-Methanes during chlorination and/or halogenation. Methods of electro-coagulation coupled with sedimentation and sand filtration to remove suspended particles and reduce ionicity should be improved and extended.

The IFS has also conducted some preliminary studies to investigate the possibility of using murunga (*Moringa oleifera*) seeds to break down algal toxins which are not destroyed even by boiling the water. The initial results have been encouraging and indicate some ability of murunga seed kernel to break down the algal toxin microcystin besides its seed coat clearing the water through coagulation.

Conclusion

This keynote presentation while reiterating the grave status of water pollution in Sri Lanka, emphasizes the urgency to embark upon steps that could be taken to ameliorate this situation. It has highlighted areas of basic and applied research that could lead to the improvement of the quality of water that is available for consumption in Sri Lanka. It is strongly recommended that such studies should be encouraged and funded by the State as a matter of high priority.

Invited Speech

WATER AND WEED MANAGEMENT IN RICE CULTIVATION IN SRI LANKA

A.S.K. Abeysekera*

Rice Research and Development Institute, Batalagoda, Ibbagamuwa, Sri Lanka.

Rice is the main crop cultivated in Sri Lanka contributing 1.5 percent of the country's GDP. It is the livelihood of more than 1.8 million farmers. Rice is unique among the major food crops in its ability to grow in a wide range of hydrological situations, soil type and climates. This is only the cereal crop that can grow in wetland condition. Water plays an important role in many practices in rice cultivation, such as land preparation, fertilizer management and pest and disease management. These factors are significant in determining quality and the quantity of rice. Water for rice is supplied by rain, natural water tables and irrigation. In rice cultivation, it is fairly a common practice to keep the land flooded throughout much of the season. It helps weed management and also provides a desirable soil chemical regime for the rice crop. Water is necessary for several important processes such as photosynthesis, for solubility of plant nutrient in the soil as well as added fertilizer and pesticides transport upward through the root systems. The movement of water through the plant is driven by a difference in water potential. Puddling followed by continuous submergence of land effectively control weeds in rice fields. The germination and emergence of many weed seeds are closely related to the moisture status and depth of water standing on the soil. The germination of many weed species is inhibited under flood conditions, due to a reduced oxygen supply and an accumulation of CO₂ and gaseous products of anaerobic respiration. Series of experiments conducted at the Rice Research and Development Institute (RRDI) has indicated that many of the commonly available dominant paddy weed species *Echinochloa crus-galli*, *Leptochloa chinensis*, *Ischaemum rugosum*, *Fimbristylis miliacea*, *Cyperus iria* and *Cyperus difformis* were effectively controlled by flooding water (2-5 cm) in rice field. However, there are some weed species that germinate under submerged conditions. *Monochoria vaginalis*, *Sphenoclea zeylanica*, *Marsilea minuta*, *Aeschynomene indica* and some *Cyperus* spp. are among them. Emergence of some weed species was found to be delayed and they exhibited poor growth under flooded condition. However, it is essential that the field be properly leveled at the last harrowing to get effective weed control efficacy from flooding. Application of herbicides for commercial cultivation of rice is a pre-requisite, because water management of rice fields for weed control is difficult under the present Sri Lankan scenario. Therefore, rice farmers have illustrated a high willingness to apply herbicides to control weeds. There are different types of herbicides available on the market which can be classified as pre- and post-emergence, selective and non-selective or sedges and broadleaves grass killing herbicides. Proper use of water is needed to increase the efficacy of herbicides. Therefore, herbicides and water are important components of integrated weed management. However, agriculture is considered as the biggest pollutant of water bodies on the global scale. Use of fertilizers, pesticides and growth stimulators has increased during the last decades, so many of these chemicals have gotten into bodies of water. However, the more important is misuse of herbicides or incorrect application of them results in low efficiency of weed control and dangers to human health and the environment.

*anuru@sltnet.lk

Invited Speech

ADDRESSING WATER QUALITY ISSUE IN SCHOOLS THROUGH INTEGRATED APPROACH AT SCHOOL LEVEL

N. Patabendi*

National Advisor (Water, Sanitation and Hygiene), Plan Sri Lanka, 110, Park Road, Colombo 5, Sri Lanka.

Plan is a child centered community development organization that has worked in Sri Lanka for over 33 years. Over the period it has a unique experience of delivering inter-sectoral projects to ensure the wellbeing of children. Plan currently has a programme in the Anuradhapura District with 45 schools in Madawachchia, Padawiya and Wilachchiya. As areas affected by CKDu the well being of children is seriously affected not only by the death of parents and caregivers but also by the fact their own health could be affected at any time.

The school Water, Sanitation and Hygiene Promotion Programme is a project designed not only to provide safe water to school children and change behavior related to hygiene but also to address issues of water quality and support and schools to explore all options of providing alternate sources of water. water quality survey among 17 schools and households of school communities, introducing water purification systems such as Reverse Osmolysis (RO) for 17 schools, promoting and rehabilitating rainwater harvesting in 4 schools, conducting hygiene promotion programmes which include water management at household level, introducing school led Water Safety Plans for about 20 schools and development of O&M manual and participatory toolkits for hygiene behavior change were some interventions. Efforts were taken to link water quality interventions with the school curriculum and enhance laboratory facilities for water quality testing. Awareness among water quality issues in the areas and knowledge on prevention and taking actions at community level were enhanced among children and school communities. Realization of importance and role of schools that can play within the communities and strengthened sector collaboration at local level were observed as outcomes of the project, while introducing appropriate alternative technological options to overcome water quality issues in schools is very challenging and with certain limitations due to nature and functionality of the school setup.

*Nilusha.Patabendi@plan-international.org

Invited Speech

REMOVAL OF HEAVY METALS BY PLANTS - AN ECO-FRIENDLY ALTERNATIVE

M.C.M. Iqbal*

Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka.

Heavy metal contamination of water resources is a consequence of modern technologies in our life style and consequent discarding of used products. The adverse health consequences of heavy metals are well documented, which occurs at very low concentrations and also through bio-magnification in the food chain. Heavy metals have been implicated in the prevalent CKDu in the North Central province of Sri Lanka, for which a solution remains elusive, with tragic consequences in the farming community. However, removal of heavy metals from aquatic resources and waterways requires challenging physico-chemical interventions such as membrane filtration, chemical precipitation and coagulation.

Since ancient times, the cascading tank system in the dry zone of Sri Lanka used particular species to remove salts from the water before entering the tanks. Plants species capable of selective or non-specific absorption of heavy metals from the soil or water have been identified. Plants growing on metal rich soils over time have adapted and evolved, to hyperaccumulate metals. Thus plants, besides providing food for our consumption, also provide a variety of resources and eco- services for human well- being.

Besides living plants, dried plant biomass can be used for bio-adsorption of heavy metals. This knowledge has been developed into phyto-filtration technologies to cleanse water using 'specialist' and 'generalist' plant hyperaccumulators, which together provide a holistic, green and affordable strategy to mitigate metal contamination in water bodies. This presentation would discuss the role of plants in heavy metal removal from our water.

WATER QUALITY STATUS OF SELECTED WATER WELLS LOCATED IN KEBITHIGOLLAWA AND MEDAWACHCHIYA, NORTH CENTRAL PROVINCE OF SRI LANKA

K.A.W.S.Weerasekara*, S.A.M. Azmy, W.D.N. Wickramaarachchi and A.A.D. Amarathunga

Environmental Studies Division, National Aquatic Resource Research and Development Agency (NARA), Crow Island, Colombo 15, Sri Lanka.

Most of the water resources in Sri Lanka are prone to contamination due to various reasons posing a high health risk to the people. Some diseases are specific to certain areas although the causes of such diseases are still unknown. Chronic Kidney Disease of unknown aetiology (CKDu) is one of the major diseases prevailing in the North Central Province during the last three decades, and it is now becoming a major problem as more and more people are affected.

The objective of this study was to determine the current status of selected water wells in Kebithigollawa and Medawachchiya, to check whether there is any relationship between water quality and CKDu. Ten sampling wells from Kebithigollawa and Medawachchiya areas, and two reference wells from Galgamuwa were selected. Total of sixteen water quality parameters were monitored during February to December, 2010. Collected and processed samples were analyzed using standard methods.

Overall water quality of the sampling wells of Kebithigollawa, Medawachchiya and reference wells is as follows:

Parameter	Kebithigollawa	Medawachchiya	Reference Wells
Ammoniacal – N(mg L ⁻¹)	0.25 ± 0.39	0.27 ± 0.26	0.28 ± 0.47
Nitrate - N (mg L ⁻¹)	1.68 ± 1.37	2.34 ± 2.16	1.08 ± 1.12
Chloride (mg L ⁻¹)	54.69 ± 22.86	79.41 ± 40.29	54.56 ± 38.04
Electrical conductivity (µS cm ⁻¹)	602.10 ± 205.44	1100.58 ± 263.87	1160.05 ± 487.23
pH	6.86 ± 0.53	7.15 ± 0.32	7.15 ± 0.38
Fluoride (mg L ⁻¹)	0.57 ± 0.40	0.95 ± 0.34	0.74 ± 0.39
Phosphate (mg L ⁻¹)	1.47 ± 1.42	1.34 ± 0.79	0.95 ± 0.34
Total hardness (mg L ⁻¹)	204.35 ± 75.91	250.76 ± 103.39	212.31 ± 90.40
TDS (mg L ⁻¹)	308.26 ± 128.04	542.33 ± 133.62	557.80 ± 262.77
Alkalinity (mg L ⁻¹)	111.71 ± 73.13	122.66 ± 89.92	141.25 ± 99.21
Turbidity (NTU)	1.85 ± 3.87	2.08 ± 3.46	0.85 ± 0.70

Results revealed that the average nitrate – N, chloride, EC, pH, fluoride, TDS, alkalinity, and turbidity were within the permissible limits but ammoniacal – N and phosphate were above the permissible limits for drinking water. Furthermore, average total hardness of Medavachchiya sampling wells was slightly higher than the permissible limits. Further studies on heavy metals and algae content need to be done to delineate the real causes of the CKDu in water.

Keywords: Chronic Kidney Disease, physico-chemical parameters, aquatic environment.

*shyamalikaww@gmail.com

DISTRIBUTION OF GROUNDWATER QUALITY IN VALIGAMAM WEST, JAFFNA PENINSULA, SRI LANKA

K.K.R. Thanushan *

Department of Geography, University of Jaffna, Jaffna, Sri Lanka.

The Jaffna peninsula seems to have limestone formed during the Miocene period, and the sedimentary rock that consists of aquifers is the important source of water in the Jaffna peninsula. The Valigamam region of Jaffna is a heavily populated area, and at the same time, the need for water is increasing in accordance with the population growth. The study area included 23 Gramasevaka Divisions: J/157, J/158, /159, J/160, J/161, J/162, J/165, J/166, J/167, J/168, J/169, J/170, J/171, J/172, J/173, J/174, J/175, J/176, J/177, J/178, J/179, J/180 and J/181. In Chankanai, the groundwater is extensively used for agricultural and handicraft purposes in addition to domestic uses. It is learned through previous research that over extraction of groundwater, as well as intensive cultivation of crops, causes severe problems in the quality of groundwater.

Forty four samples were collected and analysed with the help of National Water Supply and Drainage Board (NWS&DB), Jaffna. Electrical conductivity (EC), pH, total hardness, chloride and nitrate were determined and the relationship of their spatial distribution was mapped using ArcMap 9.3 programme. We have observed that, as per the Sri Lankan Standard 614 (1983), 1.5 % water samples have shown high nitrate values, 15.9% have exceeded the total hardness level over the maximum permissible level. The chloride values in Chankanai West, Vaddukoddai North, Vaddukoddai South and Vaddukoddai West, Moolai and Araly vary from 253 mg L⁻¹ - 886 mg L⁻¹. The above problems and variations are due to geographical factors and human activities. The sandy calcareous formation found along the coastline, causes saline intrusion into the ground water and resulting in increased, chloride and electrical conductivity. Intensive cultivation of domestic crops and vegetables with the application of agro-chemicals has caused agrochemical contamination.

The impact of physical factors seems to be unavoidable. The quantity and the quality of groundwater of the Jaffna peninsula could be preserved through the application of advanced techniques of water resource management. It could be implemented in a proper way with the representation of all stakeholders. Such activities will definitely help to prevent the underground water sources of Jaffna getting further polluted.

Keywords: Groundwater, Valigamam west, water quality parameters.

* thanushankkr@gmail.com

ORIGIN OF MOISTURE FOR RAIN PROCESSES ON THE WEST COAST OF SRI LANKA: A CASE STUDY USING STABLE ISOTOPE SIGNATURES OF RAIN

E.A.N.V. Edirisinghe^{1*}, H.A. Dharmagunawardhane², H.M.T.G.A. Pitawala²,
I.A.N.D.P. Tilakarathna¹, K.S.G.S. Priyadarshane¹ and J.D.C. Gunasekara¹

¹Isotope Hydrology Section, Atomic Energy Authority, Wellampitiya, Sri Lanka.

²Department of Geology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka.

Rain patterns show impact on sociological, economic and environmental conditions of a country such as Sri Lanka, where the water resources are mostly dependent on rainfall. ¹⁸O and ²H in water are of great importance to identify the origin of moisture that causes rainfall in any area. Identifying rain patterns is vital for explanations on groundwater or surface water issues of the country. Groundwater quality particularly depends on the conditions of the origin of water which is also decisive in dissolution chemistry. Isotope techniques can address the above issues when baseline isotope indices of rainfall are known.

The present study was carried out in Colombo on the west coast of Sri Lanka over a period of five years from 2008 to 2013. Compositions of ¹⁸O and ²H were determined in monthly rain water samples (n=57). Deuterium excess (D-excess) of the rain water together with stable isotope composition, in relation to the Local Meteoric Water Line (LMWL), provided vital information on air moisture origin and circulation on the west coast. The identified rain pattern is though more common to the western parts of the central highlands in Sri Lanka, it covers and represents total rain patterns over the whole island.

A distinct linear correlation ($R^2=0.98$) exists between $\delta^{18}\text{O}$ and $\delta^2\text{H}$ in the rainwater. The linear regression line; LMWL ($\delta^2\text{H} = 7.5 \delta^{18}\text{O} + 11.7$) shows specific isotopic characteristics (slope 7.5, intercept 11.7) of rain along the western coast of Sri Lanka. The results reveal that there are four distinct isotopic signatures of rain over a calendar year. The South-West monsoon winds from June to September bringing rain to the west coast are loaded with water vapour from the Indian ocean and have an enriched isotopic signature (Avg. $\delta^{18}\text{O} = -2.1 \text{ ‰}$, $\delta^2\text{H} = -5.7 \text{ ‰}$), displaying the oceanic origin of water vapours. Also, the average D-excess (11.2 ‰) which is close to the global value also indicates the oceanic origin of water vapours. During the period of North-East monsoon from December to February, the air moisture has to travel over the land for a long distance before reaching the west coast, causing a comparatively low intensity rainfall. This rain water has more depleted isotopic values (Avg. $\delta^{18}\text{O} = -5.4 \text{ ‰}$, $\delta^2\text{H} = -30.3 \text{ ‰}$) as compared to water of South-West monsoon rains. In addition, the D-excess value (avg. = 12.8 ‰) of the North-East monsoon rains showed that the rainwater is a mixture of both the moisture originating from Bay of Bengal and the Indian territorial areas. During the remaining periods, there are two inter-monsoon rain processes; from March to May and October to November showing different isotopic signatures as compared to the monsoon events. Both periods have high D-excess values showing moisture-recycling processes. During March to May; the first inter-monsoon period, fairly enriched isotopic signature (Avg. $\delta^{18}\text{O} = -3.2 \text{ ‰}$, $\delta^2\text{H} = -11.7 \text{ ‰}$) and high D-excess (avg. = 13.7 ‰) were observed in water. During October-November, the second inter-monsoon period, the impact of cyclonic conditions in the Bay of Bengal was evident with more depleted isotopic signature (Avg. $\delta^{18}\text{O} = -6.6 \text{ ‰}$, $\delta^2\text{H} = -46.9 \text{ ‰}$). Also, the second inter-monsoon rain shows high D excess (avg. = 13.5 ‰) value. It is expected that the results of the present study contribute to the advancement of future hydrological and meteorological studies in Sri Lanka.

Keywords: Isotopic signature, moisture origin, monsoon rain, D-excess, Sri Lanka.

*viraj@aea.gov.lk, virajta@yahoo.com

PHYSICOCHEMICAL CHARACTERISTICS OF SELECTIVE WELL WATER SAMPLES IN KILINOCHCHI AND MULLAITIVU DISTRICTS, SRI LANKA

M. Vishnumeera, R. Senthoran, G. Sashikesh and J. Prabagar*

Department of Chemistry, University of Jaffna, Jaffna, Sri Lanka.

In order to evaluate the problems of pollution of ground water and to ascertain its suitability for drinking and irrigation purposes, chemical and physical characteristics were determined using standard procedures for well water samples collected from five divisional secretariats in Mullaitivu District and four in Kilinochchi District, Sri Lanka. Physicochemical parameters such as pH, concentration of cations (Ca^{2+} , Mg^{2+} , K^+ , Na^+ , Fe^{3+}), and anions (NO_3^- , Cl^- , PO_4^{3-} , SO_4^{2-}), BOD, COD, and total alkalinity were determined for fifty six ground water samples.

Calcium content of well water samples collected from Kilinochchi and Mullaitivu districts were within the range of 32 – 103 mgL^{-1} and 24 – 207 mgL^{-1} , respectively, while the magnesium content ranged from 6 – 36 mgL^{-1} and 3 – 9 mgL^{-1} , respectively. All the values were lower than the maximum permissible level (240 mgL^{-1} and 150 mgL^{-1} for calcium and magnesium respectively) according to Sri Lankan standards for drinking water. Nevertheless Iron concentration of well water samples from the two districts ranged from 2 – 9 mgL^{-1} and 0.5 – 8 mgL^{-1} respectively, which were very much higher than the maximum permissible level. The well water samples collected from Tharmapuram and Paranthan areas in Kilinochchi district showed higher amounts of nitrate than the maximum permissible level of Sri Lanka Standards for potable water. In these areas, agricultural activities are intense and therefore indiscriminate uses of nitrogenous fertilizers could be one of the main sources for the higher value of nitrate in these areas. The amount of phosphate in water samples collected from most areas in Kilinochchi District was found to be in the range of 2 – 5 mg L^{-1} , which is above the standard level. The well water samples collected from Manthuvil and Mulliyavalai in Mullaitivu District showed higher amounts of phosphate, and it was less than the maximum permissible level in other areas. In Kilinochchi District, the well water samples collected from Poonagari area showed abnormally high chloride content and Eranaimadu, Tharmapuram and Semmankunru also had high concentrations of chloride. The low amount of sulphate was found in water samples collected from most of the areas in both districts. The pH of the water samples was between the desirable range and total alkalinity was higher compared to Sri Lanka Standards for potable water in both districts. Furthermore, the amount of COD (1.3 – 2.4 mg L^{-1}) and BOD (2.7 – 5.0 mg L^{-1}) values were within the standard values for drinking water.

It is concluded that some parameters such as concentrations of Ca^{2+} , Mg^{2+} and SO_4^{2-} were within the maximum permissible level. However, concentrations of iron, nitrate and chloride and total alkalinity were higher than the maximum permissible level in both Kilinochchi and Mullaitivu districts as compared to Sri Lankan standards for drinking water. This may be due to the over usage of agrochemicals.

Keywords: Ground water pollution, Calcium content, Magnesium content

*j_prabagar@yahoo.co.uk

DISTRIBUTION AND COMPOSITION OF CYANOBACTERIA IN SRI LANKAN RESERVOIRS

M.B.U.Perera^{1,2} and S.K.Yatigammana^{2*}

¹*Institute of Fundamental Studies, Hantana road, Kandy.*

²*Department of Zoology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka.*

Cyanobacteria are a main component of phytoplankton community of freshwater bodies. They also occur in marine and terrestrial environments. As Cyanobacteria are primitive algae with high adaptability to changing environment, they dominate even in extreme environments. Using a discovery curve, it has been estimated that there are 2698 described species and it is assumed that the group may contain at least 6000 species. Today this important group serves aquatic ecosystems for primary production, fixing atmospheric nitrogen, nutrient uptake and controlling other competing algae through toxin production. Unfortunately, these toxins threaten other organisms in the environment including humans. In Sri Lanka, a larger portion of the land is covered with inland waters and the water bodies serve the economy of the country in various ways and therefore understanding the presence of Cyanobacteria has become essential. The current study was designed to explore the distribution and composition of Cyanobacteria in Sri Lankan reservoirs. Limnological characteristics of the study reservoirs were also studied.

Sixty two reservoirs of various morphometric characteristics (surface area range 50 – 2500 ha, maximum depth range 2-35 m) located in four climatic regions (Dry Zone, Arid Zone, Intermediate Zone, Wet Zone and Highland Wet Zone) of Sri Lanka were selected for the study. The study was conducted from October 2010 to January 2012 and sampling for the analysis of cyanobacteria was done using plankton net (pore size 10 µm) at three months intervals to cover all the seasons of the year. Identification of the species was done using research microscope (Olympus CX 31) equipped with phase contrast optics. Both onsite measurements and laboratory analysis were conducted for selected physicochemical variables, pH, dissolved oxygen (DO), specific conductance, salinity, total phosphorus and total nitrogen.

Results reveal that all the reservoirs are eutrophic (TP > 30 µg L⁻¹) and freshwater (salinity <1 ppt). Specific conductance range was 38 µs/cm and 637 µs/cm. Thirty three species of Cyanobacteria were identified. *Merismopedia punctata* was the most widely distributed species and was recorded in all 62 reservoirs. In contrast, *Anabaena circinalis* was found only in three reservoirs located in the Highland Wet Zone where the annual temperature is similar to one with a temperate climate. The toxic Cyanobacteria, *Microcystis aeruginosa*, *Cylindrospermopsis raciborskii*, *Oscillatoria* sp., *Anabaena* spp., *Aphanizomenon* sp., *Anabaenopsis* spp. and *Nostoc* sp. were also widely distributed but recorded at high abundance in urban reservoirs. Fortunately *Spirulina* sp. which is known to be a super food with high nutrient content was also widely distributed and recorded in 42 reservoirs covering all the climatic conditions.

Keywords: Cyanobacteria, Sri Lankan reservoirs, limnology

*sudharma_y@yahoo.com

INACTIVATION OF *PSEUDOMONAS AERUGINOSA* AND *MYCOBACTERIUM FORTUITUM* IN WATER BY ULTRAVIOLET-C (UV-C) RADIATION

A.T. Herath^{1*}, E.A.R. Edirisinghe², C.L. Abayasekara¹, R. Chandrajith³, N.K.B. Adikaram¹, D.R.A. Dissanayake² and A. Arulkanthan²

¹Department of Botany, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka.

²Centre for Aquatic Animal Disease Diagnosis and Research, Department of Veterinary Pathobiology, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya, Peradeniya, Sri Lanka.

³Department of Geology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka.

Pseudomonas aeruginosa and *Mycobacterium fortuitum*, are food and water borne opportunistic pathogens, constituting a health risk mostly to immunocompromised patients. Previous studies revealed the presence of *P. aeruginosa* in bottled water samples and *M. fortuitum* in environmental water samples. Therefore, the objective of the current study was to evaluate the efficacy of ultraviolet radiation (UV-C) to inactivate *P. aeruginosa* and *M. fortuitum* in water. Sterile distilled water spiked with *P. aeruginosa* (10^4) was exposed separately to UV-C doses of 10,350, 17,000 and 24,500 $\mu\text{W}/\text{cm}^2$ for 5, 10, 20 and 60 second durations, while sterile distilled water spiked with *M. fortuitum* (10^5) was exposed separately to UV-C doses of 6,000, 10,000 and 17,000 $\mu\text{W}/\text{cm}^2$ for 5, 10, 20, 30, 60 and 120 second durations. Viability was tested by dilution plate count, using the Miles and Misra method, consisting of duplicate plate counts for each dilution in three replicate trials. The results indicated that exposure to an UV-C dose of 17,000 $\mu\text{W}/\text{cm}^2$ for 5 seconds resulted in complete inactivation of *P. aeruginosa*, while complete inactivation of *M. fortuitum* was obtained at the same UV-C dose within 30 seconds. As the presence of *P. aeruginosa* and *M. fortuitum* in water raises health concerns, the results of the current study can be used for the inactivation of these organisms from water sources.

Keywords: Water, inactivation, *Pseudomonas aeruginosa*, *Mycobacterium fortuitum*, UV radiation

*chalاهرath@gmail.com

SPATIAL CHANGES IN NITRATES AND PHOSPHATES IN NACHCHADUWA PERENNIAL RESERVOIR, SRI LANKA

P.A.C.T. Perera^{1*}, T.V. Sundarabharathy², T. Sivananthawerl³ and U. Edirisinghe⁴

¹Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

²Department of Biological Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka.

³Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

⁴Department of Animal Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

Nachchaduwa (8°15'0" N and 80°28'60" E) is an irrigation tank, constructed across Malwathu Oya, is situated in the upper regions of the Malwathu Oya basin in the North Central Agro-ecological Zone. Because of 55.47 MCM of water capacity and 1,780 ha of area at the full supply level (FSL), it is classified under medium perennial reservoirs in Sri Lanka. Other than its main water source from Malwathu Oya, water is diverted to the Nachchaduwa reservoir from Kala Wewa irrigation reservoir through a diversion of Jaya Ganga (Nachchaduwa Feeder Canal). Water of the Nachchaduwa reservoir is released to irrigate agricultural lands (mainly to Paddy lands) according to the downstream irrigation requirements. It has three sluices to control its water level. The main sluice located near the southern end of the embankment discharges water to the Tissa Wewa reservoir and the other two sluices discharge water to the Nuwara Wewa reservoir. Most of the discharged water of surrounding paddy lands is diverted back to the Nachchaduwa reservoir inlets during the two cultivation seasons (Maha and Yala). Paddy farmers in these areas utilize variety of agro-chemicals including inorganic fertilizers expecting high yield. Therefore, the possibility of adding nitrates and phosphates into the reservoir water is high.

This study was conducted to assess the spatial changes of major plant nutrients; nitrogen (NO_3^- -N) and phosphorus (PO_4^{3-} -P) in the Nachchaduwa reservoir. Sampling was carried out from 12 locations of the reservoir from the Malwathu Oya inlet area to the reservoir outlet area, and from the two main inlets and three sluice outlets. In all water samples, dissolved NO_3^- -N and PO_4^{3-} -P were determined using standard laboratory techniques. Results of the water samples obtained from the different locations of the reservoir were compared with each other. Similarly, the results of the water samples of the reservoir were compared with the results of the water samples obtained from inlet and outlet canals. Concentrations of PO_4^{3-} -P in the reservoir water showed significant spatial changes from inlet areas to outlet areas. This change is associated with significant steady decrease from the reservoir inlet region to the outlet region. However, the concentrations of NO_3^- -N in water did not show significant spatial changes. Therefore, it can be concluded that the reservoir presently can mitigate comparatively less soluble PO_4^{3-} -P in water but this is not effective for NO_3^- -N due to inefficient aquatic resource management.

Keywords: Irrigation tank, nitrate, phosphate, spatial changes

*chintakaperera@gmail.com

CHEMICAL COMPOSITION OF ATMOSPHERIC PRECIPITATION IN SELECTED INDUSTRIALIZED STATIONS IN GAMPAHA DISTRICT, SRI LANKA

W.G.R.C. Wickramasinghe¹, A.B. Liyandeniya^{2, 3}, M.P. Deeyamulla^{1*} and N.Priyantha^{2, 3}

¹*Department of Chemistry, University of Kelaniya, Kelaniya, Sri Lanka.*

²*Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka.*

³*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.*

Monitoring rainfall acidity and its chemical composition are very important for a rapidly industrializing country such as Sri Lanka since they provide a clear picture of the extent of air pollution. Increasing rain acidity could have adverse implications on agriculture and the quality of potable water supplies. Understanding about the chemical composition of rain water and possible sources of those elements would possibly help environmental policy makers and regulatory agencies to develop strategies to control possible future acid rain conditions in Sri Lanka. Therefore, the objective of this study was to determine the chemical composition of atmospheric precipitation in some industrialized areas in Gampaha District. Bulk deposition samples were collected from three sampling locations, namely, the University of Kelaniya premises, Sapugaskanda and Sedawatta from May 2013 to October 2013. All the samples were analyzed for pH, electrical conductivity and trace metals (Pb, Cu, Al, Zn, Fe and Mn). Weekly samples were collected from all three sampling sites, and additional samples were collected after each rain event at the University of Kelaniya premises from January 2013 to November 2013. The pH of individual precipitations ranged from 4.38 to 7.75 and five incidents of acid rain conditions (pH < 5.60) were recorded during this period. The electrical conductivity of individual precipitations fluctuated widely within a range from 4 to 191 $\mu\text{S cm}^{-1}$. Volume weighted means of the individual precipitations for Pb, Cu, Al, Zn, Fe and Mn in the sampling site at the University of Kelaniya ($\mu\text{g L}^{-1}$) were 1.5, 3.7, 61.5, 28.5, 6.7 and 3.6, respectively. The dominance of various trace metals of volume weighted means of the weekly collected samples in the sampling sites at University of Kelaniya, Sapugaskanda and Sedawatta followed the sequence Al > Zn > Fe > Mn > Cu > Pb. Samples collected from the site near Sapugaskanda oil refinery and the site at Sedawatta showed higher concentrations of most trace metals investigated.

Keywords: Atmospheric precipitation, bulk deposition, trace metals

“CHRONIC KIDNEY DISEASE OF UNKNOWN ETIOLOGY (CKDu)” IN SRI LANKA: ARE ALUMINOFLUORIDE COMPLEXES (AlF_x) THE LIKELY CAUSE?

H.M.S. Wasana^{1*}, G.D.R.K. Perera², P.D.S. Gunawardena³ and J. Bandara¹

¹*Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka.*

²*Department of Farm Animal Production and Health, Faculty of Veterinary Medicine, University of Peradeniya, Peradeniya, Sri Lanka.*

³*Department of Veterinary Pathobiology, Faculty of Veterinary Medicine, University of Peradeniya, Peradeniya, Sri Lanka.*

Even though AlF_x complexes are suspected as a risk factor for CKDu, no study has been carried out to confirm whether it is the root cause for CKDu, by using animal models in Sri Lanka. Thus, in this study, the effect of F, Al and AlF_x complexes on CKDu was investigated. Even though there is strong evidence to demonstrate the neurotoxicity of AlF_x, there is no firm evidence to assert that the drinking water containing fluoride (1-10 mg L⁻¹) and Al (1-10 mg L⁻¹) or AlF_x(0.01-18 mg L⁻¹) increases the risk of developing Chronic Kidney Disease (CKD). Hence, an animal trial was carried out in this investigation to ascertain the relationship among F, Al and AlF_x complexes on CKD.

Mice were treated either with WHO recommended or moderately above F and Al levels in drinking water as follows: 0.05-10.0 mg L⁻¹ of F, 0.08-10.0 mg L⁻¹ of Al or 0.01-18 mg L⁻¹ of AlF_x. Treatment period of forty two weeks was used in order to study the effect of chronic exposure. Nine test groups of (n=54) were used for treatment solutions and the control group (n=6) was administered only with distilled water (dw). Adult ICR female mice (seven to eight months) were used for this study. Blood urea levels and creatinine levels were investigated as a measure of malfunction of kidneys at the end of the treatment period. Histopathological evaluations of kidney, liver, heart and lung tissues were carried out to assess the extent of damage which could be caused by F, Al and AlF_x complexes.

Observations of behaviour, external examination of carcasses, gross and histological evaluation of kidney, liver, heart and lungs of mice euthanized at the end of the test period revealed the absence of abnormalities with reference to CKDu. Post-mortem findings of dead animals during the test period were also not related to CKDu. Furthermore, blood urea nitrogen and creatinine values of test groups are comparable with the control group; indicating no adverse effects of given concentrations in the series of Al and F in ddw.

According to above findings, it can be concluded that; chronic exposure of treated drinking water, containing F and Al on par with WHO or moderately above the WHO levels or AlF_x at low level (0.01-18 ppm) do not lead to CKD in mice.

Keywords: CKDu, aluminofluoride complexes, creatinine levels, drinking water

*wasanahms@gmail.com

COULD DIETARY WATER OF CHRONIC KIDNEY DISEASE OF UNKNOWN ETIOLOGY (CKDu) PATIENTS OF MEDEWACHCHIYA, SRI LANKA BE A LIKELY SOURCE FOR NEPHROTOXIC AGENTS?

E.A.R.I.E. Siriwardhana^{1*}, P.A.J. Perera¹, R. Sivakanesan², T. Abeysekara³ and D.B. Nugegoda⁴

¹*Department of Biochemistry, Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Saliyapura, Anuradhapura, Sri Lanka.*

²*Department of Biochemistry, Faculty of Medicine, University of Peradeniya, Peradeniya, Sri Lanka.*

³*Department of Pharmacology, Faculty of Medicine, University of Peradeniya, Peradeniya, Sri Lanka.*

⁴*Department of Community Medicine, SAITM Faculty of Medicine, Malabe, Sri Lanka.*

An interventional study was carried out to assess the effects of standard quality (SQ) bottled water on kidney functions of confirmed CKDu patients attending Medawachchiya renal care unit. Two groups of stage three CKDu patients were randomly selected. The intervened group (Group I) was given SQ water instead of previous dietary water whilst the non-intervened group (Group II) continued the use of usual drinking water. Water was used for drinking and cooking for 18 months. Kidney functions were assessed at the commencement and at 3 months intervals for a period of 24 months. Blood pressure, plasma creatinine, serum calcium, serum phosphate, blood hemoglobin, estimated glomerular filtration rate (eGFR) and urinary protein were measured. Significant variations were not found in any of the tested parameters between the two groups with the commencement of the study.

The disease progression rate in each group was analysed by comparing each parameter as a difference between the zero time value, and the values at 3, 6, 9, 12, 15, 18, 21 and 24 months and by comparing the mean values between the two groups. Accelerated disease progression rate was seen in CKDu patients of Group I than those of Group II, according to kidney function evaluated using plasma creatinine, eGFR, Hb and urinary protein. When the plasma creatinine value at each time point was compared with the initial value of that particular group, significantly high values ($p < 0.05$) were noted among CKDu patients of Group I only from 12 to 24 months, whilst significant variations in the CKDu patients of Group II were noted from 3 months onwards. When the mean values of the two groups were compared, significant variations ($p < 0.05$) were found at 3, 6, 12 and 18 months. When the supply of bottled water was discontinued in Group I after 18 months, a significant variation was not seen ($p > 0.05$) in plasma creatinine values between the two groups.

A significant decrease ($p < 0.05$) in the eGFR value from the initial value occurred with CKDu patients of Group I at 21 and 24 months only, whereas significant variations ($p < 0.05$) were observed from 3 months onwards in Group II, when compared with the initial value. Comparison of eGFR between the two groups showed significant variations ($p < 0.05$) at most of the time points. Significant variations ($p < 0.05$) in Hb value when compared with initial value were observed at 12 and 15 months with CKDu patients of Group I and from 3 months onwards in patients of Group II. The mean Hb value of CKDu patients of Group I decreased at a slower rate than the CKDu of Group II with time.

The mean serum calcium and phosphorous levels of CKDu patients of both groups varied within the normal range, and the majority (>50%) of CKDu patients of both groups were negative for proteinuria, at the commencement of the project. With time, the percentage positive for proteinuria markedly increased in Group II. In conclusion, kidney function of CKDu patients of intervened group are less affected than those of the non-intervened group, suggesting that habitual dietary water is a likely source of nephrotoxic agents.

Keywords: Dietary water, chronic kidney disease, Medewachchiya, nephrotoxic agents

A MODEL OF RAINFALL AND OTHER CLIMATIC FACTORS EFFECTING DENGUE INCIDENCE IN SRI LANKA: A MULTILEVEL STUDY

W.T. Jayanetti and M.R. Sooriyarachchi*

Department of Statistics, Faculty of Science, University of Colombo, Colombo 3, Sri Lanka.

Dengue is the most significant mosquito-borne disease, now endemic in most tropical countries causing a major public health concern. Dengue Fever (DF) and Dengue Hemorrhagic Fever (DHF) have been classified as a leading cause of hospitalization and death in Sri Lanka. Since the first reported outbreak of DF in 1965, there had been outbreaks on and off until the recent past with progressively large outbreaks occurring more frequently. Thus, in order to prevent dengue, it is vital to conduct research and identify possible contributing factors to the disease in Sri Lanka. The most commonly encountered response of interest in epidemiological studies of life-threatening viral diseases, such as dengue, is the counts of patients having the disease. As the mosquito is the main vector of dengue and mosquito breeding is dependent on water and climatic factors, the major objective of the study was to determine the effect of climate parameters, such as rainfall, temperature and humidity, on the dengue incidence in Sri Lanka.

This study is based on analyzing information about dengue cases reported from high risk areas in Sri Lanka during the period of 2006 to 2009. Due to the cluster correlation observed in this data set, simple methods of correlation analysis cannot be used. Therefore, the response of interest was modeled univariately in a multilevel framework. The patterns of incidence of the disease with respect to climatological parameters were obtained by using graphical analysis. This was further followed by the univariate analysis using Generalized Cochran Mantel Haenszel test for correlated categorical data to assess the individual effects of climate factors on the counts in the presence of the multilevel data structure. In order to achieve the main objective, a multilevel Poisson error model was fitted. The response was the number of dengue cases recorded monthly during the particular period of a certain district. The model reveals that the clustering variables such as district and year and also the environmental factors, such as temperature, rainfall and humidity, influenced the incidence of dengue.

Keywords: Generalized Cochran Mantel Haenszel Test, multilevel data, poisson multilevel model, Dengue, climate.

*roshinis@hotmail.com

DRIP IRRIGATION IN MULLAITHIVU DISTRICT, SRI LANKA: A CASE STUDY OF CLIMATE CHANGE ADAPTATION

K.S. Sivanesan *

Institute of Fundamental Studies, Kandy, Sri Lanka.

Needs of agricultural productivity and the poverty of farmers are increasing in Sri Lanka. Weather patterns in the country seem to be gradually changing affecting the rainfall pattern on which agricultural activities are dependent. Water scarcity is increasing in the dry zone. Some organizations have provided solar powered drip irrigation systems to the dry zone farmers at a low price. After the war period, farmers of the Mullaithivu district also adopted this system for farming activities.

The objective of the study was to find out the current status of drip irrigation adoption and factors affecting it for the adoption of drip irrigation in the Mullaithivu district. The data were collected by field visits, direct interviews and structured questionnaire surveys. The sample consists of a total of 149 respondents from the Mullaithivu district who use drip irrigation. Adoption had a positive relationship to education, attitude, knowledge, training and a negative relationship with age and farming experience. Most of the farmers above 40 years of age had education levels below Grade 10, but had farming experience of more than 25 years. These farmers earlier used ridge and furrow irrigation from the ground water. Drip irrigation farmers are weaker in attitude and adoption level. It was found that emission uniformity coefficient and distribution uniformity were below the recommended level which reflects the water shortage at some emitters resulting in water stress to plants. It was also observed that a major constraint faced by farmers to continue drip irrigation to the frequent clogging of the emitters, and non-availability of spare parts with easy access. The study identified that most of the field rate of discharge was below the infiltration rate of soil. The study showed that 40% of the farmers did not use fertigation units, 48% of the farmers claimed that their systems maintenance was not at a satisfactory level, and some 35% of the farmers did not select suitable crops. 38% of the farmers did not cover the pump properly. However, only 50% drip system could be used in their fields successfully. Demonstration fields, mass media, training and awareness and farmer-to-farmer exchange of information can improve the adoption of micro-irrigation in the study area.

Keywords: Drip Irrigation, Mullaithivu, Climate change, Agriculture

* nesasiva@gmail.com

ASSESSMENT OF EXPOSURE LEVELS OF DRINKING WATER CONTAMINANTS IN GROUNDWATER SOURCES IN HAMBANTHOTA DISTRICT, SRI LANKA

H.S.A.D. Perera¹, H.B. Asanthi^{1*} and P.M.C.S. De Silva²

¹*Department of Limnology, Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna, Sri Lanka.*

²*Department of Zoology, Faculty of Science, University of Ruhuna, Sri Lanka.*

This study was conducted to assess the exposure of drinking water contaminants (NO_3^- , PO_4^{3-} , F^- , Hg^{2+} and Mn^{2+}) in groundwater at the selected areas of Tangalle, Beliatta, Angunukolapellassa and Balangoda (reference site). The water samples (n=6) were collected from groundwater sources whose owners were kidney patients, during the dry period of September - October, 2013. Hg and Mn were analyzed using atomic absorption spectroscopy with the combination of cold vapour generator for Hg analysis, and the accuracy of the method was determined using the standard addition method. NO_3^- , PO_4^{3-} and fluoride concentrations were determined by the standard methods. Questionnaire based field survey was conducted to identify the status of the hazard and to collect relevant data from the families to apply risk assessment models.

Hg was detected only in the groundwater of Tangalle and Angunukollapellassa areas and the mean concentrations were $0.005 \pm 0.002 \text{ mg L}^{-1}$ and $0.002 \pm 0.001 \text{ mg L}^{-1}$, respectively, for the two locations. Although the exposure of Hg in Tangalle and Angunukollapellassa areas were lower than the recommended exposure of 0.0003 mg/kg body weight/day, serious effects may occur with long term exposure. Mn was detected only in the above two areas and the mean concentrations were recorded as $0.65 \pm 0.20 \text{ mg L}^{-1}$ and $0.18 \pm 0.20 \text{ mg L}^{-1}$. Mean concentration of fluoride (1.48 mg L^{-1}) at Tangalle and Angunukollapellassa areas is higher than the Sri Lankan standards. Mean values of NO_3^- and PO_4^{3-} concentrations were relatively higher at the same locations but the levels recorded were lower than SL standards. The hazard quotient values for fluoride and nitrate exposure exceeded the unity of the model in all four areas (1×10^{-6}) and Mn exposure exceeded the unity of the model only at Tangalle and Angunukolapellassa areas which predicts a potential health risk for noncarcinogenic effects.

Keywords: Risk assessment, hazard quotient, Fluoride, groundwater

* asanthi@fish.ruh.ac.lk

INTRODUCTION OF SUBURBAN RECREATIONAL AREAS IN RIPARIAN LANDS WHILE ENHANCING URBAN BIODIVERSITY

M. Panapitiya^{1*} and S. Bandaranayake²

¹*Richfield Lanka Pvt. Ltd., Mudungoda, Sri Lanka.*

²*Provincial Road Development Authority of Western Province, Battaramulla, Sri Lanka.*

Many of the stream reservations are owned by the government. Currently urban areas have a severe shortage of recreational spaces. Therefore public use of those reservations for recreational purposes, especially those located in urban areas, can be considered as a fair use of the land. A five-km stretch of Uruwal Oya adjacent to Gampaha Town was selected to implement a program to re-configure the riparian reservations into recreational areas while improving the stream for flood mitigation. Basically the project was a landscape exercise to create a recreational park along stream banks. Diversity of the landscape in aquatic and terrestrial interface of stream banks provided ideal conditions to grow different kinds of flora while forming a bio-corridor connecting isolated forest patches in urban landscapes. Those paths also serve as environmentally sustainable transport for local communities by providing safe environment for walking and cycling. Out of the five km stretch selected, recreational facilities with jogging paths were introduced in the first two km. The balance three km was developed as a low cost nature trail. After the completion of the Gampaha Project, there is now a big public demand for more similar interventions for local water bodies.

Keywords: Flood mitigation, recreational spaces, riparian lands, bio-corridor

*davids@slt.net.lk

DETECTION AND QUANTIFICATION OF CYLINDROSPERMOP SIN IN WATER RESERVOIRS OF SRI LANKA USING HIGH PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC)

H.M. Liyanage¹, D.N. Magana–Arachchi^{1*}, N.V. Chandrasekharan² and S.A. Kulasooriya¹

¹*Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka.*

²*Department of Chemistry, University of Colombo, Colombo 03, Sri Lanka.*

Toxigenic cyanobacteria are increasingly being perceived as a potential health hazard, particularly in waters used for drinking and recreation. Exposure to cyanobacterial toxins in freshwater systems through direct and indirect paths is emerging as a potentially significant threat to human health. Among the cyanotoxins, cylindrospermopsin (CYN) is being recognized as one of the most important freshwater toxin. The toxin is a tricyclic alkaloid which is neurotoxic, cytotoxic and also affects kidney and liver functions. The occurrences of cyanobacterial blooms in fresh waters of Sri Lanka and their potential contribution to the recent epidemics of Chronic Kidney Disease of uncertain etiology (CKDu) prevailing in the North Central Province and its surrounding areas have increased the concern of such contaminants in these water bodies. This study used High Performance Liquid Chromatography (HPLC) to detect and quantify CYN in water reservoirs of Anuradhapura. Water samples were collected from Kala Wewa, Nuwara Wewa, Thisa Wewa and Jaya Ganga. Microscopic observations revealed *Cylindrospermopsis* as the dominant cyanobacterial species along with *Microcystis*, *Anabaena*, *Chroococcus*, *Phormidium*, *Oscillatoria*, which were comparatively moderate to low in number. Molecular detections also confirmed the presence of *Cylindrospermopsis* species in these reservoirs. CYN toxin was extracted from all the samples and subjected to HPLC along with CYN standards. According to chromatographic results, the presence of CYN was confirmed in three samples and the highest concentration was found in the Thisa Wewa sample (18.6 µM) followed by Kala Wewa (13 µM) and Nuwara Wewa (12 µM). It is concluded that these water reservoirs contain *Cylindrospermopsis* species which has a high potential to produce CYN which can cause adverse health effects to humans. It may therefore be a major risk factor for various environmentally related illnesses recorded in the dry zone. More epidemiological studies are required to explore the relationship between human illnesses and cyanotoxins in water.

Keywords: Cyanotoxins, Cylindrospermopsin, environmental health, HPLC.

*dmaganaarachchi@gmail.com

PRELIMINARY OBSERVATIONS ON BIRD DIVERSITY IN VADAMARACHCHI AND UPPARU LAGOONS IN JAFFNA, SRI LANKA

P. Rajkumar^{1,2*} and C. Wijesundara^{1,3}

¹Posgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.

²Divisional Secretariat, Chundukkuli, Jaffna, Sri Lanka.

³Department of Zoology, University of Peradeniya, Peradeniya, Sri Lanka.

Bird diversity is an excellent indicator of ecosystem health, both terrestrial and aquatic. Hence, bird diversity can also be taken as an indicator of water quality. The objective of the present study was to identify the major migratory and resident bird species in the Vadamarachchi and Upparu lagoons, both of which are notable for their bird diversity as well as being major habitats in the Jaffna area. Migratory birds are regularly present in the Jaffna peninsula from September to April. No previous studies have been carried out in the Jaffna peninsula on the diversity and abundance of bird species, mostly due to the security status of the area in the past. Proper scientific studies are essential for the effective management of these species. These lagoons include mudflats and sea grass beds which provide suitable habitats for migratory as well as resident birds. The present study was carried out from January to March 2014. Point transects were used to count birds. Peak counting hours were between 0630 and 0830 h each day, and counts were taken weekly. A 10 km² area was selected from each habitat and fourteen sampling points were selected using simple random sampling. A minimum distance of approximately 100 m was kept between points to avoid pseudo replication. Birds were counted for 20 minutes at each point, using binoculars. The most abundant species was the Northern pintail (*Anas acuta*) (total count: > 5000). Other migratory species included the gull-billed tern (*Gelochelidon nilotica*) (total count: 27), wood snipe (*Gallinago nemoricola*) (3), pintail snipe (*Gallinago stenura*) (3), common sandpiper (*Actitis hypoleucos*) (10), and common redshank (*Tringa totanus*) (10). Among the other notable species were resident birds, such as the painted stork (*Mycteria leucocephala*) (9), black-headed ibis (*Threskiornis melanocephalus*) (40), spoonbill (*Platalea leucorodia*) (5) and black-winged stilt (*Himantopus himantopus*) (36). Given the large number of bird species (both migrant and resident) present in these lagoons and the eco-touristic potential they hold, they are undoubtedly very important areas for bird conservation. The high species richness is also indicative of the overall high health condition of these habitats, especially water quality.

Keywords: Avifaunal diversity, lagoons, point counts, Jaffna peninsula, water quality.

*vpraj25@yahoo.com

FRESHWATER DIATOMS AS PROXIES OF ASSESSING ENVIRONMENTAL CHANGES IN RESERVOIRS IN SRI LANKA

P.A.I.U.T. Perera and S.K. Yatigammana *

Department of Zoology, University of Peradeniya, Peradeniya, Sri Lanka.

Proxy indicators are used worldwide to understand the changes in the environment we live in. Among them, diatoms are well known for their species specific responses to environmental variables and thus play a major role in reconstruction of the past environment. However, only a very few studies have been conducted using diatoms as environmental indicators in Sri Lanka. Therefore, this study was carried out to determine whether reservoir diatoms can be used to understand the changes in the environment.

Six reservoirs selected for the study included, Bathalagoda, Bowatenne, Kurunegala and Nalanda representing the Intermediate Zone, and Kandy and Dambarawa reservoirs representing the Wet Zone of Sri Lanka. Physico-chemical characteristics (pH, temperature, conductivity, dissolved oxygen, nitrate and phosphate) of six study reservoirs, were obtained using both onsite and laboratory analysis at monthly intervals from February to July, 2013. Plankton and sediment samples were also collected using plankton net, a dip net and a gravity corer. Relative abundance of present day diatoms and subfossil remains of diatoms were used to understand whether diatoms are preserved in sediments and whether they are sensitive to measured environmental variables.

Twelve diatom species were identified from six reservoirs during the study period. *Aulacoseira granulata* was the most abundant diatom in all six sites. Bathalagoda, Dambarawa and Nalanda reservoirs supported a high diversity of diatoms, while the lowest diversity was observed in Kandy Lake. Although a monthly variation of relative abundance of species was detected in different reservoirs, sediment analysis showed that they were well preserved at reservoir bottoms (Pearson correlation values obtained between the present day diatoms and subfossil diatoms: Kurunegala-0.996, Bathalagoda-0.994, Nalanda-0.983, Bowatenne- 0.999, Dambarawa-0.841 and Kandy -1.000). Results also revealed that the species are sensitive to environmental conditions and help to discriminate study reservoirs.

Keywords: Diatoms, subfossil diatoms, environmental changes, reservoirs

* isharaperera88@gmail.com

NUTRIENT REMEDIATION CAPACITY OF FLOODPLAIN LAKES (VILLUS) OF LATTER REGION OF MAHAWELI RIVER BASIN: A PRELIMINARY STUDY

A.G. P. Aravinna^{1,4}, N. Priyantha^{1,4*}, H.M.T.G.A. Pitawala^{2,4} and S.K. Yatigammana^{3,4}

¹*Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka.*

²*Department of Geology, University of Peradeniya, Peradeniya, Sri Lanka.*

³*Department of Zoology, University of Peradeniya, Peradeniya, Sri Lanka.*

⁴*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.*

Floodplain lakes (Villus) are natural fresh water aquatic ecosystems located in association with floodplains of a river, which serve a vital role in fisheries. Mahaweli river which drains water from nearly 13 km² contains several Villus (Handapan, Gengala, Karapola, Sevenapitiya and Velankadu), at the hindmost end of the river in the North Eastern region of Sri Lanka. These Villus are fed mainly by periodic floods especially during the North-East monsoon (November to February). As the river catchment contains agricultural areas, where intensive farming is carried out throughout the year, draining and accumulation of agrochemicals along the river bed and associated systems is unavoidable. As Villus are known to play an important role in nutrient remediation, dilution and ecosystem restoration, studies leading to assess the importance of Villus in maintaining health of lotic systems have become important, especially when river water is used for agriculture. Therefore nitrogen and phosphorus variations were studied along the drainage system of Mahaweli system C to evaluate the nutrient remediation capacity of Villus after the rainy period of year 2014.

Various species of nitrogen and phosphorous were determined according to APHA method and HACH DR890 colorimetric methods. Levels of nitrate nitrogen (NO₃-N) were significantly ($p = 0.9909$ at 95% confident level) reduced along the drainage with the maximum reduction of 75%. Although the average rate of decrease in NO₃⁻-N through Villus was approximately 0.1 mg L⁻¹km⁻¹, the decrease was higher at the first part of the series of Villus, probably due to the absorption by macrophytes in water and aquatic plants in inundated areas of Villus. However, when NO₃-N reached a low value of 0.3 mg L⁻¹, the reduction was not uniform, which may be indicative of biological activities of the system. Nitrite nitrogen (NO₂-N), reactive phosphorous and total dissolved phosphorous along the drainage system were present at trace amounts 0.001- 0.007 mg L⁻¹, 0.001 - 0.008 mg L⁻¹ and 0.006 - 0.013 mg L⁻¹, respectively. Levels of ammonia nitrogen (NH₃-N) remained below the minimum detection limits of 0.01 mg L⁻¹. However, decreasing trend of these nutrient variables was not clearly evident. Thus the study indicates that Villus play a role in controlling NO₃-N. As excess nitrogen and phosphorous fertilizer is discharged to the drainage canal, nutrient levels would be high during the cultivation period of paddy. Therefore, an investigation leading to nutrient variation until harvest would be essential to evaluate the nutrient remediation ability of Villus with respect to both species of N and P.

Keywords: Villu, nutrient, fertilizer, macrophyte, remediation

*piyalaravinna@yahoo.com

PLANKTON COMMUNITY: INDICATORS OF WATER QUALITY IN KOTHMALE RESERVOIR, SRI LANKA

A.L. Warusawithana^{1,3*} and S.K. Yatigammana²

¹Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.

²Department of Zoology, University of Peradeniya, Peradeniya, Sri Lanka.

³Department of Entomology, Medical Research Institute, Sri Lanka.

Microscopic organisms in aquatic systems are sensitive to the physico-chemical and biological changes of the environment they live in. Hence, the understanding of the community structure of such organisms, including Cladocera, Diatoms, Chironomids and other planktonic organisms, will provide a better facility to understand past and present environmental conditions and future directions. Kotmale reservoir, recently built for hydroelectric power generation, obtain nutrient-rich water through Pundalu Oya, Puna Oya and Kotmale Oya. Although past studies indicate that this reservoir is moving towards eutrophication, unfortunately, monitoring is not yet started. As plankton indicates environment changes through community turnover, the study was designed to explore if plankton communities vary in different locations of recently built 28 km long reservoir.

Monthly samplings of plankton were conducted from June 2008 to June 2009, and sampling at three month intervals was conducted from June 2009 – June 2011 from 22 sites. The sites were identified by considering the catchment characteristics and the presence of inflow canals. Both phytoplankton and zooplankton samples were collected using plankton nets with appropriate pore size, and planktonic organisms were identified. From each sample, at least 500 individuals were counted for calculation of the relative abundance of plankton. This procedure was repeated for each sample and the mean value was taken to determine the species dominance at each site. Testing for important limnological variables were done at each visit.

A total of ~117 different plankton species were identified and most of them were phytoplankton. The abundance of phytoplankton was higher than that of the zooplankton in all the sites. Orders Desmidiaceae and Chroococcales were the dominant phytoplankton groups, while Cladocera and Protozoa were the dominant zooplankton. *Staurastrum cingulum* was dominant in sites, where the catchment is covered with reservation forest with no significant inflow streams, and located along the right bank of the reservoir. Water quality measurements of DO, pH, Total phosphorus (TP), Dissolved phosphorus (DP) and NO₃⁻ indicate that the region maintains mesotrophic condition. In contrast, *Microcystis* spp. dominates especially in sites located in the left bank, where several inlets bring water from adjacent villages. In addition, where Punaoya reach the reservoir contain high levels of TP and *Botryococcus braunii* was the dominant phytoplankton. Closer to the dam where deep water column and bottom anoxia prevail *Microcystis* spp. was abundant. Further, *Cladocera* species were abundant in sites where *Staurastrum cingulum* was abundant, rotifers and ciliate protozoans were identified closer to the dam and the sites with high dominance of *Microcystis* spp. Diatom species, *Navicula* spp. and *Aulacoseira granulata* were abundant in sites where Pundaluoya reach the reservoir. Generally, these species are found in healthy unpolluted water. Thus, our study suggests that plankton respond to limnological conditions prevailing in different regions of the reservoir showing the potential use of these organisms to assess water quality.

Keywords: Kothmale reservoir, nutrient, plankton, indicators, water quality

*allw3182yahoo.com

REMOVAL OF Pb(II) IONS FROM WASTEWATER USING PEAT COLLECTED FROM BRUNEI DARUSSALAM

T. Zehra^{1*}, L. B. Lim¹, N. Priyantha^{2,3}

¹*Department of Chemistry, Faculty of Science, Universiti Brunei Darussalam, Jalan Tungku Link, Gadong, Brunei Darussalam, Brunei.*

²*Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka.*

³*Sri Lanka Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.*

Removal of pollutants from wastewater has been an important area of research in recent years. Among different techniques used, adsorption is found to be very effective, and many natural biosorbents show good adsorption capacity for heavy metal ions and dyes, demonstrating their use in treatment of wastewater. Peat is a porous and complex naturally occurring soil material with partially decomposed organic matter. In addition to its adsorption properties due to porosity, low-cost is an additional advantage. In this research, representative peat samples collected from Brunei Darussalam were used for the investigation of the removal of Pb(II) from synthetic wastewater as determined by atomic absorption spectroscopy. Variation of a single parameter, while the other parameters are kept unchanged, indicates that the optimum values of shaking time, settling time, medium pH, ionic strength and temperature of firing of peat are 2 h, 30 min and ambient pH, respectively. These parameters significantly affect the extent of the adsorption process. In presence of nitrate ions, removal efficiency decreases, but increases with the increase in temperature of the medium. Scanning electron microscopy, Fourier Transform infra-red spectroscopy and X-ray fluorescence spectroscopy of Pb(II) treated peat samples provide information on the surface functional groups and elemental composition changes, further supporting of the Pb(II) removal from wastewater. Isotherm studies were carried out using 0.10 g peat and 50.0 mL of Pb(II) solutions of different concentrations ranging from 5 mg L⁻¹ to 100 mg L⁻¹. The removal process fulfills the requirements of pseudo second order mechanism according to kinetic studies with an apparent rate constant of 1.41 g mol⁻¹min⁻¹, while the Langmuir isotherm model leads to an adsorption capacity of 16.0 mg g⁻¹.

Keywords: Peat, adsorption, isotherm, kinetics.

POTENTIAL USE OF CEMPEDAK DURIAN PEEL (CDP) FROM NEGARA BRUNEI DARUSSALAM FOR THE REMOVAL OF METHYL VIOLET (MV) DYE: EQUILIBRIUM, THERMODYNAMICS, KINETICS AND REGENERATION STUDIES

M. K. Dahri¹, H. I. Chieng¹, N. H. M. Mansor¹, N. Priyantha^{2,3} and L. B. L. Lim^{1*}

¹*Department of Chemistry, Faculty of Science, Universiti Brunei Darussalam, JalanTungku Link, Gadong, Brunei Darussalam, Brunei.*

²*Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka.*

³*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.*

Increase in population requires more textile supplies for mankind. Various dye and textile manufacturing industries discharge tons of industrial effluents causing damage to aquatic life as well as human. Therefore, it has become important to discover economical and effective natural material to address these problems. Treatment methods used for removing dyes include coagulation and electrochemical techniques. Among many methods, adsorption has gained favor due to its efficiency and low cost.

This study investigated the potential use of (cempedak) durian peel (CDP) from Negara Brunei Darussalam, which is a low-cost, locally available, eco-friendly and highly efficient material to remove methyl violet (MV) dye from wastewater. The adsorption study was carried-out under conditions optimized for agitation time, settling time, pH of dye solution, temperature and ionic strength. All experiments were carried out using 1:500 w/v (CDP: MV) at 10 to 1000 mg L⁻¹ for MV and the absorbance of MV was recorded at 584 nm using a UV-Vis spectrophotometer. The results showed that the optimum agitation and settling times for CDP to reach equilibrium were 2 h and 1 h, respectively, indicating faster adsorption compared to other fruit waste adsorbents. The optimum pH for the removal of MV was at its ambient pH (5.39), and therefore no adjustment of pH was required. The point of zero charge (pH_{pzc}) for CDP was at pH 4.0. Adsorption isotherm models, namely Langmuir, Freundlich, Temkin, Dubinin-Radushkevich (D-R), Redlich-Peterson (R-P) and Sips were used together with error functions to predict the adsorption behavior between CDP and MV. The experimental data best fit both the Langmuir and Sips isotherm models with adsorption capacity (q_{\max}) of 275.8 mg g⁻¹. Thermodynamic data indicated that the adsorption was spontaneous, feasible and endothermic in nature. Adsorption kinetics obeyed the pseudo second order model with high correlation coefficient (R^2), and q_e values closer to their experimental values. MV-loaded CDP was regenerated using water, acid or base solution for at least 5 consecutive cycles. The best regeneration was achieved by base solution, showing about 95% removal efficiency even after five cycles, indicating that CDP can be regenerated and reused, which is beneficial for continual application for the proposed treatment method.

Keywords: Industrial effluents, aquatic life, durian peel, adsorption, Brunei

*linda.lim@ubd.edu.bn

OXIDATION METHODS OF WATER MANAGEMENT AND TREATMENT

P. B. Jayathilaka^{1,4}, G. C. Pathiraja^{1,4}, N. D. Subasinghe¹, A. Bandara^{2,4} and
N. Nanayakkara^{1,3,4*}

¹*Institute of Fundamental Studies, Kandy, Sri Lanka.*

²*Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka.*

³*Department of Civil Engineering, University of Peradeniya, Peradeniya, Sri Lanka.*

⁴*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.*

Since the water quality is important for human health, water management and treatment techniques receive more attention in today's world. Among these techniques, electrochemical techniques, such as advanced oxidation processes (AOP), are more popular. Anode material plays the most important role in efficiency of an anodic oxidation process. Therefore, recent attention has been paid on the development of novel anode materials for anodic oxidation of water pollutants. The aim of this study is to develop and introduce a novel anode material; steel/IrO₂-Sb₂O₃.

The steel/IrO₂-Sb₂O₃ anode was developed through pretreatment followed by dip coating. Since IrO₂ has preferable properties, such as high electrical conductivity, low over-potential for oxygen evolution reaction and corrosion resistance, it was selected as the noble metal oxide for the novel anode. Antimony (Sb) was used because of its high electrical conductivity and cost effectiveness. The reason to use stainless steel substrate is its corrosion resistance, and more importantly, the low cost as compared to other substrates. In the pre-treatment process, substrate was mechanically treated using a sand paper in order to enhance adhesive properties of the surface. Chemical pre-treatment was performed with 5% (w/w) oxalic acid solution and 37% (w/w) HCl acid prior to the coating process (geometrical area of one electrode ~1 cm²). Finally, the substrate was sonicated in distilled water and dried at 100 °C and calcinated at 500 °C. Then, the anode was tested and its efficiency was monitored by its radical generation capacity, decrease in chemical oxygen demand (COD) of the solution and anodic charge measurements using electrochemical techniques.

Steel/IrO₂-Sb₂O₃ anode showed 76% COD removal efficiency for phenol in Na₂SO₄ electrolyte. In qualitative determination of hydroxyl radicals, rapid colour bleaching of 4-nitroso-N, N-dimethylaniline (RNO) solution was observed during the initial 10 minute period. Moreover, the radical generation was confirmed using Na₂CO₃ radical scavenger. These radical generation tests confirm that steel/IrO₂-Sb₂O₃ anode material surface effectively participates in the generation of hydroxyl radicals compared to that of steel/IrO₂. The value of anodic charge of the steel/IrO₂-Sb₂O₃ anode was 0.202 mC, which is higher as compared to the anodic charge of the steel/IrO₂ anode (0.175 mC), demonstrating its capability to oxidize pollutants in water. According to the anodic charge analysis, the anode showed improvement of its electrochemically active area compared to steel and steel/IrO₂ anodes. The study concluded that the steel/IrO₂-Sb₂O₃ anode functions as a satisfactory anode material in oxidation of organic pollutants in water. This method can be implemented in large scale water management and treatment purposes. Further optimization studies are being carried out to enhance the stability and catalytic activity of the anode and to reduce its iron content.

Keywords: Electrochemical Techniques, Advance Oxidation Processes, Steel/IrO₂-Sb₂O₃ Anode

*kgnn@pdn.ac.lk

ELECTROCHEMICAL PROPERTIES AND DEGRADATION OF CHLORPYRIFOS ON DIFFERENT DIMENSIONALLY STABLE ANODE (DSA) ELECTRODES

G.C. Pathiraja¹, P.B. Jayathilaka¹, K. Karunarathna¹ and N. Nanayakkara^{1,2*}

¹*Environmental Engineering/Electrochemistry Research Group, Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka.*

²*Department of Civil Engineering, Faculty of Engineering, University of Peradeniya, Peradeniya, Sri Lanka.*

Chlorpyrifos, at present, is one of the top commercial insecticides in Sri Lanka due to the high usage of organophosphate pesticides in agriculture and in households as a termiticide. Since it has the potential to have an impact on human health and ecosystems, even at low concentrations, removal of chlorpyrifos from contaminated water is very important. Among different water treatment techniques, electrochemical oxidation is a promising technique for degrading organic pollutants due to its high oxidation efficiency, fast reaction rate, and easy operation. Although the anode material plays a major role in electrochemical oxidation, the lack of ideal anodes in electrochemical oxidation is still a critical problem.

Therefore, two dimensionally stable anodes (DSA), Ti/IrO₂ and Ti/IrO₂-SnO₂ were developed in this study in order to degrade chlorpyrifos in a chloride-free environment. The efficiency of degradation and electrochemical properties of the above anodes were investigated. The chemical oxygen demand (COD) results revealed that Ti/ IrO₂-SnO₂ electrode degrades 78.2% of chlorpyrifos, while Ti/ IrO₂ electrode removes 65.1% after six hours of electrolysis. Moreover, the results showed that COD removal followed pseudo-second order kinetics. Further, radical scavenger studies confirmed that the hydroxyl radical can be the major factor responsible for degrading chlorpyrifos. Finally, the anodic charge and the stability of anodes were investigated. It was observed that anodic charge of Ti/IrO₂ anode and Ti/ IrO₂-SnO₂ anode were 153.76 mC and 145.15 mC, respectively. The Ti/IrO₂ anode showed a life time of 2 h, while the Ti/ IrO₂-SnO₂ anode showed a 9 h life time in the accelerated life time test, indicating the higher stability of the Ti/ IrO₂-SnO₂ anode.

Keywords: Electrochemical oxidation, anode material, dimensionally stable anode, chlorpyrifos, chloride free environment, accelerated life time test.

*kgnn@pdn.ac.lk

USE OF *Mimosa pigra* SEED POD POWDER TO REMOVE AQUEOUS Pb(II)

D.M.R.E.A. Dissanayake^{1,2}, W.M.K.E.H. Wijesinghe¹, S.S. Iqbal³, N. Priyantha² and M.C.M. Iqbal^{1*}

¹Plant Biology Laboratory, Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka.

²Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.

³Faculty of Natural Science, Open University Sri Lanka, Nawala, Sri Lanka.

Pb(II) is a widely used heavy metal in battery manufacturing and the paint industry. Untreated effluents from these industries would contaminate the environment and is a health hazard to humans. Pb(II) toxification can occur through inhalation, oral contamination and dermal contamination. Chronic toxic effects of Pb(II) are mutations, cancers and birth defects, and therefore, decontamination of Pb(II) is an important requirement in industries. This study investigated the capacity of the use of *Mimosa pigra* seed pod powder as a biosorbent to remove aqueous Pb(II) ions.

Dried *Mimosa pigra* seed pods were ground and sieved. Thereafter, 0.20 g of the biosorbent was shaken with 100 ml of 5.0 mg L⁻¹ Pb(II) solution. Suspensions were removed and filtered at desired time intervals and filtrates were analysed using an atomic absorption spectrophotometer. Effect of experimental conditions were investigated by varying the pH, initial Pb(II) concentration and the biosorbent dosage.

The maximum adsorption percentage of 60% was observed at 90 min for ambient pH (pH = 5). The removal capacity was 1.63 mg g⁻¹ of the biosorbent. The equilibrium data were compatible with the pseudo-second order kinetics model, and the rate constant was 0.58 g mg⁻¹ min⁻¹. The maximum adsorption of 90% was observed at pH= 4. The Freundlich isotherm was found to represent the adsorption process. This study indicates that *Mimosa pigra* seed pod powder could be used as a cost effective and an environmentally friendly biosorbent to remove Pb(II) from contaminated aqueous environments.

Keywords: Biosorption, *Mimosa pigra*, Pb(II).

AFFINITY OF FIRED PEAT FOR SIMULTANEOUS ADSORPTION OF Cu(II) AND Cr(VI) FROM AQUEOUS SOLUTION

S. Wickramasooriya^{1,2}, N. Priyantha^{1,2*} and L.B.L. Lim³

¹Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka.

²Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.

³Department of Chemistry, Universiti Brunei Darussalam, Brunei Darussalam.

Fired peat shows a higher affinity to remove heavy metal ions from aqueous medium than its natural form. Adsorption equilibrium established by treatment of 50.0 cm³ of 4.0 mgL⁻¹ - 1000 mgL⁻¹ solutions consisting of both Cu(II) and Cr(VI) with 5.00 g (d < 1 mm) of Muthurajawela peat fired at 200 °C after allowing 3.0 h shaking time and 2.0 h settling time leads to the fulfillment of both Langmuir and Freundlich isotherms according to their linearised plots. The adsorption capacities of Cu(II) and Cr(VI) are determined to be 454 mg/kg and 1428 mg/kg, respectively, based on the Langmuir model, which favours monolayer adsorption. Further, the extent of removal of Cu(II) and Cr(VI) from a solution containing both ions at 10 mgL⁻¹ levels, determined using atomic absorption spectroscopic measurements under optimum conditions, are 80% and 40%, respectively.

Simultaneous adsorption of Cu(II) and Cr(VI), both of which are at 10 mgL⁻¹ levels on fixed bed columns [internal diameter = 2.0 cm, column height = 15 cm, mass of adsorbent = 26 g, particle size of packing = 1.0 mm - 2.0 mm, flow rate ≈ 5 cm³min⁻¹] shows an initial increase in the extent of removal for both metal ions up to a period of 2.0 h. Application of the Bohart-Adams model, which assumes that equilibrium is not instantaneously achieved, provides mass transfer coefficients of 2.6×10⁻⁴ Lmg⁻¹min⁻¹ and 9.0×10⁻⁴ Lmg⁻¹min⁻¹ and saturation concentrations of 887 mgL⁻¹ and 176 mgL⁻¹, respectively for Cu(II) and Cr(VI). This difference can be explained by considering the hydrated radii of the two metal ions.

Keywords: Peat, adsorption, Chromium, Copper, isotherm.

*namal.priyantha@yahoo.com

INTRODUCTION OF A LOW-COST DOMESTIC LEVEL WATER FILTER ON THE INTAKE OF CADMIUM AT KATIYAWA VILLAGE IN NORTH CENTRAL PROVINCE (NCP) OF SRI LANKA

H.M.M.S. Seneviratne¹ and J.M.R.S.Bandara^{2*}

¹*Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.*

²*Environmental and Life Science Programme, University of Brunei Darussalam, Brunei, Darussalam.*

Elevated levels of heavy metals in drinking and irrigation water are a major problem in both industrial and agricultural countries. Elevated cadmium (Cd) level in irrigation and drinking water has been reported from the North Central Province (NCP) of Sri Lanka, where chronic renal failure is wide spread among people. This is a result of extensive use of cadmium contaminated fertilizers over long period of time. Several researchers and the World Health Organization (WHO) have reported that the elevated cadmium level in food and water is a possible cause for the Chronic Kidney Disease of unknown aetiology (CKDu) in NCP. Cadmium is one of the most toxic heavy metals that could cause CKDu with point source pollution of reservoirs by contaminated agrochemicals. In NCP, major reservoirs use for irrigation and drinking purposes are contaminated with Cd (0.03-0.06 mg L⁻¹) and Pb (0.01-0.03 mg L⁻¹). Many farmers and residents use reservoirs or dug wells (close to their major reservoirs) to obtain water for domestic and farming purposes. The agricultural produce (*i.e.* rice) in the region is also reported to contain high Cd (0.09-0.20 mg/kg) and Pb (1.07-1.35 mg/kg).

Early detection of cadmium poisoning is vital to minimize kidney disease. However, it is highly expensive and laborious to continuously monitor Cd levels in drinking water. Therefore, finding an effective method to minimize the exposure to Cd in potable water has become essential. In this study, our main goal was to monitor the impact of Cd free water on Cd level in urine. A low-cost domestic filter was designed with amorphous silica produced from rice husk with activated charcoal (coconut shell charcoal) and fixed in the house hold of a group of selected residents at Katiyawa village to filter out and remove cadmium from the drinking water. The low-cost filtering device is composed of a poly vinyl chloride casing packed with amorphous silica and activated charcoal.

For the experiment, 60 families were selected and 30 filters were distributed among 30 families, and the urine Cd levels were checked in selected males from each family. Urine samples were collected monthly over a period of six months and analyzed for urinary cadmium. The residents who used the water filter showed a significantly low level of urine cadmium than the residents who did not use the water filter. It is known that, out of the total amount of the cadmium ingested, 15% is contributed by the drinking water. Therefore, this filtering method effectively minimises the ingestion of cadmium via drinking water.

Keywords: Cadmium, processed rice husk, amorphous silica, urine Cd level

*bandara.sarath@gmail.com

DETERMINATION OF HEAVY METAL ADSORPTION CAPACITY OF CHITOSAN AND REMOVAL OF HEAVY METALS FROM DRINKING WATER USING CHITOSAN

S.M. De Silva¹, W.T.I. Fernando¹, A.T. Kannangara¹, J.G.P.S. Ubesena² and C.S.K. Rajapakse^{1*}

¹*Department of Chemistry, University of Kelaniya, Kelaniya, Sri Lanka.*

²*Department of Chemistry, University of Sri Jayewardenepura, Nugegoda, Sri Lanka.*

Over the last few decades, drinking water sources especially in the North Central Province of Sri Lanka have been polluted from heavy metals in considerable amounts. Therefore, there is a pressing need for efficient and affordable water purification methods for the removal of heavy metals from polluted drinking water. This work explores the possibility of using chitosan (deacetylated product of chitin), as an environmentally friendly drinking water purification agent. Although chitosan has been used as a heavy metal removal agent for industrial wastewater, few attempts have been made to understand the ability of chitosan to uptake heavy metals in the polluted drinking water, containing trace amounts (ppb levels) of metals. This study focuses on the potential of using chitosan as a biosorbent for purification of drinking water contaminated with low levels of heavy metals.

In the current study, metal adsorption capacity of chitosan for Cd(II), Pb(II) and Cr(VI) was determined at room temperature (29.0 ± 0.5 °C) under different experimental conditions; initial metal ion concentration, agitation time period, initial solution pH, and presence of co-ions in the solution, using graphite furnace atomic absorption spectrophotometry. Optimal performance for Pb(II) was obtained when the initial metal concentration was $70.00 \mu\text{g L}^{-1}$ at pH ~7.0 with 2 hours agitation while that for Cr(VI) was observed at $70.00 \mu\text{g L}^{-1}$ initial metal concentration at pH 5.5 with 6 hours agitation. The optimal Cd(II) adsorption capacity of chitosan was observed when the initial metal concentration was $50.00 \mu\text{g L}^{-1}$ at pH 7.0 with 2 hours agitation. The research further revealed that chitosan has an adsorption capacity of $89.60 \mu\text{g g}^{-1}$ for Pb(II), $93.72 \mu\text{g g}^{-1}$ for Cd(II) and $98.11 \mu\text{g g}^{-1}$ for Cr(VI) under the optimized conditions. Under the experimental conditions, Pb(II) adsorption capacity of chitosan was significantly affected by the presence of Cd(II), but not by the presence of Cr(VI) as co-ions. Cd(II) adsorption capacity of chitosan was not significantly affected by the presence of Pb(II) or Cr(VI) whereas the Cr(VI) adsorption capacity of chitosan was enhanced in the presence of Pb(II) or Cd(II) in the medium.

All samples collected from different areas of the country had pH values in the range defined by WHO, although some samples had excess levels of total water hardness. The water sample collected from Nikawewa well 10 exceeded the permissible level of Cr(VI) as defined by WHO which was successfully reduced to the permissible range by treatment with chitosan indicating that chitosan would be a good candidate which can be used to remove heavy metal ions from polluted drinking water.

Keywords: Chitosan, metal ions, absorption capacity

*shashikala@kln.ac.lk

REMOVAL OF Pb(II), Cu(II), Cr(III), Cd(II), Zn(II), Ca(II) AND Mg(II) FROM DRINKING AND WASTE WATER USING NATURALLY OCCURRING CLAYS IN MABIMA AND PANNALA AREAS IN SRI LANKA

J.M.P.I. Jayathilake, S.K. Weeraratne, R.C.L. De Silva and S.S. Subramaniam*

Department of Chemistry, University of Kelaniya, Kelaniya, Sri Lanka.

Natural clays play an important role in the environment by acting as a scavenger of pollutants. The properties, such as high cation exchange capacity, low-cost, non-toxicity and high natural abundance, lead it to be used commercially as a natural adsorbent. Over the recent years, research has been carried out to remove contaminants and toxic heavy metals from aqueous solutions using clay minerals, through the process of cation exchange. In light of that direction, this research aims to develop a method for efficient removal of heavy metals and hardness in drinking and waste water collected from different areas in Sri Lanka. This study includes the removal of Pb(II), Cu(II), Cd(II), Cr(III), Zn (II), Mg(II) and Ca(II) ions in various aqueous systems using naturally occurring clays.

For this purpose, representative soil samples were collected from Pannala and Mabima areas and characterised by determining the moisture content, soil pH, soil organic matter content, soil textural classes and mineral classes. The clay fractions (2 μm) were separated and treated with acetic acid solution (1 M) and further treated with H_2O_2 (30%) to oxidize the organic matter. Both peroxide treated and non-treated samples were used as adsorbents after converting into Na^+ homo-ionic materials. The retention capacities of each adsorbent for metal ions under investigation were determined by equilibrating the adsorbent (5.00 g) with a series of single and multi metal nitrate solutions (200.00 mL). Eight single metal ion solutions for each metal ion were prepared at concentrations ranging from 500 to 3500 mg L^{-1} . Six multi-element solutions were prepared, which contained all the studied metal ions in equal concentrations ranging from 150 to 600 mg L^{-1} . The remaining metal ion concentrations in the equilibrated solutions were determined with Flame Atomic Absorption Spectroscopy (FAAS). The highest adsorption capacity was detected for Cr^{3+} followed by Pb^{2+} , and the lowest value was detected for Mg^{2+} and Ca^{2+} on both adsorbents (Pannala and Mabima) and element (single and multi) systems. The adsorption capacities of Mabima and Pannala adsorbents were 74.48 mg g^{-1} and 71.94 mg g^{-1} respectively. The adsorbent from Mabima showed higher adsorbability due to clay type and higher organic content. Higher adsorption capacities were observed for non-treated samples due to the presence of higher organic content. Drinking and waste water samples which were collected from different areas in Sri Lanka were prepared for the analysis by acid digestion with conc. HNO_3 . Both digested and non-digested water samples were analysed. The average percentage metal removal from drinking and waste water samples were in the ranges of 95-100% and 62-99% respectively. The percentage recovery values for Pb^{2+} , Cu^{2+} , Cd^{2+} , Cr^{3+} , Zn^{2+} , Mg^{2+} and Ca^{2+} ions were 96.0, 94.0, 83.0, 98.0, 102.0, 79.0, 77.0 %. This study reveals that both Mabima and Pannala clay adsorbents are efficient in purifying the analysed drinking and waste water samples.

Keywords: Moisture content, pH, soil organic matter

*sri@kln.ac.lk

COST EFFECTIVE REMOVAL OF CHROMIUM FROM TANNERY INDUSTRY EFFLUENT AND POSSIBLE RECOVERY OF CHROMIUM

W.M.G.N. Kumari and R.C.L. De Silva*

Department of Chemistry, University of Kelaniya, Kelaniya, Sri Lanka.

Chromium is a heavy metal having high toxicity and has been of great concern in recent years among other heavy metal pollutants. The tannery industry is a major contributor for releasing chromium containing waste water to the environment. Therefore, finding a proper solution for removing chromium efficiently and effectively from the effluents of tannery industry is considered to be of great importance. The commonly used treatment method in the tannery industry is the use of adsorption processes involving a clay bed (usually ball clay), which is not very effective due to the rapid saturation of clay beds as the concentration of chromium in these waste is high (~ 3000 mg L⁻¹) and difficulties arising in replacing the clay beds and disposal of metal saturated clay. Some factories practice chemical treatment (using sodium hydroxide, magnesium oxide, sodium carbonate and lime) which is proven to be costly. The main objective of the current study was to investigate possible cost effective methods for removing and recovering chromium as a usable compound such as potassium dichromate.

In the first phase of the study, chromium was precipitated as chromium hydroxide by mixing with effluents of tannery industry that was from steps prior to chrome treatment, namely the effluents after unhairing and soaking, delimiting and batting processes. The effectiveness of the process and the purity of the precipitate were compared with the commonly used technique in which sodium hydroxide solutions of 10% and 15% were used to chemically precipitate chromium containing waste. Removal of chromium from tannery effluents using the other effluents of tannery industry was shown to be comparatively cost effective and efficient with a higher recovery of chromium (>95%). Mixtures of unhairing and delimiting samples (in 1:1 ratio) showed that it is suitable for removing chromium (III) with considerably high purity than using of effluents individually for precipitation. However the purity of chromium hydroxide precipitated from mixing effluents was less than 50% due to the presence of anions such as sulphide, sulphate and chloride ions. Increasing the volume of the effluent mixed with the chrome effluent, showed an increase in the recovery of chromium. Recovery of chromium using delimiting and batting effluent sample was less than the recovery of chromium using unhairing and soaking effluent samples.

In the second phase of the study, the possibility of converting the recovered chromium precipitates to usable compounds of higher purity were investigated. When hydrogen peroxide was used as the oxidizing agent, formation of potassium dichromate was indicated by the orange color after acidifying with concentrated hydrochloric acid. A colour change from orange to greenish orange was observed upon heating due to the presence of possible reducing species in the solutions. However, formation of usable amounts of potassium dichromate was not possible in the presence of other ions, such as sulphide ions. The conversion of the recovered precipitates to potassium chromate was possible with lower purity (<60%). The concentrations of chromium in the study were measured using Flame Atomic Absorption Spectrometer (FAAS).

Keywords: Chromium, tannery industry, effluent

*russel@kln.ac.lk

ANALYSIS OF WASTEWATER FROM SMALL SCALE RAW RUBBER PROCESSING INDUSTRIES

N.M.J. Nissanka^{1*}, W.M.G. Senavirathna² and N. Priyantha^{1,3}

¹*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.*

²*Rubber Research Institute of Sri Lanka, Ratmalana.*

³*Department of Chemistry University of Peradeniya, Peradeniya, Sri Lanka.*

Average annual contribution of natural rubber as an exportable commodity is about Sri Lankan Rupees 54,000 million to the national income. Despite, the environmental cost caused by generation of wastewater at raw rubber processing is considerable. Eventhough the large scale raw rubber processing centers have implemented proper wastewater treatment facilities, most small holders to date have not attended to wastewater management resolutely due to the unbearable high cost of implementation and maintenance of such treatment facilities. It is estimated that 25-30 L of wastewater are discharged for production of 1 kg of rubber. Since the total production of small scale processing units is higher than that of large scale in the country, untreated waste accumulation due to the small scale sector is considerable. The chemical analysis of untreated raw rubber processing wastewater would thus be important. The pH of rubber processing wastewater collected from 35 selected small scale raw rubber processing centers revealed that the variation of pH was in the range of 5.4 to 7.2, indicating non-compliance to the discharge requirement to the inland surface water bodies as per the National Environmental Act (NEA).

The average values of the Biochemical Oxygen Demand (BOD) and the Chemical Oxygen Demand (COD) determined for the 35 representative samples recorded remarkable increase of more than 100 times and 26 times, respectively, with respect to the NEA stipulated values of 60 mg L⁻¹ and 400 mg L⁻¹. Similarly, other parameters of concern, Total Suspended Solids (TSS), Total Solids (TS) and sulphides, also exhibited deviation from the NEA standards for raw effluent discharges by 29 times (2917 mg L⁻¹), 18 times (18667 mg L⁻¹) and 6 times (12 mg L⁻¹) higher. It also revealed that ammonical nitrogen and total nitrogen values are higher (539 mg L⁻¹ and 200 mg L⁻¹) compared to the approved level of NEA. Thus, untreated raw rubber processing wastewater from small scale processing centers contributes a significant pollution load to the environment. Findings of this research would be useful to develop an affordable and adoptable treatment facility for processing wastewater from small scale raw rubber processing industries.

Keywords: BOD, COD, National Environmental Act, Rubber processing, Wastewater

*nmjnissanka@yahoo.com

DESALINATION ABILITY OF MURUNKAN CLAY – A LABORATORY SIMULATED STUDY

C. Rathnayaka¹, N. Kottegoda² and C. Perera^{3*}

¹Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.

²Department of Chemistry, University of Sri Jayawardenapura, Nugegoda, Sri Lanka.

³Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka.

The availability of potable water is becoming a global concern as freshwater resources are heavily utilized. It is estimated that the average per capita supply of clean water will decrease by one third within the next 20 years. Therefore, searching for other possible sources of water, such as desalinization of seawater, is given more attention in the long term, although currently they are too expensive to exploit. Desalination is one of the major options available for producing potable water in island nations such as Sri Lanka, but currently available water desalination technologies such as reverse osmosis, electro-dialysis and distillation are not economically viable. Since natural clay types show good cation removal capacity, in this study, clay available in the Murunkan area of Sri Lanka was evaluated for its ion removal and desalinization capacity.

Clay sample collected from Murunkan was ground, sieved through 1 mm sieve and 10 g was packed well in a 10 cm³ syringe with 2 glass wool barriers. 0.2 mol dm⁻³ standard NaCl solutions were passed through the column using a peristaltic pump and eluent was collected at 10 min intervals. The column saturation time was estimated by considering percentage removal of Na⁺ ions in each time period and analyzing it using Atomic Absorption Spectrophotometry. The same procedure was followed for 0.1 mol dm⁻³ KCl solution, 0.1 mol dm⁻³ CaCl₂ solution and 0.2 mol dm⁻³ MgCl₂ solution. Under dynamic conditions at a rate of 1 cm³ min⁻¹ estimated column saturation time was 2 hours for all the 4 cations. 30 cm³ of water sample collected from Jaffna lagoon was also passed through 10 g of Murunkan clay and the removal of Na⁺, K⁺, Mg²⁺ and Ca²⁺ was determined. The eluent was further passed through another clay column and the above procedure was repeated. The experiment was repeated using Murunkan clay that was treated with 0.5 M HNO₃. The acid solution was passed through 10 g of Murunkan clay for 2 hours prior to passing the lagoon water sample. It was found that the treated clay has better absorption ability compared to that of the non-treated clay.

The concentrations of Na⁺, K⁺, Ca²⁺ and Mg²⁺ in lagoon water was found to be 20400, 608, 500, 3070 mg L⁻¹, respectively. Two repeated filtrations of lagoon water through acid treated columns resulted in a significant reduction of Na⁺, K⁺, Ca²⁺ and Mg²⁺ to 2940, 459, 46, 1985 mg L⁻¹, respectively. The highest percentage removal of 85% and 91% were obtained for Na⁺ and Ca²⁺ but lower percentages were observed for K⁺ (24%) and Mg²⁺ (35%). The kinetics and the mechanism of removal of all four cations were also evaluated.

Keywords: Desalination, Murunkan clay, AAS, absorption, lagoon water

*chandanip@pdn.ac.lk

BREADFRUIT PEEL FOR REMOVAL OF Pb(II) FROM SYNTHETIC WASTE WATER THROUGH BIOSORPTION

A.B. Liyandeniya^{1,2}, N. Priyantha^{1,2*} and L.B.L. Lim³

¹*Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka.*

²*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.*

³*Department of Chemistry, Faculty of Science, Universiti Brunei Darussalam, Brunei Darussalam.*

Lead is considered to be one out of four metals which shows most damaging effects on human health, and consequently, its removal from aqueous solutions has become extremely important from the point of health and environmental aspects. In this regard, biosorption has become popular for the removal of metal ions from contaminant water as a low-cost and an environmental friendly approach. Breadfruit peel, a waste material, provides an excellent sorption medium for the removal of Pb(II) ions from aqueous medium. Interaction of breadfruit peel and Pb(II) ions, investigated through batch experiments under laboratory scale, demonstrates great affinity of this biosorbent towards Pb(II). Effect of medium pH on the extent of biosorption, and equilibrium and kinetics aspects provide strong evidence for the removal of Pb(II) ions by the biosorbent. Adsorption isotherm experiments performed for the interaction of Pb(II) and the biosorbent leads to the validity of the linearized Langmuir model with high regression coefficient, suggesting that Pb(II) forms a monolayer on the biosorbent surface with an adsorption capacity of 71.4 mg g⁻¹ at ambient pH. Further, kinetic modeling demonstrates pseudo second order kinetics with an apparent rate constant of 1.5×10⁻⁴ g mg⁻¹min⁻¹, and that the mass transfer of Pb(II) ions towards the biosorbent is mainly controlled by time-independent interparticle diffusion.

Keywords: Biosorption, Breadfruit peel waste, kinetics, equilibrium

*namal.priyantha@yahoo.com

CHARACTERIZATION OF PAPER MILL EFFLUENT AND INVESTIGATION OF THE SYNERGISTIC IMPACT AT VALAICHCHENAI DUE TO OTHER ANTHROPOGENIC INPUTS

S. Sathees^{1,2}, S. Malavipathirana^{1,2*} and S. Arasaretnam³

¹Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.

²Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka.

³Department of Chemistry, Eastern University of Sri Lanka, Batticaloa, Sri Lanka.

The process of paper manufacturing generates a considerable volume of effluent. Paper processing effluent from the National Paper Corporation (NPC) at Valaichchenai, Sri Lanka has been discharging effluents into the adjacent marshy land surrounded by many open wells and agricultural fields for decades. Impacts of such discharge on the environment, however, have not been investigated so far. Evaluation of the current status of the effluent at the recipient environment is an important prerequisite to understand the waste treatment process. Accordingly, the present study provides an assessment on the current status of physicochemical characteristics and collective impact of the paper mill effluent together with other anthropogenic inputs on the quality of potable water quality.

Samples were collected along the length of the effluent channel and eleven susceptible open wells within the 200 m and 400 m radii from the center of the effluent accumulation point from July to November, 2013. In situ measurements were taken at the time of sampling for pH, temperature, turbidity and conductivity. Individual parameters were determined as per the standard methods of American Public Health Association (APHA). Findings were assessed against the Central Environmental Authority (CEA) standards and Sri Lanka standards for potable water (SLS 614:1983), and compared with the control systems. Data were analyzed by means of SPSS (version 18.0.0) statistical software.

A substantial variation ($p < 0.05$) of temperature, turbidity, TDS, EC, pH, BOD, COD, SO_4^{2-} , NO_3^- and PO_4^{3-} was observed among sampling locations along the length of effluent channel. Nevertheless, temperature, pH, BOD, COD, PO_4^{3-} , oil and grease, and heavy metals (Pb, Cd, Ni and Zn), were within the tolerance levels whereas TSS ($189.67 \pm 102.07 \text{ mg L}^{-1}$) exceeded the level stipulated by CEA (150 mg L^{-1} ; discharged into marine environment and 50 mg L^{-1} ; discharged into inland surface waters).

Having drastically higher levels of turbidity, EC, TS, COD, SO_4^{2-} , PO_4^{3-} and NO_3^- than the SLS 614:1983 and that of the control system, wells within both the radii of 200 m and 400 m exhibited influences of the paper mill effluent. Wells in areas contaminated due to agricultural and livestock activities also expressed similarly peak levels of NO_3^- , SO_4^{2-} , PO_4^{3-} , TS and EC which apparently have no connection with the paper mill effluent. The study showed a deterioration of the water quality of potable wells collectively due to untreated discharges from the paper processing industry and other human activities, suggesting the need of management measures for untreated discharges.

Keywords: Effluent, Heavy metals, paper manufacturing, waste treatment, water quality

*malavisarath@gmail.com

EUGENOL FROM CINNAMON LEAVES AS A GREEN CORROSION INHIBITOR FOR MILD STEEL: A REMEDIAL MEASURE FOR WATER POLLUTION DUE TO SYNTHETIC CORROSION INHIBITORS

N. Priyantha^{1,2*}, S.B. Rathnayake^{1,2} and K. Godigamuwa^{1,2}

¹Department of Chemistry, University of Peradeniya, Sri Lanka.

²Postgraduate Institute of Science, University of Peradeniya. Sri Lanka.

Iron is the major metallic constituent in mild steel (MS), which is the most important material in engineering and construction. Cost associated with the corrosion of mild steel structures and its prevention are significant to the global economy. Synthetic chemicals, such as chromates, used in corrosion prevention cause risks to the environment due to their high toxicity. Increase in ecological awareness and strict environmental legislations have led to the development of “green” alternatives to mitigate corrosion. Although many green inhibitors based on plant materials have been tested, identification of substances responsible for corrosion inhibition has not been paid much attention.

Steam distillate of cinnamon leaves is found to be an efficient inhibitor against corrosion of mild steel in a strong corrosive medium of 0.10 mol dm⁻³ NaCl prepared in HCl of extremely low pH of 0.5 in the mixed distilled water - methanol solvent system (3:7 v/v), as evidenced by a multi-technique approach: mass loss method, electrochemical impedance spectroscopy and linear polarization. More importantly, eugenol isolated from the steam distillate of cinnamon leaves exhibits better corrosion resistant properties as compared to the steam distillate, confirming its corrosion inhibition action. The inhibition efficiency, determined in comparison with the extent of corrosion in the absence of any inhibitor (blank system), increases with the increase in the concentration of eugenol. Further, polarization studies reveal that eugenol acts as a mixed-type inhibitor, indicating the possibility of altering the corrosion mechanism in the presence of eugenol. The adsorption of the eugenol on MS surface obeys the Langmuir adsorption isotherm. These studies would open up avenues to search for green corrosion inhibitors in place of chemical-based synthetic inhibitors which would cause water pollution if discharged without proper treatment.

Keywords: Mild steel, corrosion inhibition, aggressive media, cinnamon leaves, eugenol

*namal.priyantha@yahoo.com